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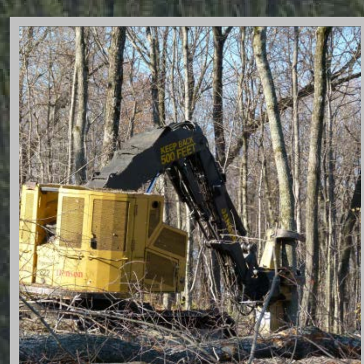
Forest Management Guide to Silviculture in the Great Lakes-St. Lawrence and Boreal Forests of Ontario



Forest Management Guide to Silviculture in the Great Lakes-St. Lawrence and Boreal Forests of Ontario

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Preface

This guide should be thought of as a toolbox. Like all tools, the skill of the person wielding it can greatly influence the quality of the result. Successful implementation of this guide is completely dependent on the judgement of a knowledgeable and experienced silviculturalist. Similarly, a tool does not tell you what to do, but helps you achieve a pre-determined goal. The first step to implementing this guide is deciding what kind of future forest you want.

Silviculture is a means to achieve an end. It is ultimately about achieving local forest management objectives in an efficient and predictable manner. Those objectives have shifted over time from timber to ecosystem management, to the extent that integrative thinking has become second nature for most practitioners. The influence of silviculture decisions on ecosystem health and productivity is considered at all stages from strategic planning to implementation.

Effective silviculture can positively influence the forest for decades to come and on many sites we are now realizing those benefits. Ineffective silviculture can do the opposite for equal or even longer periods with some of the most challenging sites to manage caused by less than desirable past practices. To be fair, some of what we may now regard as ‘mistakes’ were once considered appropriate given the best available knowledge and management paradigm of the day. It is not unreasonable to think that some of what we consider leading edge today, will become tomorrow’s ‘mistake’. This fact should not be cause for concern but evidence that a healthy adaptive learning environment is present.

The job of the silviculturalist is a mixture of routine application of time tested treatments and experimentation with novel techniques or sites, interspersed with the occasional head scratching when one or the other does not provide the expected outcome. Our knowledge has progressed to a point where successes far outnumber failures, but cause and effect is not always obvious, nature is messy, and things do not always go as planned. This does not mean we throw our hands up in frustration with the occasional failure, but that we embrace the uncertainty with which we are working, and commit to learning through practice. As long as we never answer “why do you do it that way” with “cause that’s how we’ve always done it” we can be assured that ineffective practices will be identified and effective practices will get even better.

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The Provincial Forest Technical committee helped steer this project through all stages of development and provided invaluable advice and support.

Illustration and photo credits included with images. Technical edit by Christina Trevisan. Logistical support provided by Gloria Vidal and Fran Paterson.

1.0 Introduction

Silviculture is the science and art of managing forest communities based on knowledge of tree silvics. More particularly, the theory and practice of controlling the establishment, composition and growth of forest vegetation.

This silviculture guide is a revision and amalgamation of four previous silviculture guides (see section 1.5.3). Those four guides were based on earlier guides, research reports, practice notes, and other documents. Appendix 1 provides a discussion and documentation of the history of silviculture guides in Ontario. Much of the knowledge in this guide has built upon what was first presented in these earlier documents. While the scope, presentation, and content of previous guides varied over time and across guides, the common thread was the importance of good silviculture in maintaining a healthy forest and achieving forest management objectives.

This silviculture guide is one of a series of forest management guides used by forest managers when planning and implementing forest management activities. The series of guides provide direction to assist forest managers to decide, for example, what areas of forest to harvest (and equally important, what areas not to harvest), how large the harvest areas should be, and what harvesting and regeneration practices to use in order to protect or enhance environmental, economic, and social values.

Similar to all forest management guides, the mandate of this document is limited to Crown forests, within the Area of the Undertaking (AOU) of Ontario and for any Crown forests outside the AOU for which MNRF has Environmental Assessment approval to undertake forestry activities. The direction and information provided may also be helpful when managing other Crown forests outside of the AOU and private forest lands.

1.1 Purpose of the Silviculture Guide

The purpose of the silviculture guide is to provide practitioners and forest management planning teams with information and direction to determine which silviculture activities are effective in meeting local forest management objectives.

The guide presents a number of tools (i.e. combinations of treatments) that have a reasonable probability of creating specific future forest conditions given certain site and initial forest conditions. It is the responsibility of the user of this guide to determine what future forest conditions are desirable and to consider what tools are fiscally, socially, or operationally appropriate. This determination is first made during the development of a Forest Management Plan (FMP) through setting of objectives, application of other forest management guides, incorporation of operational realities, and public consultation. Final implementation of this guide relies on the judgment of practitioners to refine and match treatments to local stand/site conditions and realities.

1.2 Content and Organization

This guide is comprised of the main text, appendices, and a background and rationale document (in prep). The main text and appendices are included in the printed version. The background and rationale is a separate digital-only document providing background information and rationale for direction.

The main text has a total of 6 sections. The first section is primarily introductory providing definitions, context, and an implementation schedule. The second section speaks to the importance of integrated thinking when making silviculture decisions. The third section provides a brief description of the silviculture practices commonly used in Ontario and serves as an expanded glossary. The fourth section provides further context describing how this guide fits into forest management planning and a discussion of implementation. The fifth section includes the bulk of the direction including categorization of systems, methods, and treatments, example management approaches, and decision keys for the species considered in this guide. The sixth section describes how adaptive management principles have been incorporated including monitoring, guide effectiveness, and key uncertainties. The appendices provide information, best management practices, and an expanded discussion on selected topics.

The background and rationale document includes a description of the information that was used to develop the direction in the guide and the rationale for decisions made. This includes rationale for first order decisions like amalgamating previous guides into a single guide as well as rationale for individual pieces of direction and significant changes from direction in previous guides.

1.2.1 Definitions

This section provides a brief discussion and definition of the terms used in this guide to categorize the direction being provided. Further definition of terms can be found in Section 3 (Silvicultural Practices), and Section 5 (Management Interpretations).

1.2.1.1 Standards, Guidelines, and Best Practices.

This document uses the convention established in previous forest management guides (e.g. OMNR, 2010b) to characterize each piece of direction as a standard, a guideline, or a best management practice. It is important to understand the differences between these three terms since they have different implications when implementing this guide. Standards, as described below, should not be confused with *regeneration standards*, a forest management planning term further described in section 4.1.3.1.

Standard: a component of a guide that provides mandatory direction
Guideline: a component of a guide that provides mandatory direction, but requires professional judgment for it to be applied appropriately at the local level
Best management practice: a component of a guide that suggests a practice or strategy to help implement the overall purpose of the standards and guidelines

Standards must be followed as written; there is no room for interpretation on the part of the planning team. Guidelines are also mandatory and must be followed, but require professional expertise and local knowledge in order to be implemented. They may be expressed as a range of values or may need to be implemented in different ways according to the site conditions or circumstances encountered. Best management practices are not mandatory direction, but are examples of practices that the planning team may wish to use. The list of best management practices is not intended to be exhaustive; planning teams and field practitioners may think of and implement other ideas or strategies. There is no requirement to use any of these best management practices, and a specific best management practice may not be applicable to local circumstances.

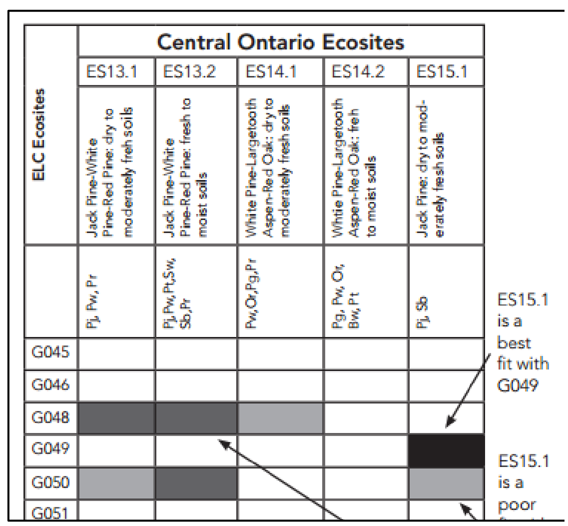
The guidelines and best management practices will be used by planning teams to assist them as they develop and implement silviculture prescriptions specific to their management unit and circumstances. They are neither written nor intended to be copied word for word from the guide into a forest management plan.

The symbol at left is used within this document to highlight standards and guidelines. Any other text, tables, figures, numbers, or examples within this guide, including appendices, that are not clearly identified as a standard or guideline using this symbol, should not to be construed or interpreted as such, regardless of how the text is worded.

1.2.1.3 General Standard Site Type

Term and condition 94 of the 1994 approval of MNRF's class environmental assessment for timber management on Crown lands in Ontario (MOEE 1994) formalized the concept of, and requirement for, a *general standard site type* to be used in developing silviculture ground rules. The intent of the general standard site type was to provide a common classification and labelling of similar sites across the province. Previous silviculture guides used regional ecosites as the general standard site type.

This guide maintains the use of a general standard site type and adopts the provincial ecological land classification (OMNR, 2009) as the basis for aggregating similar site types. The general standard site type language used in this guide adopts the broad soil groups corresponding to the first order sort of the ecological land classification (Figure 1a). These broad soil groups then become the



As planning teams transition from previous regional ecosites to the provincial ecological land classification (ELC) system it will take some time for the information in the Forest Resource Inventory (FRI) to be updated. In the interim 'crosswalk' tables (e.g. Wester et al. 2011) have been developed to help translate the regional ecosite information in existing inventories into the new provincial classification.

language used when a differentiation in site type is required to express how a tree species responds to site characteristics and management treatments. Direction is not provided individually for each broad soil group, but rather further aggregated based on the variable (e.g. depth, texture, moisture) of influence. When site type does not have a strong influence on what treatments are recommended, no differentiation by broad soil group is included.

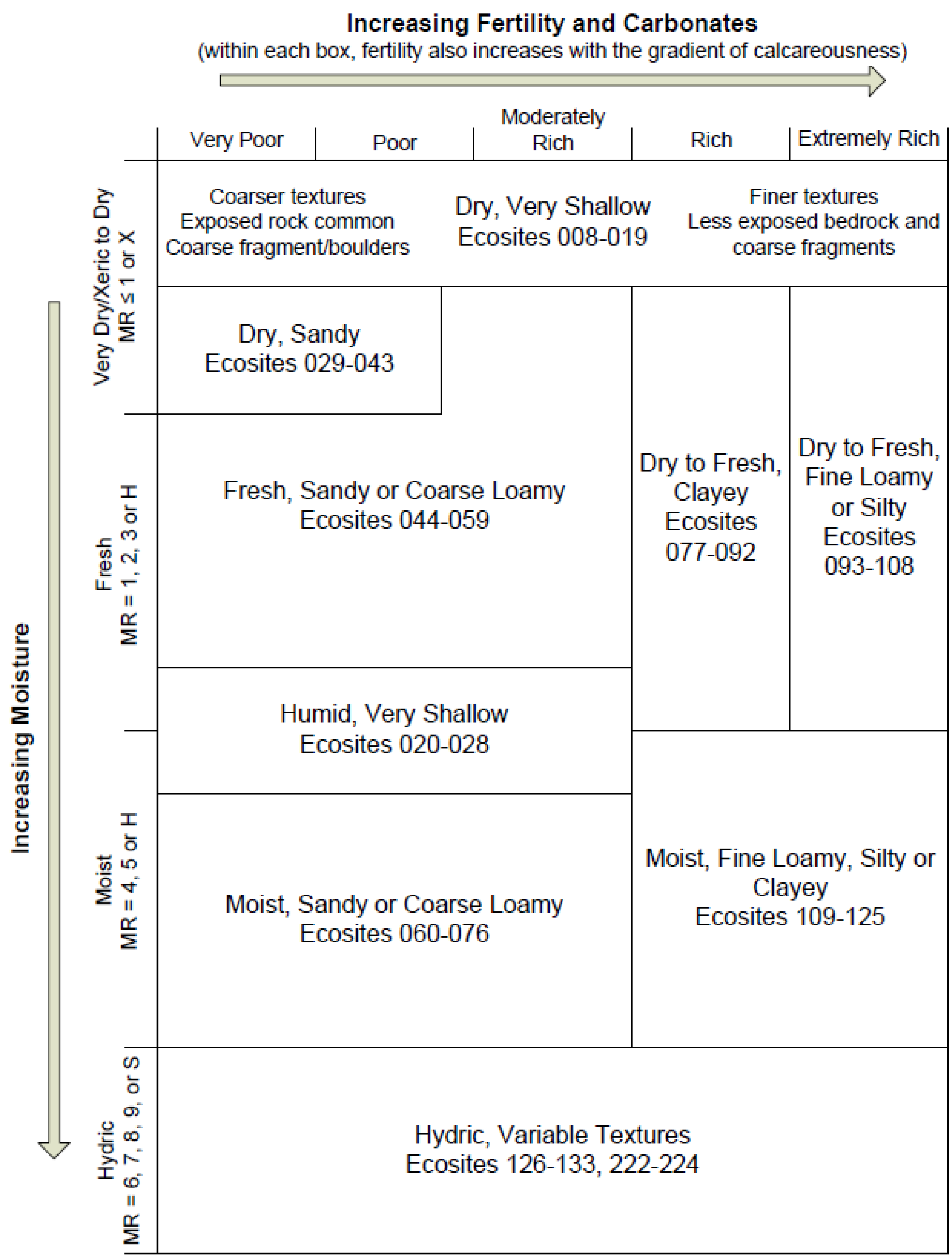


Figure 1a. Depiction of general standard site types (groupings of ecosites based on soil depth, moisture, and texture) along a nutrient and moisture gradient.

1.3 Legislative and Policy Context

The two key pieces of legislation that govern forest management on Crown land in Ontario are the *Crown Forest Sustainability Act (CFSA)* and the *Environmental Assessement (EA) Act*.

The CFSA requires the development and distribution of four regulated manuals, two of which give legal context to forest management guides, including this one. The *Forest Management Planning Manual* (FMPM) requires that forest management guides, including this Silviculture Guide, be used during the preparation of a forest management plan. Similarly, the *Forest Operations and Silviculture Manual* lists the various policies, including the forest management guides, that relate to forest operations on Crown land.

Using the forest management guide during the planning and implementation of forest management activities is also a legal requirement under MNRF's class environmental assessment approval for forest management on Crown lands in Ontario as set out in Declaration Order MNRF-71, as amended by MNRF-71/2, under the Environmental Assessment Act (Condition 38a). Other parts of Condition 38 include posting the status of current guides on the internet; reviewing and where necessary, revising each guide at least every five years; reflecting up-to-date scientific knowledge in the guides; where feasible and with the advice of the Provincial Forest Technical Committee, pilot testing new direction before it is finalized; describing the approach to the effectiveness monitoring program that will be implemented for the new guide; and providing opportunities for public review of draft guides, most notably Condition 31, the continuation of a program of scientific studies to assess the effectiveness of the guides, and condition 37, the maintenance of the Provincial Forest Technical Committee as a public advisory committee to the Assistant Deputy Minister, Policy Division with respect to content of and changes to forest management guides.

There is also other provincial and federal legislation that must be followed during forest operations (e.g. Endangered Species Act 2007). If there are inconsistencies or gaps between federal or provincial legislation and the direction in this guide, however, the legislation will always take precedence.

1.4 How This Guide Was Developed

Forest management guides are regularly reviewed to ensure they reflect current scientific knowledge as it applies to Ontario. Among other things, a review considers the results of applicable scientific research and monitoring programs, advances in analytical and operational technology, and consistency with the current implementation of sustainable forest management concepts. This guide was initiated based on the recommendations of reviews of four previous silviculture guides (see section 1.5.3) in 2005 and 2008.

After some initial scoping with practitioners, planners, and the Provincial Forest Technical Committee (PFTC), an Advisory Team was formed to assist in the amalgamation and revision of the then four silviculture guides into a single guide. The purpose of the Advisory Team was to provide a detailed review of the draft guide and associated products, advise on issues and areas of disagreement as they arise, and provide oversight on practical and administrative linkages between the silviculture guide, the forest management planning system, operational realities, and basic common sense. The Advisory Team included 6 members representing Sustainable Forest Licence holders and 6 members from MNRF. The members represented a broad spectrum of experience including silviculture operations, silviculture planning, forest management planning, SFL management, applied research, monitoring, and policy development.

In addition to reconciling the different approaches in each of the four previous guides, a large part of the amalgamation and revision process was the synthesis of available knowledge to support decision making. This included both empirical information from research and monitoring, as well as experiential knowledge from practitioners. To facilitate the combination of these potentially disparate sources of evidence, Bayesian Belief Networks (BBN) were employed. A BBN is a graphical model that portrays the probabilistic influence of relevant variables on a specified goal (e.g. a future forest stand). It is a simple way of showing how different variables interact and cause specific outcomes. In basic terms, trees need soil, water and light and our silviculture treatments influence soil, water and light in different ways. The BBNs developed to support this revision attempt to describe the probability of reaching certain future forest conditions given our knowledge (experiential and empirical) of a trees requirements for soil, water, and light, and how our silviculture treatments influence soil, water, and light.

The BBNs were initially developed based on expert knowledge, and then augmented with empirical knowledge where it was available. The BBN development process generally included a multi-day workshop with experts, followed by an independent review of empirical information (e.g. literature) designed to test the assumptions being made by the experts. The expert BBN was then reconciled with the empirical review with variables, states, relationships, and probabilities adjusted based on the empirical evidence either confirming or contradicting the view of experts. Where no empirical information was available, the experts view was untouched.

The BBN framework allows for the inclusion of incomplete knowledge and forces the user to be explicit about the assumptions they are making. Each of these assumptions then become testable hypothesis to be applied in an adaptive management framework. The BBN provides a description of how we think the system works, highlights areas where our knowledge is rich or incomplete, and demonstrates the critical uncertainties that may lead to different conclusions in terms of recommended management direction. A more fulsome introduction to BBNs can be found in McCann et al. (2006).

Over the course of the revision, multiple drafts of this guide were developed and reviewed by PFTC, the Advisory Team, and interested silviculture practitioners. This included not only the written product, but the information that supported it. Subsequent drafts incorporated the input received during review of the previous draft eventually leading to pilot testing of the draft direction.

Pilot testing was conducted by 3 mock-forest management planning teams, one in each of the 3 MNRF administrative regions. Pilot test teams completed a number of exercises designed to evaluate both the efficiency and effectiveness of the revised guide. Results of pilot testing revealed a number of areas for improvement, including improved integration with the forest management planning system, which have been incorporated into this draft.

1.5 Integration With Other Guides and Implementation

1.5.1 Integration With Other Guides

This guide is part of a series of forest management guides that collectively direct sustainable forest management practices. It is necessary to consider the direction in the other guides while implementing this guide.

Silviculture decisions on any given site need to consider what is silviculturally possible, what other objectives have been set for the site (e.g. maintain residual forest), and how the sum of silviculture decisions on all sites contributes to achieving landscape level objectives (e.g. increase the area of white pine).

On some sites, the direction in other guides may require the practitioner to make a choice between no harvesting, re-evaluating the future forest objective, or choosing a low probability treatment, method, or system (refer to section 5.2 for definitions). Choosing a low probability treatment, method, or system will add some additional planning and monitoring requirements as described in section 6.2.2 and 6.2.3.

1.5.2 Implementation

This guide will be used in the preparation of phase I forest management plans that come into effect on or after April 1, 2018 and phase II plans that come into effect on or after April 1, 2017. Plans that come into effect prior to these dates may choose to use all, part, or none of the direction in this guide at the discretion of the planning team.

Amendments to phase I plans that came into effect prior to April 1, 2018 or phase II plans that came into effect prior to April 1, 2017, may choose to use all, part, or none of the direction in this guide at the discretion of the planning team. The decision to use this guide or continue to follow the direction used when the plan was originally written will be made locally and should reflect the circumstances, scale, and reason for the proposed amendment.

Contingency plans will use the silviculture guide(s) that were used in the development of the long-term management direction of the plan from which the contingency is being drawn.

Where direction in this guide overlaps with direction included in the tree marking guide (OMNR 2004), this guide takes precedence.

1.5.3 Previous Guides Replaced

This guide replaces the following forest management guides:

- *Silvicultural Guide to Managing for Black Spruce, Jack Pine and Aspen on Boreal Forest Ecosites in Ontario (1997)*
- *A Silvicultural Guide for the Great Lakes-St Lawrence Conifer Forest in Ontario (1998)*
- *A Silvicultural Guide for the Tolerant Hardwood Forest in Ontario (1998)*
- *Silvicultural Guide to Managing Spruce, Fir, Birch, and Aspen Mixedwoods in Ontario's Boreal Forest (2003)*

Although no longer the source of planning direction, these guides remain a valuable source of information suitable for future reference.

1.6 Consideration of MNRF's Statement of Environmental Values

In 2008 the MNRF revised its Statement of Environmental Values (SEV) under the Environmental Bill of Rights (EBR). The SEV is a document that describes how the purposes of the EBR are to be considered whenever decisions that might significantly affect the environment are made in the Ministry. The Ministry has considered its SEV during the development of the *Forest Management Guide to Silviculture in the Great Lakes St. Lawrence and Boreal Forests of Ontario*. This document is intended to reflect the direction set out in the SEV and to further the objectives of managing our natural resources on a sustainable basis.

2.0 Integrated Management

This guide provides information on which silviculture practices are likely to be successful in managing or creating a stand with specific composition and structure (i.e. what works). It does not however indicate if that composition and structure will provide good habitat, specific timber yields, meet broad management principles (e.g. CFSA, 1994) or provide any other myriad of desired benefits (i.e. what do you want).

The direction in other forest management guides, combined with broad principles (e.g. large healthy diverse forests), and the forest management planning process (including consultation), will help planning teams articulate specifically what benefits are desired. This normally includes both aggregate level targets that silviculture practices need to contribute to (e.g. harvest volume), as well as prescriptions for what activities can occur, or what type of forest must be retained, in any given area.
This section provides a discussion of the importance of integrating these principles, management objectives, prescriptions, and other desired benefits into silviculture planning and decision making with specific reference to the conservation of biodiversity, timber management, genetic resources, resilience in a changing climate, forest health, and invasive species.

This guide is primarily focused on ecosystem management through harvest, renewal and tending. The potential for other activities (e.g. pest management) to achieve landscape objectives should be considered. For example, prescribed fire (i.e. let burn approach) in areas of previous blowdown or insect infestation may be an efficient way to return large areas to productive forest. (photo: Mike Brienesse)

2.1 Silviculture and the Conservation of Biodiversity

In Ontario, the conservation of biodiversity at landscape, stand, and site scales is addressed during the planning and implementation of forest management operations using a nested coarse and fine filter approach (e.g. OMNR, 2010a, 2010b, 2014). The coarse filter component ensures that a diversity of habitat conditions are maintained across management units (MUs) at a variety of spatial and temporal scales in a mixture that approximates what natural disturbance regimes would produce to provide habitat for all native plant and animal species. This is often referred to as the Emulating Natural Disturbance approach. The fine filter modifies the coarse filter to create more habitat for specific species than might be produced by the coarse filter alone, to mitigate potential adverse effects of operations on individual species, and to ensure the conservation of soil and water resources.

This section describes how direction in the forest management guides that address biodiversity may constrain normal silviculture practices and, in broad terms, how silviculture practices may be modified to meet the objectives of these guides.

2.1.1 Composition

This guide (in concert with other resources such as OMNR, 2004) is essential to achieving objectives in the Landscape Guides (OMNR, 2010b and 2014) as it identifies the silviculture practices necessary to perpetuate or create the desired mix of forest communities within each management area. Planners need to ensure that the silviculture options selected from this guide provide adequate tools to meet any targets developed through application of the Landscape Guides.

In addition, Large Landscape Patches (OMNR, 2010b and 2014) or other Emphasis Areas (OMNR, 2010a) may be identified as landscapes where forest management operations will be modified to maintain or enhance habitat (e.g. white-tailed deer, moose, woodland caribou). Modified silviculture approaches may be required to meet specific habitat requirements (e.g. maintenance of browse in strategic locations).

The influence of silviculture on composition needs to be considered both in terms of the relative amount of different forest units and the diversity within forest units (e.g. OMNR, 2010a – Section 3.2.1). Thus, in forest communities that are normally dominated by few tree species following a natural disturbance (e.g., jack pine forest on deep outwash sands), silviculture practices should normally strive to maintain this low diversity condition. Conversely, in forest communities that are normally dominated by a variety of tree species following a natural disturbance (e.g., mixedwood forest on coarse loamy soils), silviculture practices should normally maintain this high diversity condition. When considering diversity, timing of assessment should also be taken into consideration. The diversity at a young age may not be reflective of the diversity at a later development stage after the net effect of inter-stem competition and other stand dynamics are taken into account.

It should be noted that the direction in this guide is primarily a coarse filter, focusing largely on the tree species present. When specific shrubs, herbs or mosses are an important component of desired communities, this guide provides little direction for their direct management. In these cases, the silviculturalist will have to consider the conditions associated with the possible coarse filter approaches, and design their own fine filter adjustments as necessary, using the best available information.

2.1.2 Structure

Various structural aspects of the forest community influence the variety of plant and animal species present. Three structural components that forest managers have direct control over during silviculture operations are retention of; residual patches, individual trees, and downed woody material.

Residual patches are commonly described as unharvested (or partially harvested) groups of trees retained within or adjacent to harvest areas. They may fulfil a variety of ecological functions for a range of plants and animals, including facilitating movement across harvest areas, providing refugia for species that will recolonize the regenerating harvest area, and providing future patches of old growth forest within regenerated stands (see Rosenvald and Lohmus, 2008). When other forest management guides require the retention of residual patches, forest managers will have to carefully evaluate how silviculture treatments can be used to meet these requirements and equally any constraints on the timing and eligibility of future treatments.

Individual trees are normally retained in a harvest area for ecological, silvicultural, and/or operational reasons. Retention for silviculture and operational purposes is discussed in section 2 and section 5. The following text is specific to retention of individual trees for ecological purposes, commonly referred to as wildlife trees (e.g. OMNR, 2010a).

Wildlife trees are individual trees or small clusters of trees retained within harvest areas to provide specific ecological functions immediately after harvest and/or into the future. These functions include nest or den sites, perch or roost sites, and feeding sites for species using recently harvested areas (see OMNR, 2010c). Some trees are expected to survive and become future supercanopy trees; other trees are expected to die and become standing dead and eventually downed woody material (see below). Forest management guides (e.g. OMNR, 2010a) specify the number, size, and types of wildlife trees to retain in different silviculture systems (or stages of management).

To implement wildlife tree requirements, managers are encouraged to identify the specific types of wildlife trees to be retained in different Forest communities (or groups of Forest communities) to meet objectives considering habitat functions, worker safety, and wind firmness. Within the limits set out in other guides (e.g. OMNR, 2010a), some customization is allowed to ensure the mix of wildlife trees prescribed is consistent with the proposed silviculture treatment package and desired future forest condition. For example, when aerial tending is part of the treatment package, a combination of stubbing (cutting a live tree well above normal stump height [i.e. 3-5 m]) and clumping of residual trees (where permitted) may improve access for spray aircraft by creating more open airspace. Similarly, where there is flexibility on the choice of species, if the regeneration objective is pure conifer, it may be counterproductive to retain hardwoods (e.g. white birch) that will act as a seed source.

Downed woody material (DWM) refers to the twigs, branches, boles, and stumps of trees on the forest floor (OMNR, 2010a). DWM can provide many ecological functions including contributions to nutrient cycling and soil formation, micro-sites for regeneration, erosion prevention, and nest, display, feeding sites, cover, and travel corridors for a wide variety of species (see OMNR, 2010c). The amount of DWM in a regenerating stand is a function of the amount of pre-harvest DWM, the impact of the harvest operation on pre-existing DWM, the volume of logging residue left on site, and the density of residual trees, which represent future recruitment of DWM. The latter 2 are largely determined by logging method (i.e. fulltree vs cut-to-length or tree length) and utilization.

Excessive retention of logging residue or residual trees may interfere with renewal or tending operations, ultimately affecting the achievement of both silviculture and biodiversity objectives. Further, logging slash, particularly when suspended and not in ground contact, can increase the fire hazard. The potential conflict between retention of DWM and achievement of silviculture objectives may require a shift in the preferred regeneration approach when unavoidable.

It should be noted that the Landscape Guide (OMNR 2010b, OMNR 2014) equates structure to age class structure. The suitability of different silvicultural approaches to contributing towards Landscape Guide targets will have to be considered carefully. The steps involved in matching the management interpretations in this guide with forest management planning objectives are outlines in section 4.1.1.

2.1.3 Site Level Biodiversity Prescriptions

At finer spatial scales, key habitats and habitat features required by a diversity of species are addressed through a variety of Area of Concern (AOC) prescriptions or Conditions on Regular Operations (CRO) (see OMNR, 2010a). In some AOCs, all silviculture operations are prohibited while in other AOCs, some may be permitted. In some of these cases, regular harvest, renewal, and tending operations are permitted if conducted when there is little risk of adversely affecting the value being addressed. For example, regular operations are permitted within some portions of the AOC for bald eagle nests if conducted outside the nesting season. In other cases, the type of harvest, renewal, or tending operations that are acceptable may be limited by prescribed stand structure targets. For example, silviculture operations in the outer portion of the AOC for large great blue heron colonies must retain residual forest (OMNR, 2010a).

Although the FMPM (2009) does not include a requirement to follow silviculture ground rules within AOCs[1], there is an expectation that any silviculture operations will carefully consider their effect on the future condition of treated stands. While the primary objective is to develop and implement operational prescriptions that prevent, minimize and mitigate adverse effects on the value addressed by the AOC, operations should, to the extent practical and feasible, be consistent with OMNR's emulation of natural disturbance philosophy and a forest management plan's overall objectives for conserving biodiversity. In some cases, this will require that operations replace the initial stand with one of a similar composition and structure, whereas in other cases, stand conversion to a different FU or stand structure may be acceptable or preferred. For example, within woodland caribou range, it is not desirable to use silviculture practices within AOCs that will convert conifer-dominated forest to mixedwood or hardwood forest. Although it may not always be possible, when AOC prescriptions preclude standard silviculture treatment packages, creative alternative treatment packages should be considered. At the same time, it needs to be recognized that some AOC prescriptions may not be compatible with some future forest objectives. For example, retention of mid-story cedar and balsam fir as critical thermal cover will make it very difficult to regenerate white pine on most site. When restrictions within AOCs do not allow the target composition or structure of the future forest to be achieved, excluding all operations may be the best choice.

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[1] As such, protection of the value takes precedence, and silviculture practices can include low probability and not recommended treatments (see section 5.0 for definitions) without the normal restriction of occurring as part of a trial area (section 6.2.2) or exceptions monitoring plan (section 6.2.3).

2.2 Timber Management

The shift from exclusively timber management to ecosystem management recognizes the value of other benefits from the forest (habitat, carbon storage, cultural resources, etc.) and reduces the potential negative impacts of an exclusively timber focus. However, this shift does not discount the continued importance of managing the forest to produce timber as one of many benefits of a healthy forest ecosystem. This section briefly discusses the integration of timber management principles into silviculture planning and decision making.

2.2.1 Crop Planning and Strategic Silviculture

Crop planning is a process of custom designing and optimizing the density of regeneration, the timing and intensity of stand-tending treatments, the timing of future harvests, and the selection of trees for retention (when applicable). For crop planning to be effective it must be applied at both strategic and operational levels, with one providing context for the other.

During strategic planning it is necessary to identify the different silviculture treatments that are possible, the cost of applying those treatments, and the expected success in achieving a specific future forest condition. In identifying these inputs a number of assumptions must be made about the specific treatments being applied. Using a crop planning approach forces the manager to explicitly state and evaluate assumptions about forest stand behaviour over time and in response to treatments. Rather than basing these inputs on broad concepts of renewal pathways, specific detailed scenarios are developed (exact treatment pathways on fictitious sites) and then aggregated into the model inputs. This explicit process forces the silviculturalist to justify silviculture programs in the context of their cost, relative success rates, and contribution to forest level objectives.

The explicit statement of assumptions at the strategic level, allows for testing and refinement through monitoring of actual results. If the performance of actual treatments is significantly different than projected in strategic modelling there is a risk that objectives will not be achieved and sustainability of the plan may be called into question. By explicitly stating assumptions not only is the initial forecast less likely to vary from the actual results, but when deviations do occur, the discrepancy can be easier to find. For example, the cost, forecast of future condition, and probability of success for a treatment that includes planting would ideally be based on explicit assumptions about how often site preparation is used, the average density of planting, the need for vegetation management, etc. If actual results start to vary each of these assumptions can be compared to what has actually occurred and corrective adjustments can be made.

Crop planning at the individual site level is developing a schedule of treatments that will control stand development to achieve a desired end. In even-aged systems this starts with matching initial establishment densities to a desired end product and then planning required interventions to manage competition and density to achieve the desired result. This process typically involves the use of tools such as a density management diagram, stocking tables, or other ‘calculators’, which are based on empirical data, to balance the number (and cost) of treatments, the desired end product, and maintenance of optimal growth rates.

2.2.2 Management Intensity

Management intensity is a label used in Ontario's forest management planning process to describe different expectations of future timber yield within each even-aged forest units and document the anticipated treatment pathways required to achieve them. Increasing intensity generally means increasing site occupancy, control over species composition, implementation of competition control and density management, and may include improved stock. In general, increased intensity is associated with increased effort/expense, but this is a problematic description of intensity as high effort/expense does not guarantee results will meet expectations. Common management intensity labels include extensive, basic, intensive, and elite but the meaning of these terms can vary significantly from one forest to the other. Bell et al (2011) propose a framework for classifying management intensity including definitions for extensive, basic, intensive, and elite intensities of silviculture.

The forest management planning process involves developing objectives, desired levels, and targets for different forest types over time. Some objectives can be tracked at a coarse level (e.g. area by forest unit or forest unit group) while others require greater resolution. Timber management objectives are commonly expressed as volume by species (or species group) and may include targets for specific products within each group. Management intensity provides additional resolution to track achievement of timber management objectives and verify that harvest, renewal, and tending activities are consistent with achievement of short and long-term management objectives.

2.2.3 Investment Considerations

The extent to which timber management is emphasized on any given site is influenced by a number of factors. Common sense combined with sophisticated modelling approaches can be used to help determine the optimum location and arrangement of different management intensities on the landbase. This silviculture guide only deals with site selection as it relates to silviculture success, which may not translate directly to optimal yield or quality, and certainly does not consider location or other factors. The decision on where to emphasize timber management objectives is a separate process not directed by, and only partially informed by, this guide.

2.3 Genetic Resource Management

Biodiversity can be described as the variety of ecosystems, the variety of species, and the variety of individuals within a species. Genetic diversity is the basic unit of biodiversity - it is the inherited difference between individuals of the same species. Genetic resource management can be defined as the incorporation of genetic principles into forest practices in order to conserve genetic diversity in trees while promoting economic development through maintenance and enhancement of productivity (Joyce et al 2001).

Genetic diversity is important for maintaining healthy tree populations that are able to respond favourably and adapt to changes or disturbances in their environment. Changes to genetic diversity occur through the creation of new genes (through mutation), and the loss of existing genes (through genetic drift in small populations and through elimination of populations).

Humans can affect the rate of change in genetic diversity accidentally or deliberately, such as through the sustained selective removal of individuals in “high grade” selective harvest operations, selection and propagation of certain individuals, or the introduction of new genetic material through movement of genetic material in artificial regeneration operations. Successful and sustainable forest management practices should include maintenance of natural levels of genetic diversity as a priority.

The principles of genetic resource management differ slightly between natural and artificial regeneration methods. Natural regeneration requires the maintenance of a broad genetic base by ensuring that a large number of trees contribute to the regeneration. Artificial regeneration requires control of the seed source to ensure seed/stock is adapted to the seeding/planting site. Tree improvement programs attempt to limit the variation in phenotypic expression while maintaining some genetic diversity. Selective harvesting offers a particular challenge as trees are selected for both size and form which may cause the exclusion of some genes from the future population.

Tree improvement programs are directed at improving the productivity and quality of commercial forest tree species. Strategies for realizing genetic improvements are varied and reflect local choices and responses to geographic, technical, economic, social, and political factors.

Isolated tree populations and scattered individuals, particularly at the outer ranges, need to be considered carefully. They represent opportunity in the potential of unique genetic material but also a challenge in terms of genetic effects when targeting natural regeneration (e.g. selection of seed trees). Population structures that have restrictive habitat requirements, even when local densities are high, are more susceptible to genetic effects (inbreeding depression, genetic drift, etc.) than those with broader habitat requirements (Joyce et al 2001).

2.4 Managing for Resilience in a Changing Climate

2.4.1 Resilience

Ontario’s Biodiversity Strategy (2011) defines ecosystem resilience as the capacity of an ecosystem to adapt to changes and disturbances and still retain its basic functions and structures.

The resilience of a forest ecosystem to changing environmental conditions is determined by its biological and ecological resources, in particular (i) the diversity of species, including micro-organisms, (ii) the genetic variability within species (i.e., the diversity of genetic traits within populations of species), (iii) the functional diversity, species, and redundancy (i.e., not all species are necessarily equally important in maintaining ecosystem processes, and (iv) the regional pool of species and ecosystems. Resilience is also influenced by the size and structure of forest ecosystems (generally, the larger and less fragmented, the better), and by the condition and character of the surrounding landscape (Thompson et al 2009).

Forest ecosystems can be threatened by insects and disease, natural disturbance, changing climate, and many other factors. Management decisions that maintain healthy and diverse forests may be a key strategy for retaining a resilient forest that can endure these threats, including climate change.

2.4.2 Projected Climate Change

Weather is the condition of the atmosphere (temperature, precipitation, wind, humidity, etc.) over a short period of time in a local area. Climate is the average weather conditions for a given region over a long time period (e.g. 30 years). Climate change is a shift in climate (patterns of temperature and precipitation) relative to a given reference time period.

Climate is influenced by greenhouse gases (e.g. water vapour), ocean temperature cycles (e.g. Pacific Decadal Oscillation), changes in solar output (e.g. Maunder minimum), aerosol particles (e.g. volcanoes) and many other factors. Some greenhouse gases (e.g. CO_2) have increased substantially since pre-industrial times and are projected to continue to increase in the future. Based on projected increases in greenhouse gas concentrations and a number of estimated parameters (water vapour and cloud feedback, aerosol concentrations, sensitivity to changes in radiative forcing, etc.), scientists have used climate models to predict future climate.

A warmer, more variable climate is predicted to be accompanied by regionally altered precipitation regimes and increased frequency of extreme weather (IPCC 2007). Colombo et al (2007) provide an overview of Ontario's future climate based on the Canadian Coupled Global Circulation Model using two scenarios of future greenhouse gas emissions resulting from human activity in the 21st century. Temperatures are expected to increase across the entire province with more pronounced warming in the north. The timing and amount of precipitation is also expected to shift, with some regions getting drier, and others getting wetter. Like any prediction of the future, there is a relatively high degree of uncertainty in these estimates with different emissions scenarios, and different climate models, predicting different futures for any specific location. The consensus from the major global climate models, however, is for significant warming, with uncertainty largely focused on the magnitude of warming.

2.4.3 Predicted Effects of Climate Change on Forests

Climate has long been identified as a primary control on the geographic distribution of plants (Box, 1981). If climate changes as projected (e.g. Colombo et al 2007), changing environmental conditions and/or the frequency and intensity of disturbances will be an additional stress on ecosystems.

McKenney et al (2007) provide an estimate of future climate niches for 130 North American tree species by determining present day climatic niches and then delineating similar conditions on maps of predicted future climate. This analysis indicates where each species could potentially occur by the end of the century from a climate niche perspective. In general, many climate niches are projected to shift northward at a faster pace than the species' natural dispersal mechanisms can keep pace with. However, geographic range limits may also be influenced by competitive interactions between fast growing southern species and slower growing northern species (e.g. Loehle 2014) thereby softening or adding a significant time lag to potential temperature effects at the southern edge of the current range.

Even when a species is still within its climate niche, increased temperature fluctuations or periodicity of precipitation may have negative consequences. For example, temperature fluctuations, particularly in spring when trees can de-harden during an early warm spell followed by cold days, can lead to damage and mortality (e.g. Man et al 2009). Similarly late frosts and prolonged droughts can reduce growth and vigor, increase dieback and mortality, and reduce the number of good mast years. Worral et al (2013) list increased summer temperatures and reduced April to September precipitation as significant contributors to a recent decline and dieback of aspen in parts of North America.

Northern forests may initially see an increase in productivity with warmer temperatures and longer growing seasons, provided moisture is not limiting (Boisvenue and Running 2006).

Changes in temperature and precipitation are expected to lead to a drier forest floor. This could increase the potential for more lightning and human caused fires to start and spread. Wotton et al (2005) project a 15% and 50% increase in the number of fires by 2040 and 2090 respectively, with an 80% increase in the number of fires that escape initial attack by 2100. Changes in temperature and precipitation may also influence the distribution of and damage from insects and pathogens (e.g. Sturrock et al 2011). Growth rates, reproductive success, and the distribution of hosts, alternate hosts, and predators may shift with a changing climate. Most insects and pathogens will be able to migrate at a faster rate than tree species and their shorter life cycle may allow them to adapt more quickly to changing conditions.

2.4.4 Adaptive Silviculture

Managing forest ecosystems to maintain or restore ecological resilience may make them less vulnerable and better able to cope with the stresses from climate change (Parker et al. 2012). Fundamentally, managing for resilience is about conserving or enhancing biodiversity at genetic, species, and population scales to maintain ecosystem processes and complexity at multiple scales, while meeting management objectives.

Sustainable forest management on Crown lands in Ontario includes a number of practices that promote forest resilience (maintenance of biodiversity, protection of sensitive sites, use of local seed sources, maintenance of structural complexity at multiple scales, etc.). Direction in the Landscape (e.g. pattern class targets) and Stand and Site Guides (e.g. structural legacy), along with decisions made through the forest management planning process, contribute to the resilience of the future forest.

Silviculture practices have the potential to influence future resilience by directly and indirectly influencing future composition at a species and genetic level. Direct effects include favouring specific species or genotypes through artificial regeneration, tending, compositional treatments, and selective harvest. Indirect effects involve manipulation of environmental conditions (light, soil temperature, etc.) that may favour one species or genotype over another.

There is no specific prescription or direction included in this guide to respond to climate change; however, the forest manager is encouraged to employ an adaptive and flexible decision-making framework that incorporates new knowledge and experience over time. Given the uncertainty of both the extent of climate change and an ecosystem's response to the changes, "no regrets" adaptation tactics that result in a wide variety of benefits, and choosing practices aimed at promoting the natural adaptive processes of ecosystems that enable them to accommodate and respond to change should be considered (Parker et al. 2012, Millar et al. 2007),

Evaluating if a particular adaptation tactic is "no regrets" is complex and will require careful consideration of a number of factors, not the least of which is satisfying a basic assumption that the new approach will have a higher probability of success than the current. For example (adapted from Swanston and Janowiak, 2012):

Managers often express frustration with being stuck between a general desire to 'do something' but lacking certainty on the effectiveness of specific actions. 'No regrets' tactics (e.g. planting mixed species) are robust actions that provide benefits under multiple scenarios of the future and have little or no risk even under current climate conditions. These types of tactics may be initial places to look for near-term climate change adaptation wins. While the information in this guide is intended to be helpful (e.g. seed transfer considerations in appendix 3, mixedwood management in section 5.2) it is not intended as a definitive source and does not constitute rationale for any specific actions.

- **Likelihood of Success** – Is an adaptation tactic likely to be effective in the future across a variety of potential conditions? Will implementation of an adaptation tactic help achieve existing management objectives and goals?
- **Trade-offs** – What are the potential trade-offs associated with selecting and implementing a tactic? If you select an adaptation tactic, will there be negative consequences on other parts of the ecosystem or on other management actions? Can adverse impacts be avoided or mitigated?
- **Urgency** – Is there a need to implement an adaptation tactic in the near term? Will implementing a tactic now provide clear benefits in the future?
- **Cost** – Does an adaptation tactic have a high financial cost? If there are no new funds, what other items will not occur? Will implementing a tactic now prevent greater costs in the future?

- **Effort** - Is the adaptation tactic labour- or time-intensive? If there is a limited pool of labour resources, what other activities will not occur? Will implementing a tactic now reduce the amount of work needed in the future?

Individual forest management planning teams may determine that specific adjustments to standard forest management practices to enhance or maintain resilience are desirable. Careful analysis of the interaction with other guides (e.g. Landscape Guide composition targets) and policies (e.g. seed zones) is advisable before proceeding.

2.5 Forest Health

Section 2.1 includes a discussion of integrating the conservation of biodiversity into silviculture planning and activities. That biodiversity includes forest insects and pathogens that play a vital role in ecosystem dynamics and in themselves contribute to the diversity in our forests. The majority of insects and disease cause only minor or localized impacts; however, the influence of some insects and pathogens can be significant enough to compromise achievement of other objectives in the forest.

Silviculture activities have the potential to influence the susceptibility of forest communities to various insects and pathogens. Silviculture activities can change the overall stand vigor, manipulate habitat conditions (e.g. humidity) for the insect/pathogen, change the diversity of tree species present, or manipulate habitat for secondary organisms. Each insect/disease is unique, and the influence of silviculture activities on their development, prevalence, spread, and severity of impact is varied. Silviculturalists should make themselves aware of the insects/diseases in their local area, and consider the potential influence of silviculture treatments on the role of insects and pathogens in the ecosystem. A listing and brief discussion of insects and pathogens relevant to the tree species addressed in this guide can be found in Appendix 3 (factsheets) and Section 5.1 (summary and suggested management approaches by species).

2.6 Invasive Species

The health and biological diversity of Ontario's forests are threatened by the introduction and spread of a variety of invasive insects, plants, and diseases. Invasive species often have no natural enemies, can develop unchecked, and have long-term impacts on forest composition. Some affect trees directly (e.g. emerald ash borer, beech bark disease, chestnut blight, white pine blister rust) while others may influence the regeneration environment (e.g. dog strangling vine). Silviculture activities have the potential to influence the establishment, spread, and persistence of invasive species in positive and negative ways. Where relevant, invasive insects and pathogens are addressed in the information and direction for individual species in section 5.1.

In addition, silviculturalists should apprise themselves of the latest information for invasive species known or expected to occur in their area. Various sources may be consulted for the latest information on how to identify and control invasive species such as the Canadian Forest Service's Forest Invasive Alien Species of Canada website (www.exoticpests.gc.ca) and the Ontario Federation of Anglers and Hunters' Invading Species Awareness Program website (www.invadingspecies.com).

3.0 Silviculture Practices

Silviculture practices are treatments applied at the stand scale to achieve specific forest management objectives. Treatments are broadly categorized as either harvest, renewal, or tending. Ideally these practices are applied in a coordinated fashion with a long-term view of what is possible, practical, and desirable at both a stand and landscape scale. The coordination and long-term view is achieved through application of a silviculture system.

The following text provides a description of the silviculture systems, harvest methods, logging methods, renewal treatments, and tending treatments typically applied in Ontario and considered in this guide.

3.1 Silviculture Systems

A silviculture system is a planned program of silviculture treatments that extends throughout the life of a stand for the purposes of controlling stand establishment, composition, and growth (Smith et al 1997). While this view implies a certain intensity of effort and manipulation, on suitable sites the simplest application may include only a single harvest with natural regeneration (assuming a seed source, seedlings or root suckers are present in sufficient quantity to restore the forest to a desired composition and structure).

The concept of silviculture systems emerged in Europe after the “wood famines” of the 17th and 18th centuries. The systems were developed in an effort to classify, document, and share a large body of local knowledge. Over time the accepted systems developed into a “toolbox” that local managers could apply and adapt to their specific social, economic, and ecological realities (Puettman et al 2009). These somewhat standardized tools allowed what was learned in one location to be transferred to another, eventually being transferred from Europe to North America.

As silviculturalists continue to innovate and introduce new (or revived) practices, particularly harvest practices, they are commonly fit into one of the three traditional silviculture systems (selection, shelterwood, and clearcut). In some cases, it is difficult to assign a new practice to the appropriate silviculture system, largely due to a lack of a clear, quantifiable, and unique definition. As well, some suggested practices do not fit well into any of the three single traditional systems (e.g. matching the regeneration approach of one system but the future age class structure of a different system).

While recognizing some limitations, silviculture systems are further modified to ensure the structure and composition of a forest after a logging operation more closely matches or emulates the conditions found after fire, wind, or other natural disturbance. Emulation refers not only to an attempt to match the natural disturbance mechanism (e.g. gap development resulting from blow down), but also to the post-disturbance growing conditions to which trees have adapted over millennia. Natural disturbance can be further emulated through consideration of natural fire pattern, function of residual trees, mitigation of adverse effects of machinery, and other requirements as outlined in OMNR, 2010a.

The following text and tables describes the silviculture systems framework used in this guide. The framework is largely based on the traditional silviculture systems but with some elaboration of definitions to provide clarity and represent the full range of possible silviculture practices.

3.1.1 Definitions

Table 3a. Silviculture systems referenced in this guide.

Silviculture System	Description	General characteristics
Clearcut	Most of the overstory trees are removed over a short period of time to create a fully exposed microenvironment for the establishment of a new even-aged stand.	• even-aged future stand • regeneration established[2] in >70% full sunlight
Shelterwood	Most of the overstory trees are removed in a series of two[3] or more harvests for the purpose of establishing and sheltering regeneration under a residual canopy.	• even-aged future stand[4] • regeneration established[2] in 30-70% full sunlight • regeneration period <20% of the intended rotation[3] • final removal creates >70% full sunlight[3]
Selection	Periodic partial harvests timed based on basal area recruitment using vigour, risk, and species preference, to select trees for harvest and retention.	• all-aged future forest • regeneration established[1] in ≥70% residual cover (approx. ≤30% full sunlight) • dense mature forest cover maintained in perpetuity

The definitions presented in table 3a allow the user of this guide to consistently assign any proposed combination of silviculture treatments into one of three silviculture systems - provided they can forecast the target age distribution, the expected light conditions resulting from harvest(s), the planned duration of overstory retention, and the timing of the regeneration. This assignment becomes important when applying the management interpretations (i.e. recommended silviculture systems for different species) in section 5 of this guide and selecting a silviculture system to achieve local objectives.

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[2] And/or advance regeneration released

[3] The shelterwood system includes a special case where unmanaged regeneration and/or poles established through natural processes and/or historic (~30 yrs or older) harvesting are released in a single harvest. A single harvest shelterwood can be distinguished from a clearcut with advance regeneration based on the proportion of future stems present prior to harvest. As a rule of thumb 80% or more of the future stand should come from stems present prior to harvest to consider it a single harvest shelterwood.

[4] Irregular shelterwood (see table 3b) typically creates a multi-aged future stand, the regeneration period is >20% of the intended rotation, and the final removal may be delayed or absent.

3.1.2 Growing Conditions Created

The clearcut system provides light conditions similar to those following a stand replacing disturbance (e.g. fire) with sheltering of the forest floor limited to logging residues and sparse residual trees. The clearcut system is most suited to light-demanding species (e.g. jack pine and aspen) but can be an option for some shade tolerant species when competition is controlled and shelter for insect and disease control is not required.

The shelterwood system provides an environment of partial shade from a high, evenly-distributed crown canopy, with living seed producing trees, and moderated temperature and moisture conditions on the forest floor. These conditions emulate the environment for which many mid-tolerant species have evolved. Natural analogues may be a non-stand replacing fire or a partial blow down.

The selection system provides an environment ranging from partial to full-shade and a forest floor protected from temperature extremes and desiccation. Regeneration under single tree selection favours shade tolerant species while some mid-tolerant species are well suited to group selection openings.

3.1.3 Variations Within Silviculture Systems

The definitions presented in table 3b include a range of possible growing conditions (e.g. light) within each silviculture system. Variations within each silviculture system include differences in the amount, arrangement, and size of residual trees retained after harvest and the timing of their removal. These variations are commonly referred to as *harvest methods* (see section 3.1.2.1). Harvest methods may further vary to meet a variety of site specific objectives depending on the amount, size, and function of residual trees retained (see section 3.1.3.2, 4.1, and 4.2).

3.1.3.1 Harvest Method

Harvest method is a description of the variation in the amount or pattern of retention within a silviculture system. The level of variation introduced by each harvest method is constrained by the definition for each silviculture system (e.g. % full sunlight). Not all harvest methods are applicable to all silviculture systems. The terminology regarding harvest method has evolved over time with some terms having subtle but important differences when applied in different silviculture systems. Table 3b provides a definition of the harvest methods considered in this guide and the silviculture systems to which they are normally applied.

Table 3b. Description and applicable silviculture system for common harvest methods applied in Ontario.

Harvest Method[5]	Description	Applicable silviculture systems
With standards	The removal of most trees from a large contiguous area, with a low density of trees retained for silviculture or other purposes.	Clearcut
Seed tree	The removal of most trees from a large contiguous area, with a sufficient number of individual trees retained to contribute seed to the regeneration of the future stand.	Clearcut
Block[6]	Removal of most trees in a defined pattern (e.g. checker board) of cut and uncut blocks.	Clearcut
Patch[6]	Removal of trees in irregularly shaped, spaced, and sized patches that can be matched to the mosaic of terrain and original forest types.	Clearcut
Strip[6]	Removal of trees in narrow (~10-60 m) strips, often in a progressive fashion. A specific intent for the uncut strip to provide seed and/or shelter to the cut area differentiates this from long linear patches.	Clearcut, Shelterwood
Uniform/Single	Individual trees are removed at more or less regular intervals with no clear patches or edges created.	Shelterwood, Selection
Group	The removal of a small group of trees, in an area normally less than 2 tree heights in diameter, in a single entry or progressive fashion, within a matrix of mature forest canopy.	Shelterwood, Selection
Irregular	Partial removal of the overstory in successive regeneration cuts with a long and indefinite regeneration period (≥20% of the intended rotation). The final removal is delayed or absent, and the resulting stand is typically multi-aged.	Shelterwood

Figures 3a through 3i provide an illustration of the implementation of the silviculture systems described in Table 3a and their common variants described in Table 3b.

[5] Conventional clearcut, the removal of all stems from a large contiguous area, has been intentionally excluded from this list as it is no longer practiced on Crown land in Ontario. The combination of diversity (e.g. wildlife trees) requirements and silvicultural objectives results in some stems being retained on essentially every hectare.

[6] The differentiation between strip, block, patch, and clearcut with standards is somewhat ambiguous. The management interpretation tables in section 5.2 group all of these into clearcut with standards with specific comments on size/shape of the opening included only when relevant.

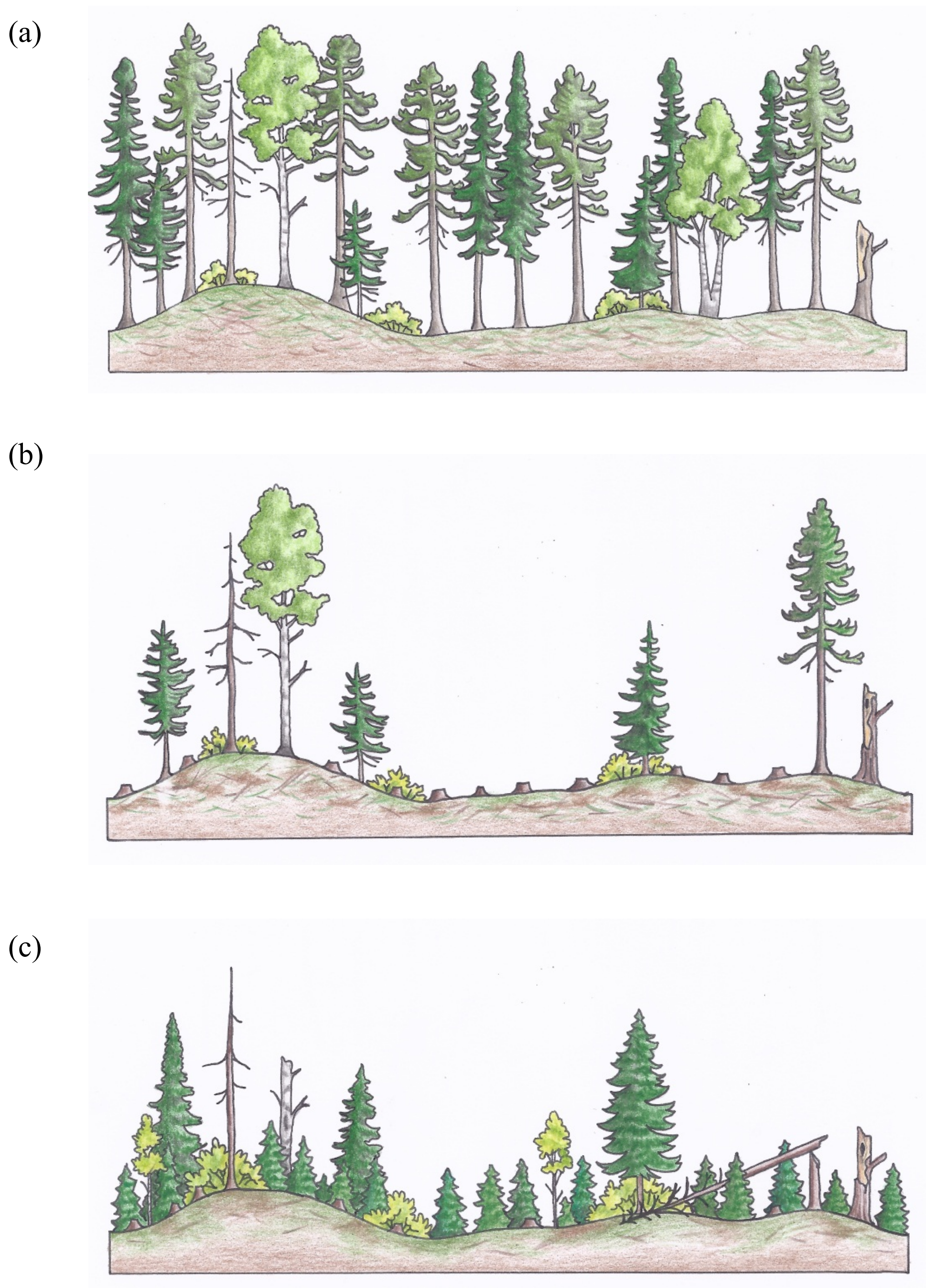


Figure 3a. A profile of a clearcut silviculture system in a conifer-dominated stand depicting the pre-harvest stand conditions (a), conditions directly after harvest (b), and 10 years post-harvest after a tree planting regeneration treatment (c) (illustrations by Jodi Hall).

(a)

(b)

(c)

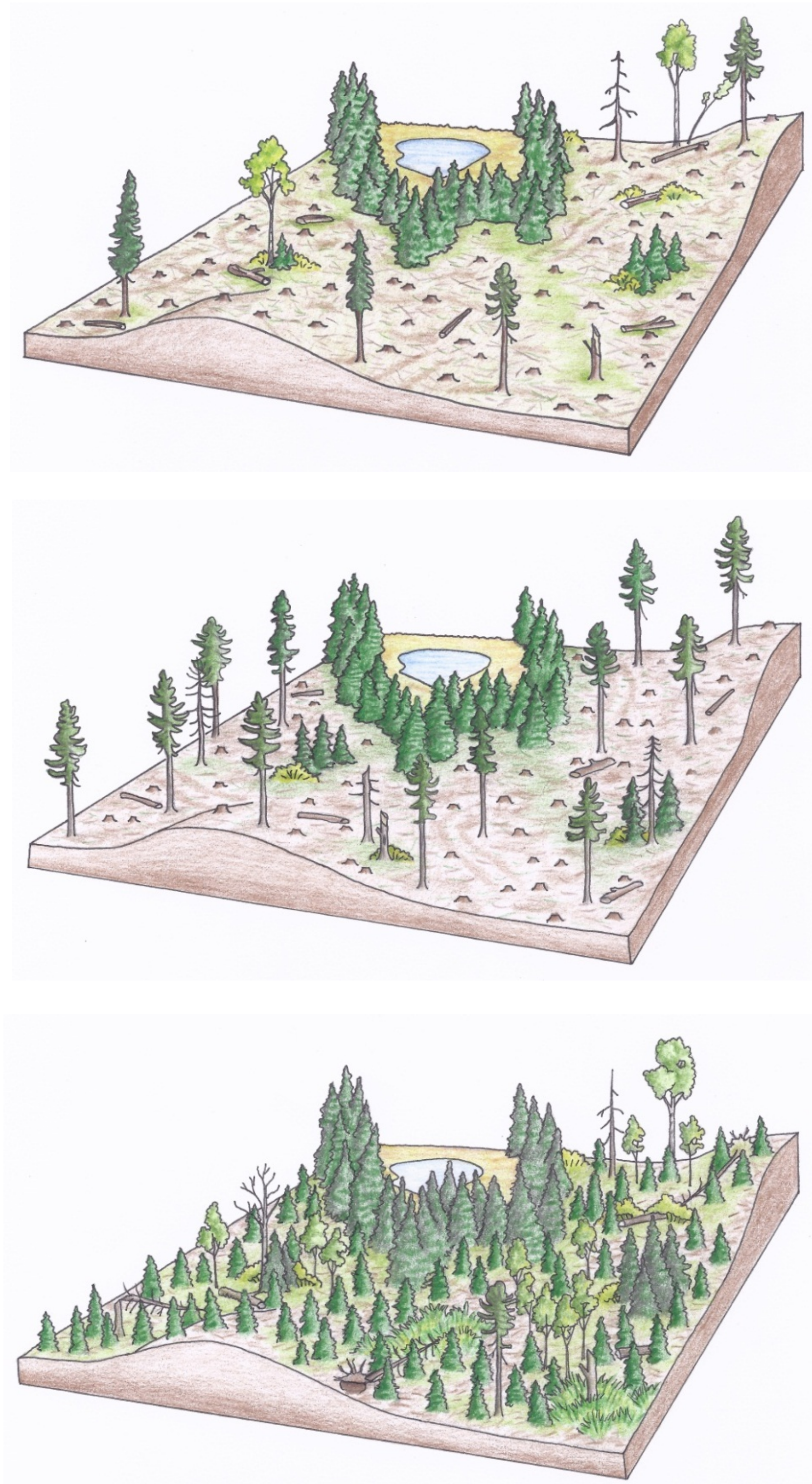


Figure 3b. Aerial views of a typical clearcut silviculture system depicting a modern clearcut directly after harvest with irregular boundaries, wildlife trees, and downed wood (a), a clearcut with seed trees (b), and a clearcut 10 years post-harvest depicting a new even-aged stand with >70% full sunlight (c) (illustrations by Jodi Hall).

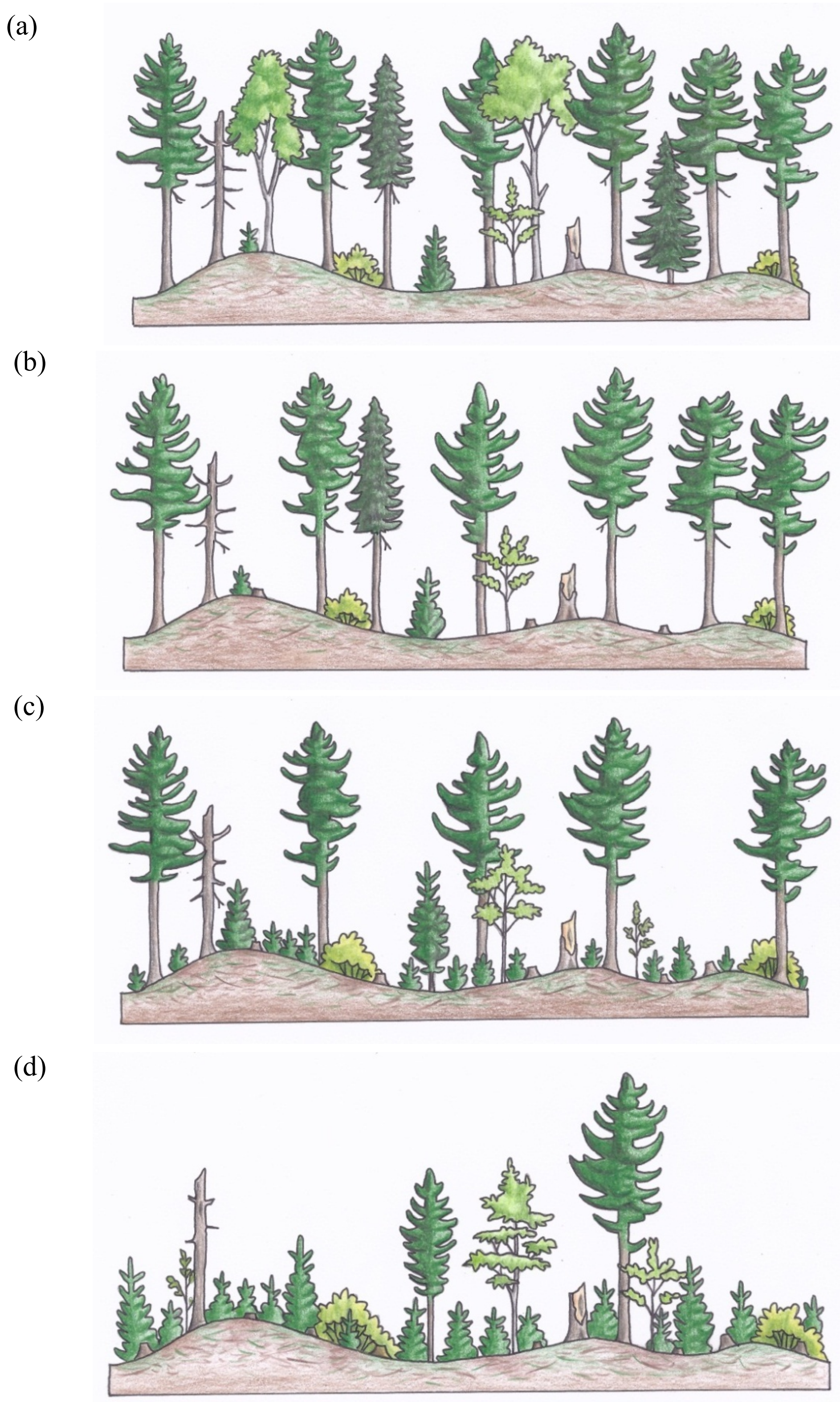
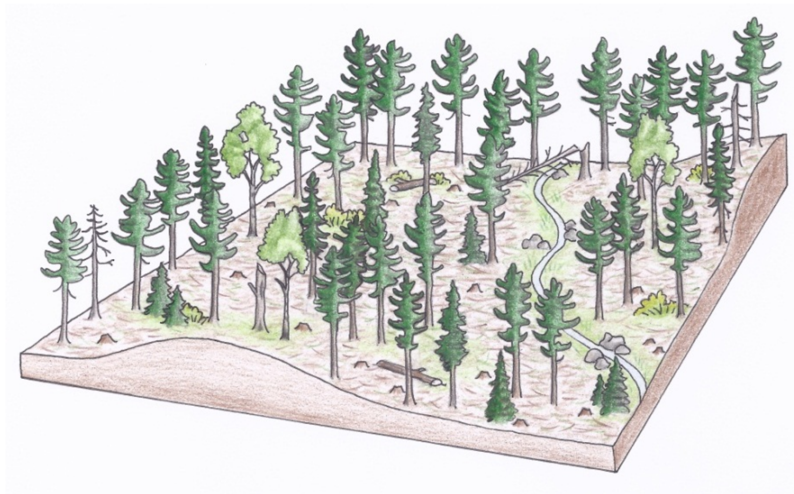
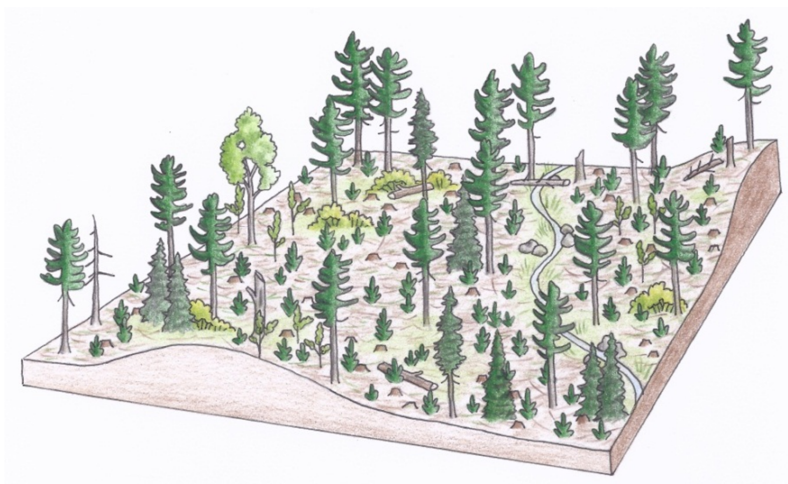


Figure 3c. A profile of a uniform shelterwood silviculture system depicting a pre-harvest white pine dominated stand (a), conditions after the regeneration cut (b), first removal cut (c), and final removal cut with a natural seeding regeneration treatment (d) (illustrations by Jodi Hall).

(a)



(b)



(c)

Figure 3d. An aerial view of a typical uniform shelterwood silviculture system in a white pine stand directly after a regeneration cut (a), a first removal cut once the regeneration is established (b), and after the final harvest resulting in >70% full sunlight conditions and a new even-aged stand (c) (illustrations by Jodi Hall).

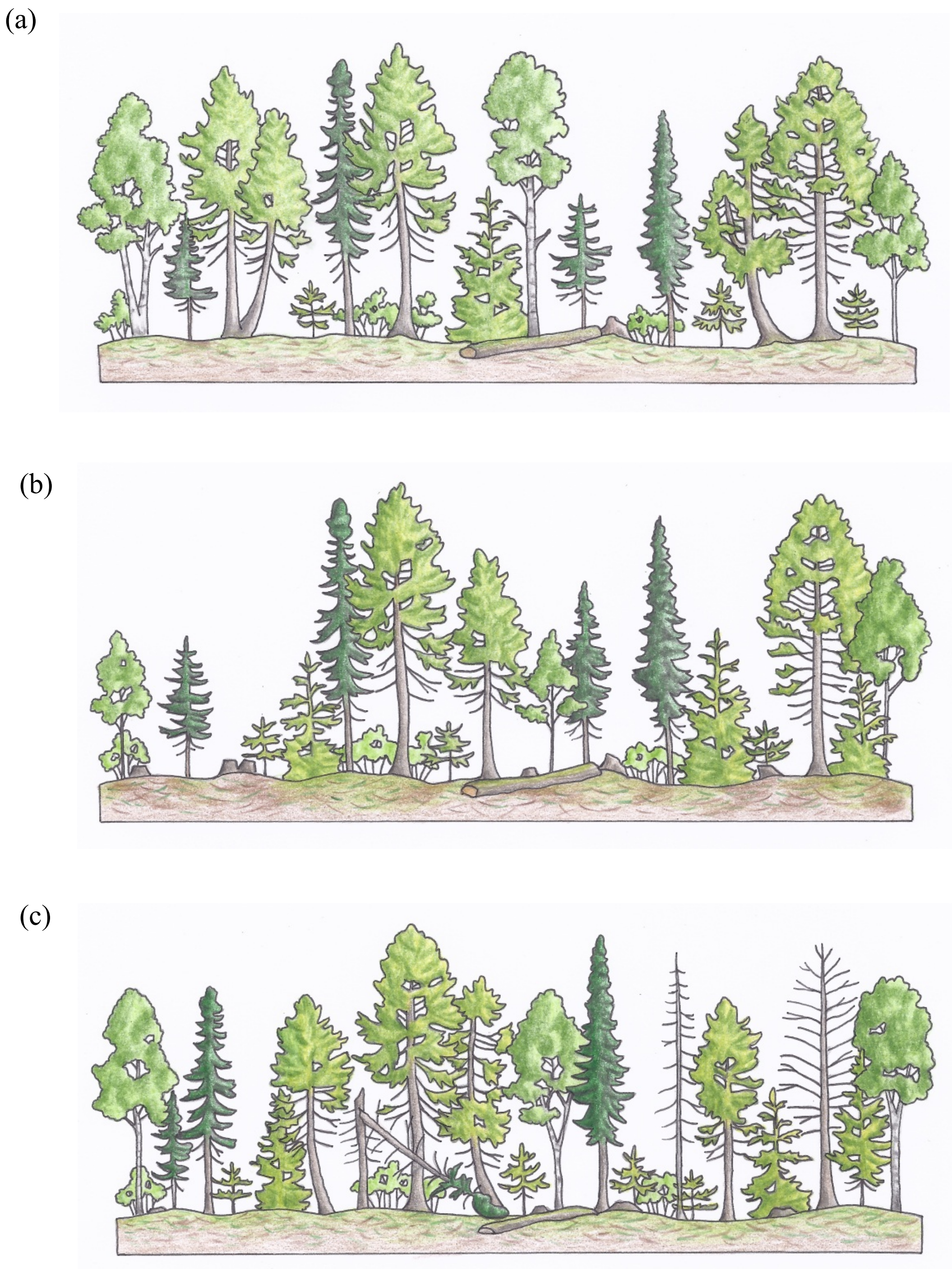


Figure 3e. An example of an irregular shelterwood harvest profile depicting a pre-harvest eastern white cedar dominated stand (a), stand conditions 15 years after a first partial harvest (b), and 50 years after partial harvest (c) (illustrations by Jodi Hall).

(a)

(b)

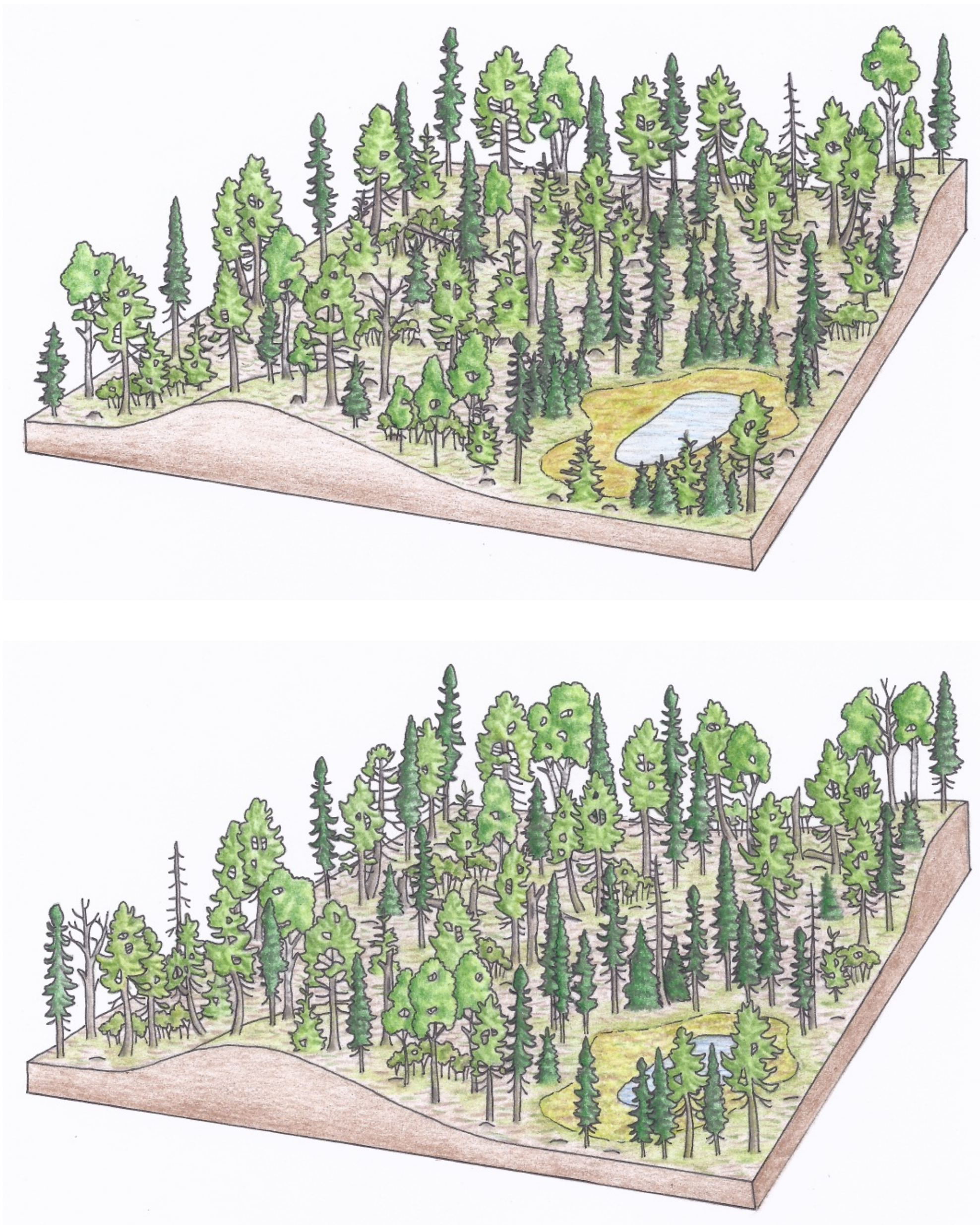


Figure 3f. An aerial view of an irregular shelterwood harvest in a cedar dominated stand 15 years after harvest (a), and 50 years after establishment resulting in a multi-aged stand (b) (illustrations by Jodi Hall).

(a)

(b)

(c)

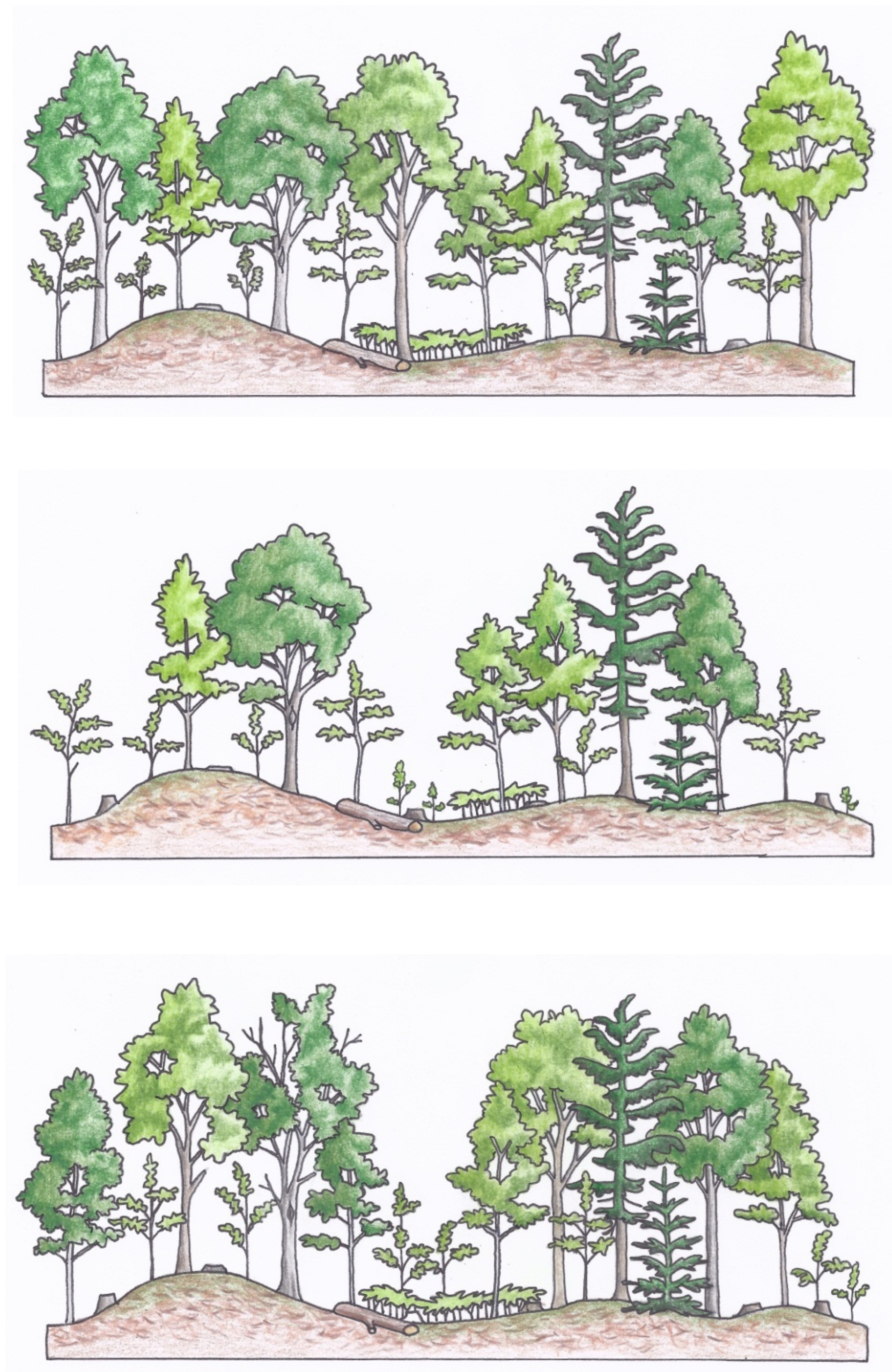


Figure 3g. A profile of an individual selection silviculture system depicting a pre-harvest tolerant hardwood stand (a), stand conditions after a partial selection cut (b), and 25 years later with the natural regeneration of shade tolerant species under the canopy(c) (illustrations by Jodi Hall).

(a)

(b)

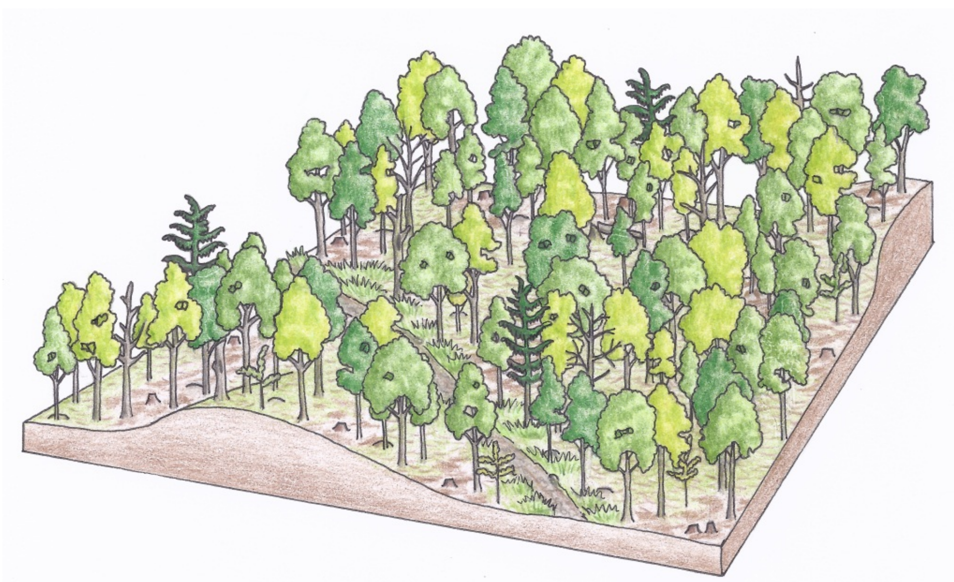
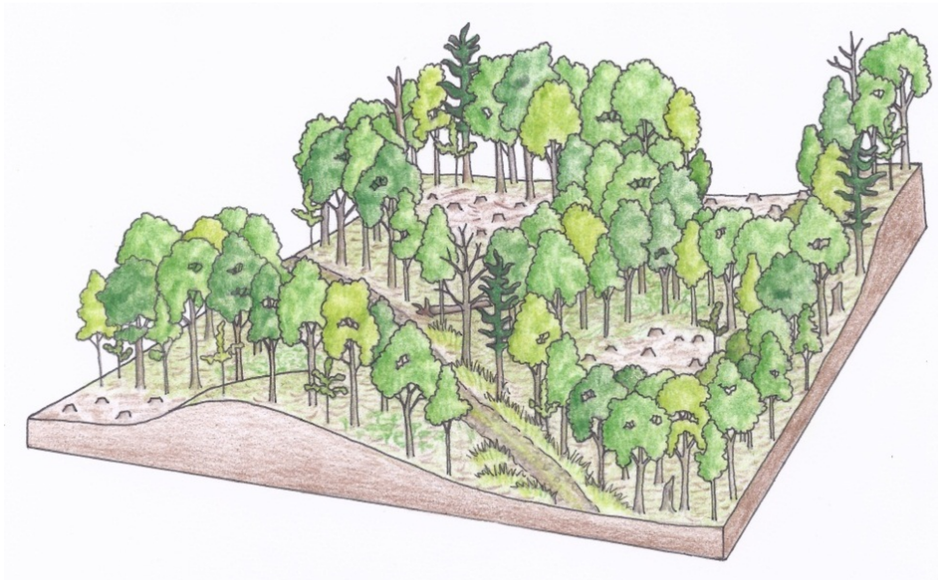


Figure 3h. An aerial view of an individual tree selection harvest in a tolerant hardwood stand resulting in >70% residual cover and perpetual all-aged stand. Image (a) depicts the initial harvest entry, while image (b) depicts regrowth after approximately 25 years and the harvest associated with the next cutting cycle (illustrations by Jodi Hall).

(a)



(b)

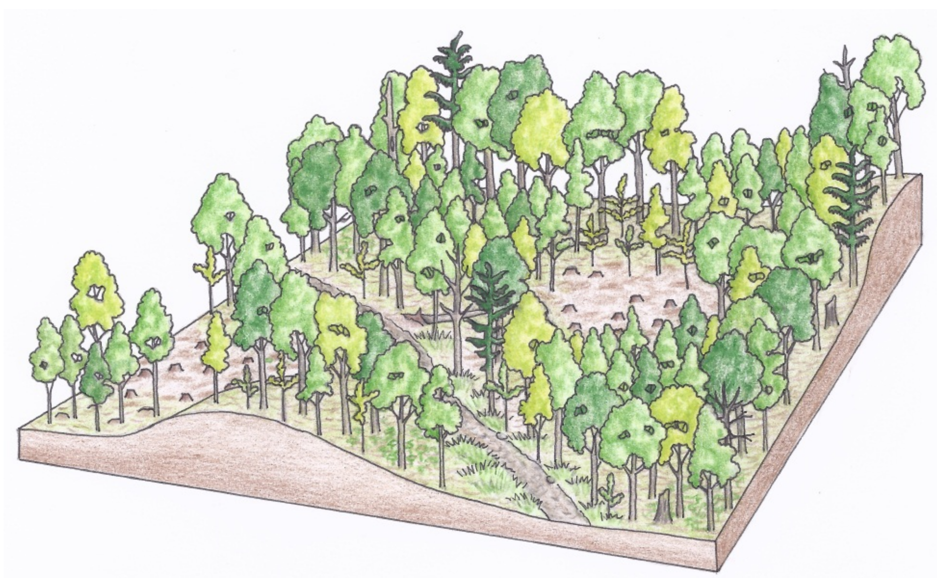


Figure 3i. An aerial view of a group selection harvest in a tolerant hardwood stand depicting an initial harvest (a) and regrowth and harvest associated with the next cutting cycle (b) resulting in >70% residual cover and a perpetual all-aged stand (illustrations by Jodi Hall).

3.1.3.2 Residual tree retention

The harvest methods described in section 3.1.3.1 are categorized based on silviculture objectives and the related growing conditions they create. The growing conditions created are largely a function of the amount and pattern of harvested and retained trees. Harvest and retention decisions are normally tuned to meet silviculture purposes but may also be adjusted to meet other management objectives (diversity, viewshed, etc.) or to address operational considerations. Often, a single retained tree can be related to more than one of these categories. For example, a large white pine may be left as a seed tree for silviculture purposes, a supercanopy tree for diversity purposes, and an oversized tree if the available equipment cannot process it.

Trees retained exclusively for silviculture purposes may be retained for short or long periods of time depending on the silviculture system being applied and future access to the harvest area. For example, residual trees retained after the first harvest in a shelterwood may be retained for only a few years while residual trees in a selection harvest may be retained for multiple cutting cycles totalling 100+ years. Trees retained exclusively to meet management objectives are generally retained for longer periods, often until natural mortality occurs, unless replacement trees of a similar function are available during a future harvest entry.

Across different silviculture systems the number of stems retained can range from tens (clearcut) to many hundreds (selection) of trees per hectare. Within each silviculture system the range of possible retention is limited to the definitions in table 3b. In some cases, the additional retention associated with diversity objectives and/or operational realities may limit which silviculture systems can be applied or which species can be successfully regenerated. Further discussion of suitable retention levels by species is provided in the management interpretations in section 5.2.

Residual trees above minimum requirements (e.g. OMNR 2010a) might also left after harvest due to market conditions. This occurs when a particular species and/or product is not in demand, or cannot be harvested, processed, and hauled at the current market price. These trees represent not only a lost opportunity from an economic point of view, but can also hinder the implementation of the silviculture prescription, resulting in an increased risk of not meeting silviculture objectives. Too many residual trees can;

- cause excessive shade
- compromise quality improvement targets
- introduce less desirable seed sources (species and genetic quality)
- suppress root suckering (e.g. aspen)
- hinder in-block access for renewal and tending
- create overhead hazards

The quantity, species, and quality of residual trees retained after harvest will be consistent[7] with the silviculture objective for the site (Guideline).

In some clearcut harvest operations, trees are removed in stages with different species or products targeted in different entries. This is referred to as two-pass harvest and can have implications on the success of regeneration. The initial harvest entry will increase available light, often disturbs the forest floor, and stimulates regeneration of target and competitor species. Regeneration that is established in the first entry risks being damaged in the subsequent entries. Shade intolerant species may be able to regenerate in the initial light conditions but as light demands typically increase with age, and the remaining canopy expands in response to the harvest release, may die off before the final harvest can occur. On richer sites, non-crop species such as beaked hazel and other shrubs may establish in the partial shade conditions created by the first harvest and inhibit regeneration of crop species, even after the final harvest occurs. The longer the delay between the first entry and completion of the harvest prescription the greater the risk to compromising regeneration objectives.

Two-pass harvest should be avoided where possible. When other factors do not allow a single harvest entry the delay between first and final harvest entries should be less than 2 growing seasons (**Best Management Practice**).

3.2 Logging Method

Logging method is a description of the components of a tree that will be removed during harvesting and the degree of processing that occurs at the stump. The logging methods typically used in Ontario include full-tree, tree-length, and cut-to-length.

Other logging methods such as whole-tree (tree and stump removed) and complete-tree (tree, stump, and large roots removed) are not a wide spread practice[8] on crown land in Ontario, generally prohibited by OMNR, 2010a, and will not be considered in this guide.

Table 3c provides a description of full-tree, tree-length, and cut-to-length logging methods.

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[7] In cases where management objectives, market conditions, or any other reason are projected (in advance of harvest) to cause residual retention that is not consistent with silvicultural objectives, the practitioner will have to decide to either defer the harvest until such time as the full prescription can be applied, OR, make a pre-harvest adjustment to the silvicultural objective (and prescription) to one that is consistent with projected post-harvest conditions. Adjustment of the silvicultural objective for the site will be done within the context set out in the long-term management direction (e.g. forest level composition objectives), and may require adjusting the objective on other sites to compensate for the landscape influence of the initial site level change.

[8] Some movement or removal of stumps and roots associated with normal operations (construction of roads, landings, and skid trails; renewal and tending; slash piling; etc.), including incidental movement or removal during harvest does occur, but not as a wide-spread practice in the general harvest area. Further, removal of stumps/roots may also occur for forest health purposes.

Table 3c. Description of the three logging methods typically employed in Ontario.

Logging Method	Description
Full-tree	The removal of the entire crown and bole to the roadside where the tree is chipped whole or limbed and topped with cutting-to-length (aka slashing) occurring at roadside or offsite.
Tree-length	The removal of the main stem to roadside with limbing and topping occurring at the stump and cutting-to-length (aka slashing) occurring at roadside or offsite.
Cut-to-length	The limbing, topping, and cutting-to-length (aka slashing) of trees at the stump followed by removal of the logs to roadside.

Selection of a logging method is complex and requires consideration of many operational realities (available machinery, requirements of receiving mills, etc.) that may constrain short-term flexibility and take many years to change. Equally important, the logging method can influence post-harvest conditions and achievement of short and long-term silviculture objectives. Additional considerations may include:

- Silviculture system employed
- Quantity of in-block slash and influence on future renewal
- Quantity of roadside slash and potential need for treatment
- Impact on desirable and undesirable residual trees
- Impact on desirable and undesirable advance growth
- Concentration of nutrients
- Tree size and operating efficiency
- Site characteristics, silviculture objective, and ground disturbance
- Footprint of extraction trails and roadside work areas

Harvest, like this cut-to-length operation, has a large influence on renewal activities. The harvest stage can dictate what site preparation type (if any) is required, the potential for natural or advance regeneration, the quality of residual stems, influence of competition, future growing conditions, long-term growth rates, and more. The influence of harvest is not limited to decisions on what to cut and retain but also the application of careful logging practices. Well trained, experienced, and conscientious operators can reduce renewal cost/effort and positively influence stand condition for decades afterward. (photo: Mike Curran)

Most of the above considerations can be both positive and negative depending on the situation and it is not possible to generalize. For example, too much in-block slash can be an impediment to operations but can also provide a seed source (cones) for regeneration and a more even distribution of nutrients. Cut-to-length operations can reduce site damage on susceptible sites by using slash mats for travel, while light soil disturbance associated with fulltree logging may provide desirable site preparation on other sites.

3.3 Renewal Treatments

Renewal involves a planned set of treatment(s) applied in a coordinated fashion, in one or more successive steps, to establish a defined forest condition. Renewal typically begins with a harvest but can also include pre-harvest treatments (see section 3.6). Treatments are selected to create or maintain conditions that favour establishment, protection, and growth of desired species.

Successful renewal starts with a clearly articulated future forest objective for the site (see section 4) followed by careful upfront planning of renewal operations, including harvesting, that will have a high probability of achieving the future forest objective given the site characteristics, current forest condition, and operational realities. The influence of the harvest treatment on overall success cannot be overstated.

The discussion on renewal treatments is divided into site preparation and regeneration. The following two sections provide a description of each. The descriptions below are somewhat general in nature and provide only an overview of the techniques and some of the factors to consider during planning and implementation. Learning from past successes and failures through dialogue with local practitioners and, detailed recording of operations and rationale behind decisions is critical to long-term success of a renewal program.

3.3.1 Site Preparation

The primary objective of site preparation is to create enough suitable, well-distributed microsites for the establishment of desirable species. This involves the disturbance of the forest floor, upper soil horizons, and/or competing vegetation prior to regeneration. In sensitive lowland areas site preparation disturbance of the forest floor may be limited to slash realignment. Treatments include manual, mechanical, chemical, and prescribed burning. These treatments may be used alone or in combination. The treatment may be applied before, after, or between harvest entries.

Within this guide, the previous distinction between site preparation (artificial regeneration) and scarification (natural regeneration) has been removed. The term scarification may still be a useful distinction in the field, but is not used in the management interpretation tables in section 5.2.

Table 3d provides a brief discussion of four general types of site preparation used in Ontario. For an expanded discussion refer to Sutherland and Foreman (1995).

Table 3d. Description of general site preparation techniques commonly used in Ontario.

Type	Description
Manual	The use of boot/shovel screefing or manual or motor-manual tools to set aside surface litter, suppress undesirable vegetation, or to otherwise prepare microsites for regeneration.
Mechanical	The use of machinery with self-propelled prime movers to prepare microsites for regeneration and may be combined with a herbicide application in a single operation. Methods (shearing, screefing, inverting, mounding, trenching, mixing) vary in the amount of disturbance of the forest floor, degree of mixing of the organic layers with the underlying mineral soil, and influence on existing vegetation.
Chemical	Application of federally registered, provincially approved herbicides by licensed applicators prior to regeneration. This treatment can be used alone or in combination with other types of site preparation or in advance of a prescribed burn (brown and burn). Herbicides can be applied from aircraft (e.g. helicopter), ground machine (e.g. skidder mounted airblast), or using manual tools (e.g. backback sprayer). The pattern of application varies from broadcast to band selective to spot selective to stem selective. A wide variety of chemicals and carriers can be used and no attempt has been made to list them here.
Prescribed Burning	The knowledgeable application of fire to a specific land area to accomplish predetermined land management objectives. Site level objectives are translated into to a desired fire severity and matched to specific fire weather indices (e.g. duff moisture code) based on local fuel conditions. The Prescribed Burn Operations Policy (OMNR, 2008) and the Prescribed Burn Manual (OMNR, 2008) provides the policy, procedures, and planning framework for the application of prescribed burning in Ontario. Appendix 5 includes additional discussion on the use of prescribed burning.

3.3.2 Regeneration

Regeneration is the establishment of a new cohort of trees either by natural or artificial means. Treatments range from passive natural regeneration using self-sown seed or vegetative reproduction (suckers, sprouts, layers) to assisted natural regeneration such as scarification, to artificial seeding and planting. Combinations of both natural and artificial regeneration, known as blended regeneration, may also be used in some circumstances.

3.3.2.1 Natural Regeneration

Natural regeneration is the establishment of desired tree species by natural seeding, sprouting, suckering, or layering. The success of natural regeneration depends upon the autecology of the targeted species and competitors, site conditions, and the growing conditions (light, seedbed, etc.) created by prior and subsequent treatments.

Natural regeneration presents an opportunity to maintain local gene pools and reduce operational costs, however, naturally regenerated stands typically have more variable stocking, clumping, and species composition. Further, some natural regeneration approaches require an extended regeneration period, contributing to an increase in the rotation age of the next stand. Groot (2001) provides an excellent review on the use of planned natural regeneration for conifers in Ontario.

To the extent practical and feasible, desirable advance growth should be protected on all sites, even if it is not the primary regeneration method. Advance growth not only provides free regeneration but can add species, genetic, and size diversity in the regenerating stand. Use of careful logging techniques (defined trails, harvesting in winter, de-limbing at the stump, directional felling, etc) can all help to minimize damage. (Photo: Mike Brienesse)

Advance growth refers to young trees under existing stands capable of becoming the next crop. Advance growth is composed of species that are mid-tolerant to tolerant of shade and may be a different species than that dominating the overstory. Advance growth can originate from any combination of seed, vegetative layering, root suckers, and stump sprouts and may range in size from small seedlings to larger poles.

Many tree species (spruce, birch, cedar, oaks, white pine, etc.) in Ontario regenerate through the use of seedling banks (seedlings establish under a closed canopy and grow slowly for a number of years, waiting for a canopy opening). In many cases these species establish a regeneration layer before a stand initiating disturbance occurs. This provides an opportunity to utilize this adaptation to establish a regeneration layer before a harvest treatment is initiated or before the majority of the canopy is removed in the case of shelterwood or selection. While advance growth can provide sufficient stocking and distribution of desirable species it is typically complimented with other natural or artificial regeneration methods. When mixed strategies are implemented, there needs to be a realistic evaluation of the value of the advance regeneration - is the density, size, vigor, and survivability of the regeneration high enough to think, that if protected, it will survive and thrive and become part of the new stand? Indiscriminate reliance on advance regeneration can compromise achievement of objectives. Undesirable advance growth (e.g. balsam fir) will not only limit success of other regeneration methods, but contribute growing stock that is not consistent with objectives and contrary to an emulation of natural disturbance paradigm.

Natural seeding is the dispersal by natural means of seeds from standing trees or from cone-bearing slash. Natural regeneration from seed requires the successful completion of a chain of events involving flowering, cone development, seed dispersal, germination, establishment, and early seedling growth. If this chain is broken (e.g. drought limits seedling establishment), it can result in regeneration failure and a delay in renewing the site. Maximum success can be achieved when a good seed year is combined with a suitable seedbed and adequate moisture during the growing season. Site preparation techniques are often used to improve seedbed or other germination and growing conditions. Many Ontario tree species can be regenerated using natural seeding including white birch, yellow birch, red oak, jack pine, black spruce, sugar and red maple, black cherry, larch, hemlock, and cedar.

Good seed years in Ontario vary by species (see Appendix 3 – fact sheets) and may vary regionally in any given year. For some species, good seed years can be predicted in advance allowing coordination of harvest, scarification, or other seedbed treatments with seed fall. Refer to the *Seed Manual for Ontario: Guidelines for tree seed crop forecasting and collecting* (OMNR, 1996) for further information.

Vegetative regeneration includes root suckers, stump sprouts, and layering. The term coppice is commonly used to refer to both stump sprouts and root suckers. In this guide layering is grouped with advance regeneration (see above). Sprouts may come from a recently harvested parent tree or from seedlings and saplings damaged during operations (e.g. maple seedlings) or intentionally clipped to encourage vigorous re-sprouting (e.g. red oak).

Vegetative regeneration offers many of the advantages of natural seed (maintain local gene pool, high initial densities, improve wood quality, etc.) but also offers rapid early growth due to support from the parent root system. The capacity for vegetative reproduction is strongly influenced by the health (drought, defoliation, pathogens, health, etc.) of the parent root system, diameter of the parent tree, and the suppressive chemical influence of any uncut stems.

Ontario species commonly managed using vegetative regeneration include basswood, trembling aspen, red maple, and red oak.

3.3.2.2 Artificial Regeneration

Artificial regeneration is the establishment of desired tree species by either direct seeding or the planting of seedlings or cuttings. Artificial regeneration requires a higher initial investment but can significantly increase control over species, genetics, density, distribution, and timing of regeneration.

Direct seeding is the manual or mechanical sowing of seeds. Stocking levels achieved are a result of the seeding rate and the amount and distribution of receptive seedbed. Direct seeding includes both broadcast (e.g. aerial) and precision (e.g. site prep mounted) seeding approaches. The biological requirements for direct seeding are more rigorous than for planting because both successful seed germination and seedling establishment are required. Successful direct seeding depends on proper site selection, adequate site preparation, and good seed distribution and quality. Seeding is most successful on sites where competition from other vegetation is minimal - competition problems become more likely when the time between harvesting, site preparation, and seeding is prolonged. Direct seeding offers some advantages over natural seeding including the option to pre-stratify, use improved seed, control timing and quantity, and achieve a more uniform distribution. Application methods include rotary and fixed-wing aircraft, site preparation mounted precision seeding, shelter cones, and hand sowing (e.g. acorns). Direct seeding has been used for many species in Ontario, but is most commonly used for jack pine and black spruce.

Planting is the establishment of regeneration by setting out seedling, transplants, or cuttings. Compared to other regeneration methods, planting can provide control over stand density and structure to achieve management objectives. However, it can also be the most costly and is a significant logistical undertaking. Planting is suitable for a wide range of sites and is often the regeneration option chosen for productive and competitive sites, whether site prepared or not. Substrate, site preparation method, stock type, stock handling, type of planting tool, weather, ability to tend, and other factors need to be considered carefully. A large variety of species are planted in Ontario but jack pine, white spruce, black spruce, white pine, red pine, and red oak are the most common.

When undertaking any artificial regeneration program, seed source and genetic variation need to be carefully considered. Provincial policies and directives (e.g. seed and breeding zones) provide further direction for implementing artificial regeneration programs. (Photo: John Lawson)

3.4 Tending Treatments

Tending is generally any operation carried out for the benefit of an already established forest crop at any stage of its life including cleaning, juvenile spacing, compositional treatments, improvement cutting, thinning, and pruning. Figure 3j indicates the timing of application for common tending treatments applied in Ontario.

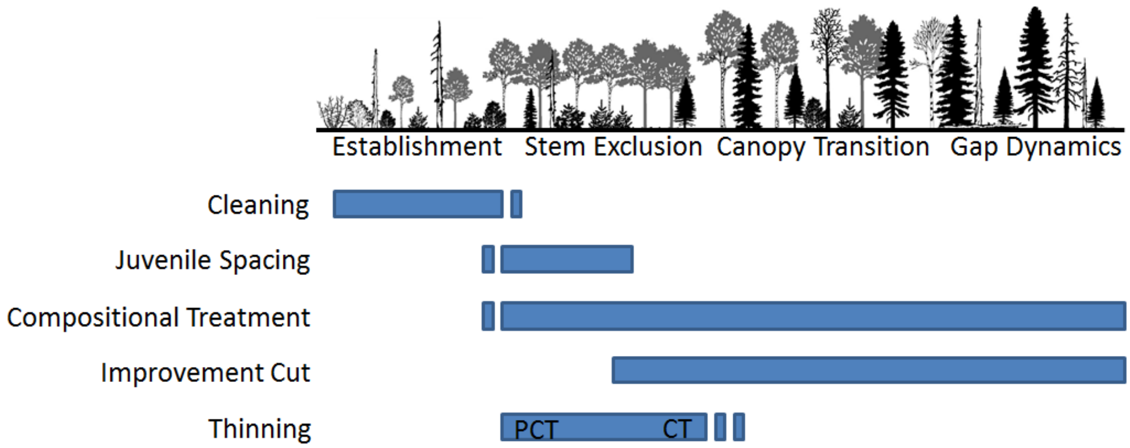


Figure 3j. Timing of application for common tending treatments applied in Ontario (header illustration from OMNR, 2003)

There is some overlap in the definition of different tending treatments and the treatment applied to any given site may serve more than one purpose. For example, manual tending between the establishment and stem exclusion stages may include removal of brush (cleaning), removal of undesirable trees (compositional treatment), and spacing of crop trees (juvenile spacing) all in a single treatment. The following text provides a definition and discussion of cleaning, juvenile spacing, compositional treatments, improvement cutting, thinning, and pruning.

3.4.1 Cleaning

Cleaning is a treatment conducted to release a regenerated stand from competing vegetation, including undesired tree species, that allows crop trees to establish dominance of the site. Removal or suppression of competing non-crop vegetation speeds stand development toward a future forest of the desired composition, structure, and growth rate (Wagner et al. 2001).

The type and timing of disturbance, pre-harvest stand condition, site characteristics, and autecology of competitor species all interact to influence post-harvest abundance of competing vegetation. Vegetation does not always have a level of impact on crop tree survival or growth that warrants an investment in cleaning; some vegetative cover may be desirable to protect conifers during establishment or to ‘train’ crop trees. Cleaning treatments must consider the tolerance of crop trees relative to the presence and abundance of vegetation, its impact on crop tree survival and growth, and the optimum timing for release.

Every tree species has a competition threshold defined as the level of vegetation abundance where there is an abrupt increase or decrease in the rate-of-change in tree growth or survival (e.g. Wagner et al. 1989). In addition, there is a critical period during which cleaning must occur to prevent loss and ensure the ability of the suppressed tree to recover.

A variety of methods are available to remove or suppress non-crop vegetation including chemical, manual, and mechanical cleaning.

Chemical cleaning is the use of herbicides to control non-crop vegetation. Generally speaking this is the most effective and least expensive means of providing longer term control of non-crop vegetation (Wagner et al. 2001). Herbicides can be applied through aerial spraying or through on-ground treatments using vehicle mounted equipment, backpack sprayers, or other hand application tools (wicks, injectors, etc.).

Manual cleaning is the manual cutting with motorized or non-motorized tools (e.g. motorized brush saws, chainsaws, and axes), girdling, clearing or scalping with hoes, and hand pulling, trampling, or binding of unwanted vegetation. Manual and motor manual cleaning are especially suited to harvest methods that leave an overstory canopy but can be costly, labour intensive, and involve greater risks to operator safety than most other cleaning methods.

Mechanical cleaning is the use of self-propelled, wheeled, or tracked prime movers with motorized cutting attachments to remove woody vegetation. Mechanical cutting, like manual cutting, is most effective in midsummer to reduce re-sprouting.

3.4.2 Compositional, Spacing, and Improvement Cuts

A number of treatments can be applied after initial establishment to manipulate the density, composition, structure, and quality of the future stand to meet current or future management objectives. These treatments may be applied as part of a planned schedule (e.g. aerial seeding with planned spacing) or opportunistically as the sites respond to previous treatments and natural dynamics are expressed.

Juvenile spacing is the spacing of crop trees during the stand initiation stage. It is similar to pre-commercial thinning, except that it is carried out before canopy closure has occurred. At this stage of stand development, it may not be possible to select for dominance if it has not yet been expressed.

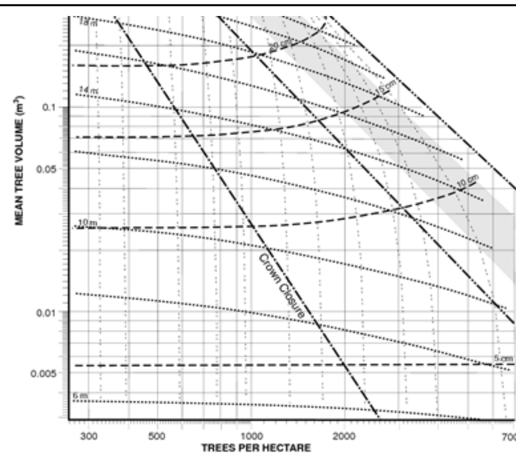
Compositional treatments alter the relative proportion of species to meet compositional objectives. Trees can be removed by cutting, girdling, or herbicide application. Stems that are removed may be merchantable or non-merchantable. One or more species may be targeted for removal in order to shift from one composition type to another. This may include removal of an undesirable overstory to release an established mid or understory.

Improvement cuts remove defective, undesirable, and overmature trees of any species to favour future stand development including release of regeneration, poles, and suppressed crop trees. Commonly applied in forest types managed through shelterwood and selection to manipulate structure between harvest entries or to remove additional stems that would not normally be removed during harvest. This may include removal of merchantable stems in stands not scheduled for a regular harvest.

3.4.3 Thinning

Thinning is a form of partial canopy removal in an established stand that concentrates potential wood production of a stand on selected trees (Smith et al. 1997). Secondary objectives may include compositional objectives or developing future seed producing crowns. Thinning may be used to influence wood quality and quantity and achieve specific management objectives (habitat, aesthetics, watershed management, etc.).

Thinning practices may be either selective or systematic. Selective thinning refers to the removal or retention of trees based on their individual merits. Systematic thinning removes



Density Management Diagrams (DMD) are stand-level models which graphically illustrate the relationships between yield, density and mortality at various stages of even-aged stand development. The DMD can be used as a stocking guide for even-aged single-species stands by determining an optimum stand establishment density or by carefully planning and timing thinning operations. Appendix 4 includes additional information on application of DMDs to commercial thinning operations.

trees according to a predetermined system that does not permit consideration of the merits of individual trees. Thinning practices are further distinguished as ***commercial*** or ***pre-commercial*** based on the size of trees being removed and FMPM categorization of harvest versus tending treatments.

Timing of initial thinning operations varies by species, site quality, spacing, thinning intensity, harvesting and marketing conditions, and site level objectives. Density management diagrams allow resource managers to forecast required thinning time-frames based on initial spacing and site quality (e.g. site index). Timing and removal rates are normally based on the age at which stands intersect the zone of imminent competition and mortality. This represents the optimum point at which to thin the stand to maintain maximum stand-level diameter growth while reducing the chance of competition induced mortality. Appendix 4, based largely on the work of McKinnon et al (2006) and Kayahara et al (2006), describes a number of best practices and factors to consider when planning and undertaking a commercial thinning operation.

3.4.4 Pruning

Pruning is the removal of lower branches from standing live trees by natural or artificial means (NRC 1995). It is generally done when the desired end product is high value knot free logs (e.g. veneer logs) or to reduce the relative humidity within a stand to reduce the incidence of disease (e.g. white pine blister rust). Pruning can also be done to improve aesthetics and interior access to a stand. Pruning is not a common practice on crown lands in Ontario.

3.5 Amelioration

Amelioration is any operation carried out on the physical site to change one or more abiotic factors in order to improve the growth or quality of a stand. Typically this would include fertilization and/or drainage improvements. Neither drainage nor fertilization were considered as part of the Class Environmental Assessment (MOEE 1994) and therefore are not permitted as part of normal forest management activities on Crown land in Ontario. **The suitability or limitations of these treatments have not been assessed in this guide.** Managers who would like to undertake an amelioration treatment will need to follow the appropriate environmental assessment process to gain approval or exemption prior to undertaking any planned amelioration treatments.

3.6 Pre-harvest Treatments

The treatments discussed in sections 3.3 and 3.4 are normally applied following a harvest entry, however, many of them could be applied before harvest (e.g. prescribed fire) to manipulate post-harvest conditions (e.g. mid-story competition). Specifically, the suitability of pre-harvest herbicide, prescribed fire, site preparation, and planting are assessed in this guide (see management interpretation tables in section 5).

4.0 Planning and Implementation

This guide is used to help plan and implement silviculture operations to achieve forest management objectives. The planning phase includes setting a management objective, identifying treatments that will achieve that objective, determining how often each of those combinations should be applied to create the kind of forest we want in the future, and developing performance standards to measure success. The implementation phase includes confirming ground conditions, stratifying the block into treatment units, committing to a future condition (e.g. forest unit and intensity) that matches the objective, identifying the likely combination of treatments required to get there, and monitoring performance.

The Forest Management Planning Manual (FMPM) provides details on the process and documentation requirements associated with each of these steps. The following sections are intended to complement the information in the planning manual and in no way replace or supersede that direction.

4.1 Planning

4.1.1 Developing Silviculture Ground Rules

A silviculture ground rule identifies the current forest condition, silviculture system, future forest condition (i.e. at maturity), development information, management standards, regeneration standards, and acceptable alternative harvest, renewal and tending treatments for a specific forest condition. A number of silviculture ground rules are developed to cover the range of objectives specified in the long-term management direction.

The forest condition in a silviculture ground rule is typically expressed in terms of forest unit and site conditions. Forest units are aggregations of forest stands with similar composition, that develop in a similar manner both naturally and in response to treatment, and to which a single silviculture system can be applied. They are the primary classification for assumptions regarding how the forest develops through time.

The following steps approximate the process to apply the information and management interpretations in this guide while developing silviculture ground rules. In practice this process may be iterative, with information at one stage leading to a modification of what was set in a previous stage (e.g. forest unit definitions). Further, forest management plans normally have a good foundation to work from, including silviculture ground rules, in the previous plan. It may be more efficient to review existing ground rules for compatibility with the management interpretations in this guide than starting from scratch.

Step 1: Identify the future forest conditions that are likely to be targeted on your forest including species composition (primary, secondary, and incidental species) and age structure. Group these into similar conditions based on the forest unit definitions, yield curves, or other criteria (intensity, habitat objectives, etc.) developed for your FMP.

Step 2: Review the management interpretation tables from Section 5 that correspond to the species and conditions identified in step 1. Eliminate any silviculture systems, treatments, or combinations that are not possible and/or desirable on your forest. Pay particular attention to low probability and not recommended treatments and the associated rationale for that designation.

Step 3: For each future forest condition identified in step 1, identify treatment combinations (i.e. harvest, renewal, and tending) from step 2 that could be used to maintain or create each future condition.

Step 4: Evaluate the designation (i.e. high, low, not recommended – refer to section 5) for each system, method, or treatment identified in step 3. If a low probability or not recommended system, method, or treatment is included, confirm your ability/desire to undertake trial areas, exceptions monitoring, or make other adjustments (e.g. minimum rotation age) as applicable.

Step 5: Complete the appropriate silviculture ground rule documentation as outlined in the forest management planning manual.

4.1.2 Strategic Silviculture Options.

Strategic silviculture options are used in strategic modeling to define assumptions about cost, success rates, and to limit model choices to reasonable and realistic treatments. The strategic silviculture options are groupings of silviculture ground rules that have the same current and future forest condition and are projected to develop on the same yield curve and successional trajectory.

The output of strategic modeling includes a schedule of how much of each strategic silviculture option (i.e. combinations of similar ground rules) is applied over time. The schedule is a combination of the options that were included (i.e. which ground rules), and balancing the achievement of multiple objectives. The schedule associated with the strategic direction becomes important context for selecting treatments at the site level.

4.1.3 Standards

Performance standards ensure results are consistent with assumptions made during development of the long-term management direction. They are set in advance of operations and provide an objective means of assessing the result of applying silviculture treatments. Performance standards vary by silviculture system and measure attributes such as the species, amount, size, and quality of regeneration and retained stems.

4.1.3.1 Regeneration standards

Regeneration standards provide a performance benchmark to determine if the results of silviculture activities were successful in meeting desired regeneration objectives, and can be used to make an early determination of whether a stand is tracking (or has the potential to track) towards a specified yield curve or desired future forest condition. Regeneration standards are normally applied to the clearcut and post regeneration stages of shelterwood systems with timing of measurement coordinated with anticipated development milestones in the stand. Formal assessment of regeneration standards (i.e. free-to-grow) typically occurs after all harvest and regeneration activities are complete and the trees have reached a size where they are free from vegetative competition. Information gathered in what is commonly referred to as 'establishment surveys' can be invaluable not just for the scheduling of tending and other supplementary treatments, but to effectively double the information available for silviculture effectiveness monitoring analysis (refer to section 6.2.1). Information from multiple surveys (i.e. establishment and FTG) facilitates investigation of cause and effect over shorter time periods and with fewer variables.

Free-to-grow monitoring compares the result of silviculture treatments to a regeneration standard. Regeneration standards are specific to a forest unit and silviculture intensity (see section 2.2.2) and set during the forest management planning process. The forest management planning manual describes the process and requirements for setting and documenting a regeneration standard. OMNR, 2009 provides a decision framework for developing regeneration standards. Additionally, OMNR, may choose to develop provincial standards, or a common framework for developing standards, that should be referenced as available. The following principles can help guide the development of a regeneration standard:

- have a high probability of developing onto the desired yield curve (consider: site occupancy, growth rate, regeneration delay, quality improvement, piece size, species composition, etc.)
- match to objective for the site including resolution/detail
- account for the influence of early stand dynamics

4.1.3.2 Performance standards in partial harvests

In partial harvests, where a mature canopy is retained (selection, commercial thinning, and shelterwood prep, regeneration, first removal) the choice and condition of retained trees has a direct influence on meeting objectives. Choices made during tree marking, block layout (landings, skid trails, etc.), harvest, renewal, and tending all contribute. In addition to developing a regeneration layer, performance standards in partial harvest areas measure:

- Improvement in Acceptable Growing Stock (AGS)
- Coverage/spacing of trees measured as basal area, crown closure, bole spacing or similar measures as defined in FMP.
- Extraction trail coverage
- Site damage


OMNR, (2010a), includes limits on the area of extraction trails to minimize damage to the soil. In some cases a different limit may be required to ensure silvicultural objectives are met. For example, to realize anticipated gains from commercial thinning, trails should be minimized (see Appendix 4). Conversely, extraction trails can provide an excellent seedbed for some species (yellow birch, cherry, etc) and reduce the need for site preparation after harvest. (photo: Mike Brienesse)

4.2 Selecting and Implementing a Silviculture Ground Rule.

Silviculture ground rules provide information about what treatments can be applied to achieve the desired result on different sites. However, ground rules typically include multiple options to get to the same end, provide only summary level description of treatments, and there is normally more than one possible ground rule for any given site. Turning a ground rule into a site level prescription requires information about the site (specific soil, species, competition, constraints, etc.), context from strategic planning, incorporation of operational realities (available equipment, stock, etc.) and perhaps most importantly experience. Details not included in the silviculture ground rules like planting density, crown spacing, timing of tending, etc. must be determined for each treatment area.

The forest management planning process requires a ground rule be assigned to each stand as the harvest is planned. This is an initial estimate of treatments and results based on the available information at the time. The following steps provide an approximation of the process for selecting and implementing a silviculture ground rule after this initial planning step.

Step 1: Confirm site conditions. The timing of confirmation and level of detail should be matched to the complexity and information needs of possible prescriptions for the site. Information should be collected with enough resolution to capture any significant changes in conditions across the planned treatment area. The method (e.g. ground survey) used to confirm site conditions must provide a reasonable level of confidence that the selected prescription will be successful. Feedback from silviculture effectiveness monitoring may help prioritize site types and/or prescriptions where improved confidence is required.

Step 2: Using both the information collected in step 1, and the context provided by forest level objectives (e.g. increase white pine), commit to a future forest unit and intensity. This may require stratification of the site into multiple treatment units to account for differences in conditions (wet and dry areas, presence of advance regeneration, etc.), objectives, or available resources (e.g. planting stock). A myriad of operational realities must be considered including the silviculture system applied to the surrounding forest, ability to return for follow-up treatments, management constraints that may limit treatment options (e.g. protection of values), and many others.

Step 3: Using the eligible silviculture ground rules as a guide (i.e. consistent with future forest and intensity from step 2), select and schedule a combination of treatments that is appropriate for the specific conditions in the treatment unit, and consistent with achieving the desired future forest unit and assigned yield curve. A number of resources are available to help determine specific parameters for prescriptions (see Appendix 6).

Step 4: Apply treatments and monitor response to ensure stand is trending towards desired condition. Apply supplemental treatments as required. When the stand is not developing in the desired direction, and supplemental treatments are not practical or feasible, forecast the likely future condition that will be achieved and use that as additional context for treatment selection in step 2 for other sites. Document reasons for change in objective through Forest Operations Prescription (FOP) change layers or other relevant processes.

Step 5: At the appropriate development stage, report on stand condition with performance standards (regeneration standard, AGS improvement, etc.). Strive to understand the cause of both successes and failures. Use that information to refine future prescription setting and assumptions used in the next round of strategic planning.

In addition to the generic steps described above, decision keys have been developed for a number of the species addressed in this guide. The decision keys include suggested thresholds for choosing one treatment path over another based on site conditions, objectives, and operational realities. These can be found in appendix 5.

4.2.1 Pre-harvest Assessment

The first step of the process above indicated the need to confirm on the ground conditions. This may include a formal and detailed pre-harvest assessment or less formal confirmation at the time of harvest. Less formal approaches to stand analysis may be appropriate where:

- Inventory is reliable and stand conditions are well-understood
- Management approaches are fairly consistent
- Levels of variability are anticipated and successfully dealt with as part of the normal fine tuning of prescriptions by well-trained forest workers at the time of operation.

Formal pre-harvest assessments of a greater intensity and resolution may be required in areas:

- Exhibiting variable level of tree quality, stocking, structure or species content
- Inventory accuracy is known to be low
- Where an error in judgment related to choice of silviculture system will have a significant impact on attainment of stand level objectives

A pre-harvest assessment can ensure that incorrect, missing or unique conditions found in an operating block are considered before operations commence. It provides an opportunity to not only verify attributes influential to silviculture success but to identify values (e.g. stick nests) and other features critical to implementation of integrated management principles (see section 2). A pre-harvest assessment of stand conditions may include:

- Species present including midstory and understory
- Stand stocking including variability, holes, and coverage by species
- Stand structure including age/diameter distribution, and canopy layers
- Individual tree quality, crown size, and canopy position
- Ecosite classification including soil texture, depth, and moisture regime
- Critical ecological features
- Confirmation of FOP

OMNR, 1996 includes further discussion and practical tools to assist with pre-harvest assessments and prescriptions development.

4.2.2 Role of Site and Ecosite in Decision Making.

Ecosite classification will allow identification of the long-term potential to achieve certain forest management objectives, and is thus an important component of the silviculture ground rules. Poor stand development and performance may be a reflection of unsuitable site conditions, which will impose limitations on potential value growth and justifiable investment level. Knowledge of a given ecosite with its characteristic mixture of species should provide the manager with the tools to consider which silviculture practices best emulate natural processes on that site. Figure 4a and 4b provide an overview of species-site compatibility by broad soil group (refer section 1.3) for conifer and broad-leafed species respectively. More detail on species-site compatibility is included Section 5.1 and appendix 2.

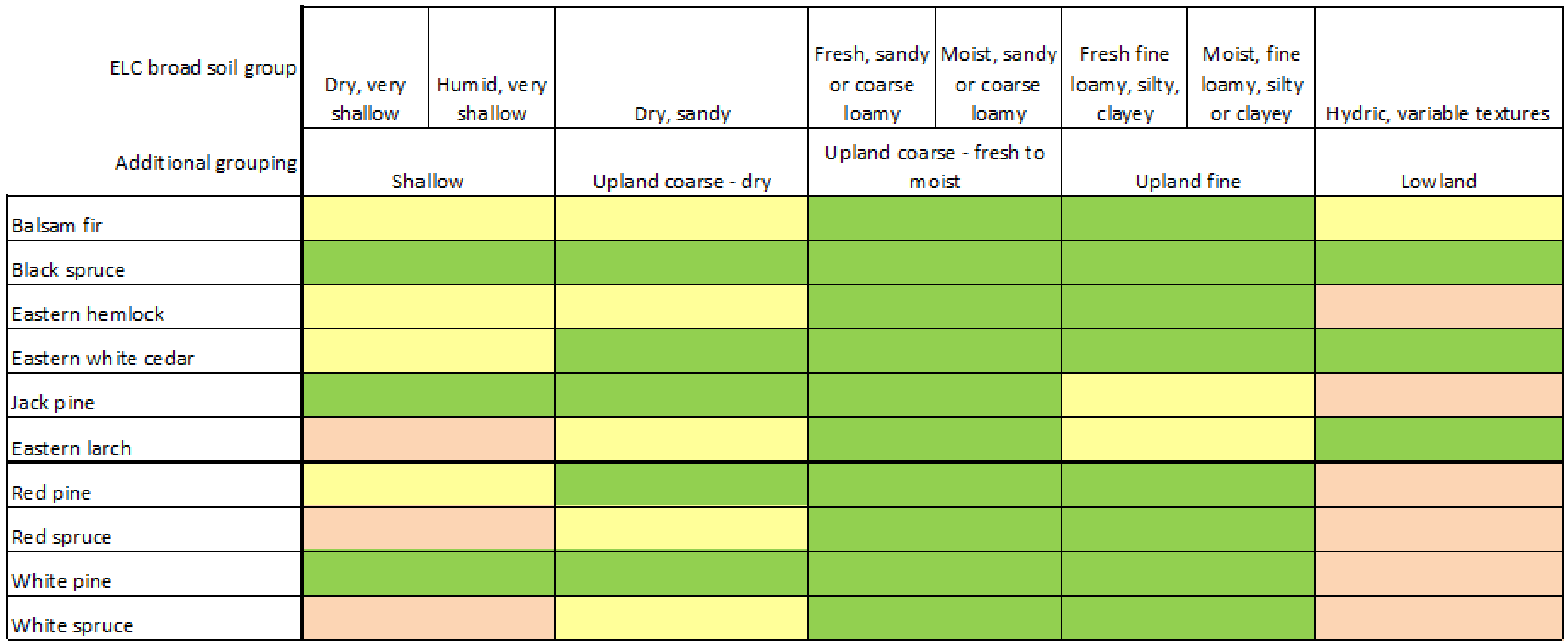


Figure 4a. Suggested species-site compatibility by broad soil group for selected conifer tree species (green = compatible, yellow = limited compatibility, pink = low to no compatibility).

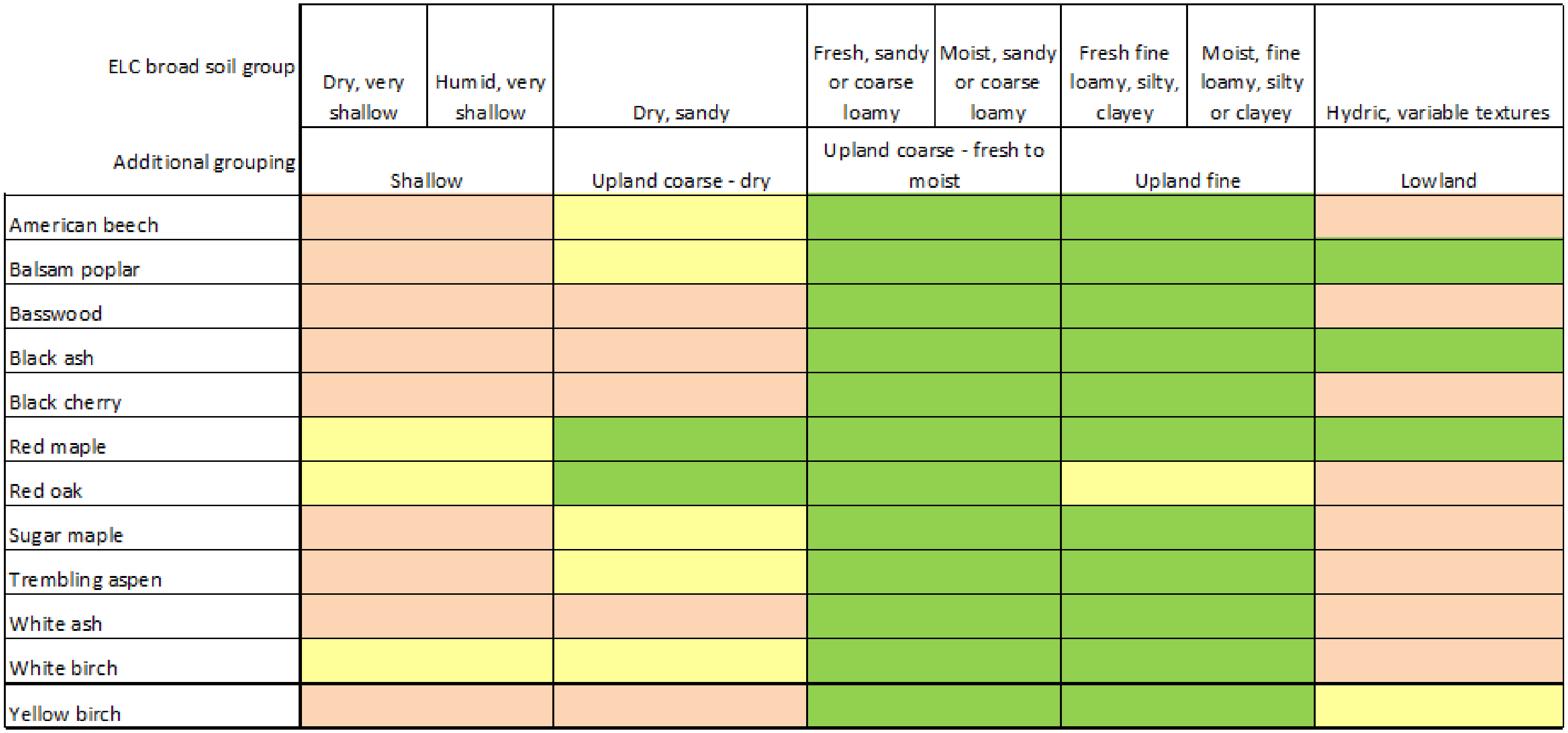


Figure 4b. Suggested species-site compatibility by broad soil group for selected broad-leafed tree species (green = compatible, yellow = limited compatibility, pink = low to no compatibility).

The frequently encountered variable stocking, structure and quality characteristics of many second growth forests may be a function of historical events (such as high-grading, natural disturbance, or even lack of disturbance), rather than limitations of site or biological potential. Current forest condition influences what is possible and how much effort is required to achieve it, but site potential should not be ignored.

The common forestry lexicon includes the concept of "off-site" species. These are cases of a species growing on atypical and/or sub-optimal sites that would generally be described as ecologically inappropriate. While it is important to recognize the influence of historical events on current distribution of species, it is also important to recognize that some off-site associations may be natural, and reasonable to perpetuate, or recreate.

Somewhat opposite to "off-site" is the concept of prime site. To the extent feasible, tree species should be matched to sites that optimize their growth. This concept extends beyond stand level choices to overall landscape and road network designs. Within an overall ecosystem management approach that balances the achievement of other objectives, silviculture efforts should be focused on the areas that provide the highest economic return.

4.2.3 Prescription Setting

The inherent variability of the natural world, combined with the myriad of possible management strategies and objectives to be applied on a given site, make it difficult to provide precise direction for setting a prescription. This guide will only speak to prescription setting briefly and in general terms.

It is important to note that this guide, particularly the management interpretation tables in section 5, do not contain sufficient detail to develop a prescription. The silviculturalist must apply their knowledge to determine the detailed parameters for planned treatments. For example, this guide may indicate that planting is recommended but does not provide advice on density, stock type, and other important parameters. To assist with the prescription development process suggested decision keys as well as example management approaches are presented for many species. In addition to the decision keys and example management approaches, suggested parameters and thresholds for some treatments are provided in the comment field of the management interpretations (see section 5.2).

4.2.4 Tree Marking

Tree marking involves the careful selection of trees for harvest or retention based on tree size, vigor, timber quality, biodiversity, and wildlife habitat value. It is a valuable tool to ensure the harvest and regeneration prescription is accurately conveyed to all involved in the harvest and regeneration of the area. In complex stands and/or when complex prescriptions are applied, tree marking is a practical way of achieving desired outcomes.

The Forest Operations and Silviculture Manual provides direction on treemarking and treemarker certification[9]. Tree marking will normally include all applications of the selection silviculture system and the preparation, regeneration, and first removal stages of the shelterwood silviculture system (**guideline**). The forest management plan will specify which silviculture ground rules require tree marking (**standard**).

Tree marking is strongly encouraged for any harvest prescription where the complexity is difficult to convey directly to the forest worker. For example, when a clearcut with seedtree prescription is more complex than simply "leave all of species X", tree marking will increase the probability of trees with the best seeding potential being left at an appropriate spacing. Other prescriptions, such as systematic row thinning, will certainly benefit from marking of rows to be removed, but do not necessarily require a certified tree marker to adequately convey the prescription.

The Ontario Tree Marking Guide (OMNR, 2004) is a companion to this silviculture guide that supports the delivery of the Provincial Tree Marker Training Program and provides operational guidance to tree markers who employ the partial cut silviculture systems. (Photo: Laurie Thompson)

It is important that the prescription indicates what the management objectives are in terms of the silviculture system to be employed, the quality of products considered, the implementation of measures concerned with non-timber values, and the long-term goals for the designated area. For Crown lands, information on forest level objectives and long term goals can be obtained from the approved Forest Management Plan. Armed with this information, a certified tree marker is expected to adapt the prescribed management approach, in an ecologically-appropriate manner, often while encountering unique forest conditions. Thus, the continuity of stand, and ultimately forest level objectives, are ensured.

[9] A certified tree marker is a person certified under the Ministry of Natural Resources' provincial tree marker training program, adhering to the tree marker's code of ethics, and applying the principles (e.g. section 6) of the Ontario Tree Marking Guide. The certification process includes training, testing, audit of work, and periodic updating of knowledge. The use of certified tree markers can include assistant, apprentice, and pre-certification audit markers whose work is supervised and endorsed by a certified marker.

4.2.5 Careful Logging

In any logging operation there is the potential for causing unnecessary damage to the site, residual trees, and advance regeneration. While many factors (site, topography, weather, trail layout, machine type, etc.) influence the potential for damage, there is no substitute for a conscientious, well-trained, and experienced operator. A good operator in challenging conditions can produce a better result than a careless operator in ideal conditions.

While many of the strategies and techniques for minimizing the potential for or degree of damage are applied at the site (e.g. high floatation tires) and block (e.g. road, landing, and skid trail layout), there are some broader influences that need to be considered.

The direction (i.e. high, low, and not recommended) presented in the individual species level management interpretation tables (section 5.2) includes considerations for potential damage. In addition to the not recommended practices in section 5.2, the following direction on damage to residual stems will apply to shelterwood (excluding final removal), selection, and commercial thinning operations.

After harvesting, 90 % of the residual AGS (acceptable growing stock) basal area and 85 % of the total residual basal area will be free of major damage (**standard**).

Table 5a provides the definition of major damage. Damage below these thresholds (i.e. minor damage) can still have a significant impact on forest health, product quality, and stand level growth rates if abundant. While it is necessary to define major damage (table 5a) and articulate an allowable level for compliance purposes (i.e. 85/90), **the goal should be as close to zero damage as possible**. If operations are routinely coming close to exceeding damage thresholds the cause should be investigated and adjustments made.

Table 5a. Definition of major damage when applying logging damage standards.

Type of Injury	Considered major when…
Bark removed – no ground contact	Trees 10-31 cm DBH: Any wound greater than the square of the DBH (e.g. for a 10 cm DBH tree a major wound is greater than 100 cm^2) Trees 32+ cm DBH: Any wound greater than 1,000 cm^2
Bark removed – with ground contact	Trees 10-31 cm DBH: Any wound greater than 60% of the square of the DBH (e.g. for a 10cm DBH tree a major wound is greater than 60 cm^2) Trees 32+ cm DBH: Any wound greater than 600 cm2.
Broken branches	More than 33% of the tree crown is destroyed
Root damage	More than 25% of the root area is exposed or severed
Broken off	Any tree
Bent over	Any tree tipped noticeably

All aspects of an operation have the potential to influence the likelihood or directly cause damage. The influence of logging method in particular on advance regeneration, residual stems, and long-term nutrient budgets was carefully considered when developing the direction (i.e. high, low, and not recommended) in section 5.2. The Background and Rationale document that accompanies this guide provides a more fulsome description of the information used to make these determinations.

A substantial portion of the information was produced from exceptions monitoring and targeted research programs related to *Not Recommended* treatments in previous silviculture guides (see section 1.5.3 for list of previous guides). These include the results of exceptions monitoring efforts on fulltree logging and residual stem damage in shelterwood harvests (Jones and McPherson, 2012) and research and monitoring of fulltree logging on shallow soils (e.g. Ponder et al, 2012).

5.0 Management Interpretations

The management interpretations in this section provide information about silviculture systems, methods, and treatments that may be used to achieve a future forest condition. The bulk of the interpretations are presented by individual species in section 5.1 with some additional considerations when targeting more than one species including in section 5.2.

5.1 Individual Species

With the exception of the lowland hardwood and other hardwood groups, the management interpretations in this section are presented by individual species. The interpretations are presented at a broad level providing bounds on the overall silviculture approach (i.e. eligible treatments) and do not provide many of the details required to develop a site level prescription.

The management interpretation tables in sections 5.1.1 to 5.1.25 are ***guidelines*** and use specific terminology to categorize each treatment as high or low probability of producing results consistent with objectives or not recommended.

High probability: A treatment, method, or system that is likely[10] to produce results consistent with objectives based on best available evidence. High probability treatments may include ***conditions*** that have to be met for the treatment to have a high probability of success. Conditions may be related to; the type of sites that support a high probability of meeting objectives, associated treatments required to ensure high probability of meeting objectives, or a narrowed range of objectives where the probability is high. If condition(s) are not met, the treatment, method, or system is deemed low probability.

Low probability: A treatment, method, or system that may produce results consistent with objectives but the degree of uncertainty is too great to consider it a high probability. All low probability treatments, methods, or systems include a ***condition*** that they occur as part of a trial area (see section 6.2.3). When this condition cannot be met the treatment, method, or system is deemed not recommended.

Not recommended: A treatment, method, or system that is unlikely to produce results consistent with objectives.

Figure 5a provides a graphic portrayal of the planning requirements for high probability, low probability, and not recommended treatments, methods, or systems as well as species not included in the guide.

[10] Professional judgement is still required to select appropriate sites, determine specific implementation parameters, and schedule pre-requisite or follow up treatments as required. Likelihood is based on best available evidence including results of research, monitoring programs, basic ecology, and experience.

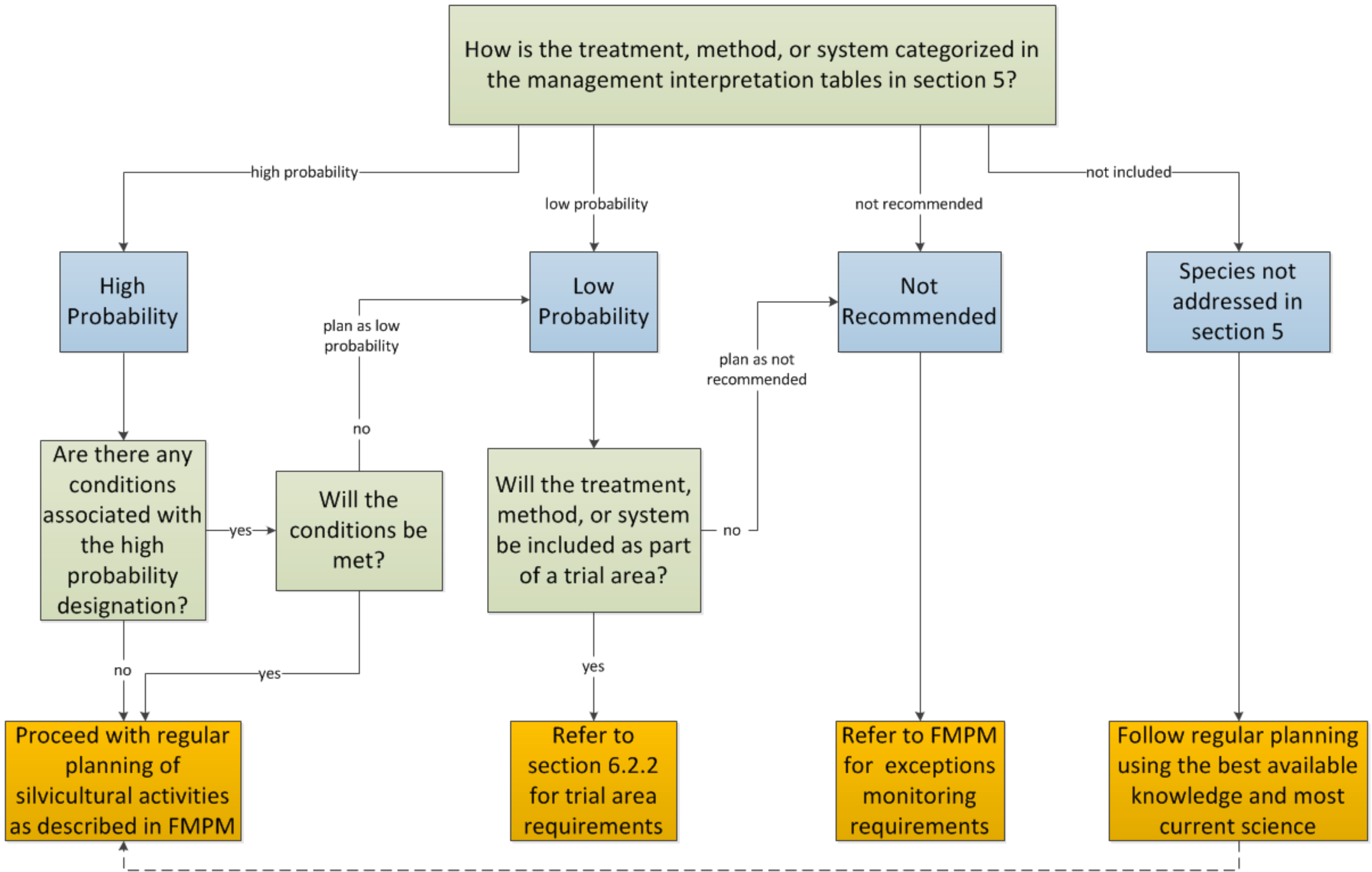


Figure 5a - Planning requirements for high probability, low probability, and not recommended treatments, methods, or systems as well as species not addressed in section 5 of this guide.

The determination of which systems, methods, and treatments were consistent with a specific future forest objective was based on the best available information including experiential and empirical information. For many species this included the development of a Bayesian Belief Network (BBN) to portray what variables (e.g. soil, water, and light) are influential, how management interventions might influence those variables, and what information is available to support that view. The background and rationale document (in prep) that accompanies this guide presents the BBNs for most of the species considered in this section. Included in the documentation are a number of literature citations that the practitioner may find useful to better understand why a particular treatment was recommended or not and to derive specific implementation parameters (e.g. what number of seed trees should I leave).

A limited number of conditions have been included in the management interpretation tables to express a narrowed range of; sites, complimentary treatments, or achievable future densities consistent with a high probability designation. Conditions that amount to stating the obvious (e.g. seedlings must be alive when planted) have not been included. Common sense is a pre-requisite for applying this guide. (Photo: Erik Wainio)

Some of the conditions in the management interpretation tables include limitations on the target density of the future forest. The target density classes used in the tables are *high*, *moderate*, and *low*. The specific values associated with these classes vary from one species to the other. Conceptually; *high* is a density where the species is expected to dominate the future composition and significantly influence the environment of the future stand; *moderate* is a density where the species is expected to be a significant but non-dominant component of the future stand; *low* is a density where the species may occur as scattered individuals, or small concentrations. For example, experience and/or ecological literature may indicate that clearcut with seedtree is not consistent with high regeneration densities of a particular species. In that case the condition would indicate clearcut with seedtrees is high probability only when targeting low to moderate densities. In this example, clearcut with seedtrees could only be used for high density objectives if part of a trial area or through formal exceptions monitoring (see section 6.2.3).

Layout of the individual species direction in sections 5.2.1 through 5.2.25.

The order of presentation is broad-leafed followed by conifer with alphabetical sorting by genus within each group.

The information and direction for each species is comprised of up to five components, each serving a slightly different purpose. The first four are included in this section - the fifth is included as an appendix.

1) A general discussion meant to provide an easy to read introduction for that species including keys to success, cautions to avoid, and recommended reading.
2) A management interpretation table categorizing each system, treatment or method as high or low probability of producing results consistent with objectives or not recommended. This includes a listing of any conditions that may apply as well as brief comments that may; explain a low probability or not recommended designation, highlight cautions, or list critical assumptions for implementation of high probability treatments.
3) Suggested management approach(es) including considerations for site selection, suggested implementation parameters, and how to choose between them.
4) A suggested decision key to assist the practitioner with selecting a management approach and choosing implementation parameters specific to the site conditions encountered while considering operational realities. For species that are typically managed as encountered and rarely drive the block-level approach, a decision key has not been developed.
5) Appendix 3 provides further information in a factsheet format on distribution, habitat, reproduction, growth, damaging agents, genetics, tolerances and response to disturbance. The factsheets are intended as a quick reminder, or reference on the silvics of less familiar species, when planning and carrying out forest management activities.

The management interpretation tables are guidelines (as noted above). The example management approaches and suggested decision keys are **best management practices.** The general discussion and factsheets are information items.

It is important to note that conditions within a harvest block (species composition, quality, post-harvest competition, moisture, etc.) can be quite variable and may require stratification into separate treatment units of feasible size and location. This may require sub-optimal treatment of some areas based on a pragmatic approach to the whole. The decision keys and example management approaches in particular need to be applied with this in mind.

For several species, a condition to "***apply principles from the treemarking guide***" is included for partial harvest silviculture systems. This is referring to the general principles outlined in the Tree Marking guide, particularly in Section 6. This would include principles like thinning from below, choosing cutting cycles and removal rates based on expected growth rates, marking for quality and stand structure improvement, `placement of group openings, crop tree selection criteria, spacing guidelines, and so on. As stated in section 1.5.2, where direction in this guide overlaps with direction included in the tree marking guide (OMNR 2004), this guide takes precedence.

5.1.1 Red Maple

Red maple (*Acer rubrum*) is tolerant of shade and can thrive on a wider variety of sites than any other hardwood species in Ontario. It has relatively low resource requirements, can tolerate dry ridges and saturated swamps, but exhibits best growth on moist loams. Regeneration occurs from seed, stump, and seedling sprouts. Seedlings tend to cycle quickly (i.e. establish, stagnate, die, repeat) under a full canopy but replacement rates are normally sufficient to capture the site when release occurs. Stump sprouts are often of poor form or high rot, particularly from larger diameter stumps. Seedling sprouts can be very successful, particularly if timed with a release event (e.g. harvest). Root form tends to adapt to soil conditions encountered with more lateral roots on high water table sites and deeper tap roots on drier sites. Red maple is predominantly managed through the shelterwood silviculture system, occasionally selection, but also well suited to open conditions following a clearcut.

Keys to success:

- Apply tree marking principles.
- Avoid very dry and very shallow sites.
- Maintain some overhead shade during early regeneration phase to provide a competitive advantage over less tolerant competition.

Cautions:

- Maple regeneration can be very aggressive and will likely require tending if other species are desired on the same site.
- The often lamented “red maple creep” – increased occurrence and dominance over large areas of central and southern Ontario that were previously logged or otherwise disturbed – may be further encouraged by some harvesting and regeneration practices. The landscape effect of harvest and regeneration decisions on red maple populations should be carefully considered.

Recommended reading:

- The red maple paradox. (Abrams 1989)

Target Species: *Red maple*

Silviculture systems and harvest method

	Designation	Conditions	Comments and Assumptions
Clearcut with standards	High Probability	Objective is for low density of maple or able to protect adequate advanced regeneration to achieve higher density.	Application normally limited to stands with low pre-harvest maple composition or severely degraded maple stands. Narrow strips/patches may limit intolerant competition.
Clearcut - seedtree	High Probability	Objective is for low density of maple or able to protect adequate advanced regeneration to achieve higher density.	Application normally limited to stands with low pre-harvest maple composition or severely degraded maple stands.
Shelterwood - uniform	High Probability	Apply principles from the tree marking guide.	
Shelterwood - strip/group	High Probability	Apply principles from the tree marking guide.	
Shelterwood - irregular	High Probability	Apply principles from the tree marking guide.	Application normally limited to sites where multi-aged structure is preferred and return harvest is unlikely.
Selection - individual	High Probability	Apply principles from the tree marking guide.	
Selection - group	High Probability	Apply principles from the tree marking guide.	Can be used to promote mid-tolerants within an uneven-aged matrix.

Target Species: *Red maple*

Pre-harvest treatments

	Designation	Conditions	Comments and Assumptions
Chemical	Low Probability		Damage and loss of maple very likely.
Prescribed Burn	Low Probability		Damage and loss of maple very likely.
Site Preparation	High Probability		Not normally required for maple as radical is able to penetrate litter.
Planting	High Probability		Maple not normally planted.

Logging method

	Designation	Conditions	Comments and Assumptions
Cut-to-length	High Probability		
Tree length	High Probability		
Full tree	High Probability	Not acceptable for shelterwood removal harvests or uneven-aged management.	High risk of damage to regeneration. Careful logging can reduce damage to boles.

Target Species: *Red maple*

Site Preparation

	Designation	Conditions	Comments and Assumptions
Mechanical	High Probability		
Chemical	High Probability		Assumes chemical will be applied in a selective fashion or with an active ingredient and/or rate that is not damaging to maple.
Prescribed Burn	High Probability	Timing of application and burn indices must be consistent with regeneration objectives.	Assumes adequate seed source (or sprout ability) and fire behaviour that will not consume seed and/or reduce sprouting ability.

Regeneration

	Designation	Conditions	Comments and Assumptions
Advance	High Probability		Primary method of recruitment to sapling/pole sizes - seedling bank cycles in understory with new seedlings quickly replacing those that succumb to suppression.
Natural seed	High Probability		Primary method of regeneration.
Vegetative (coppice)	High Probability		Stump sprouting ability reduces with increasing diameter of the cut stem. Root suckering and layering are rare.
Planting	High Probability		Not a common practice
Seeding	High Probability		Not a common practice

Target Species: *Red maple*

Cleaning

	Designation	Conditions	Comments and Assumptions
Manual/mechanical	High Probability		Not a common practice.
Chemical	High Probability		Assumes chemical is applied in a selective fashion or with an active ingredient and/or rate that is not damaging.
Midstory/Improvement	High Probability		May be required to eliminate undesirable seed sources. Assumes stem selection will be consistent with a future red maple objective.

Spacing

	Designation	Conditions	Comments and Assumptions
PCT / crop tree	High Probability		Not a common practice.
Commercial thinning	High Probability		Not a common practice.

Suggested management approaches – red maple.

Note: Although quite prolific under a number of different management approaches, red maple is rarely targeted for regeneration and more commonly inhibits management and regeneration of other species.

Option 1 – Uniform Shelterwood: Objective is the regeneration of an even-aged red maple dominated stand.

- Normally applied to tolerant hardwood stands with a minimum component of sugar maple (≥30%) combined with other species adapted to even-aged management (Pw, Sw, Or, Ow, Bd, Hi, Aw, Cb, By) and generally less than 50% poplar-birch or less than 30% hemlock or beech.
- Applied on poorer quality tolerant hardwood sites (i.e. not fresh silts and loams), or on good quality sites with low overstory quality (i.e. AGS < $9m^2$/ Ha (or < $7m^2$/ Ha AGS in sawlog sizes))
- Typically two cuts (regeneration and one removal cut) will be scheduled over a period of 5 to 15 years. When adequate density of advanced regeneration of desirable species (minimum 1m tall) is present pre-harvest, consider moving straight to a final removal cut.

Regeneration Cut

- Harvest from below to retain 50% to 70% crown closure (this would usually equate to a basal area in the range of 14 to 18 m^2/ha) removing UGS trees and undesirable seed sources. Heavier cuts will promote intolerant competition, a particular problem if little advanced regeneration is present.
- Trees to favor for retention in the regeneration cut are dominant - codominant crop trees with vigorous seed-producing crowns. Where no dominant trees are available, spacing and seed source can be provided by intermediate trees of desirable species. Seed is rarely limiting in maple stands with abundant seed occurring regularly. Retention of suitable crop trees of desired mid-tolerant species can increase species diversity of the new stand.
- Heavy mid-story of undesirable species (e.g. ironwood) should be removed to meet overstory canopy closure objectives.
- On sites with high competition (e.g. raspberry) the regeneration period may be delayed by up to 10 years as the maple establishes and grows to a competitive position.
- Site preparation is not normally required for maple as the large root radical can penetrate most litter layers.
- When stump sprouts comprise a significant portion of the regeneration on site, the sprouts should be evaluated for long-term viability. Sprouts originating high on the stump, or from large stumps, are more prone to rot and decline.

Final Removal

- When regeneration has reached a minimum of 1m with an acceptable density, remove the remaining overstory. Delayed first removal will increase damage during harvest and risk suppression of regeneration as canopy fills in.
- When regeneration fails to establish, or is dominated by undesirable species (ironwood, elm, white birch, etc.) the decision to undertake remedial treatments, wait for the stand to develop further, or proceed with final removal will have to be tailored to the site and circumstances. Generalized advice cannot be provided here.
- Careful logging to protect the regeneration is critical. Minimize the number and width of skid trails. Where feasible, scheduling a removal cut when the ground is frozen and covered with snow (ideally 30 cm+) will reduce permanent damage to regeneration.
- Some regeneration ingress following final removal will occur on some sites but should not be counted on to achieve desirable densities.

Option 2 – Clearcut: Objective is the regeneration of even-aged red maple mixed with intolerants.

- Normally applied to stands with very poor stem quality, on sites with little quality potential, and presence of intolerants (e.g. aspen). Presence of maple advance regeneration, combined with careful logging practices, will greatly increase likelihood of a future maple component.
- Harvest all stems (excepting those required for diversity targets) to create open light conditions. Harvesting in summer (i.e. leaf on) will reduce the number and vigor of aspen sprouts in the first growing season. Harvesting in winter will increase survival of maple advance regeneration
- When maple advance regeneration is not present in sufficient quantity, retain 10 to 30 seed trees per hectare.
- Low lying sites should be harvested only when frozen or very dry (see comments for lowland hardwoods). Site disturbance can lead to a prolonged grass (e.g. calamagrostis) or brush dominated condition.

5.1.2 Sugar Maple

Sugar maple (*Acer saccharum*) is very tolerant of shade, can have an even, multi, or uneven aged structure, and can tolerate a wide range of sites. Best growth is on well drained loams, it grows poorly on dry shallow soils, and is rarely found in swamps. Regeneration is primarily from seed and stump sprouts, occasionally from layering, rarely from root suckers, with seed being the most common. Germination and establishment can occur on a wide range of seed beds from leaf litter to mineral soil. Sugar maple typically produces an extensive seedling bank and clipped or broken seedlings readily re-sprout to pre-damage height. In open growing conditions established grass and herbaceous competition can impede establishment and growth. Sugar maple can tolerate low light at all stages of development and responds very well to eventual release. Concentrations of maple are typically managed through shelterwood or selection systems, but good growth can occur in clearcuts, particularly when advance regeneration is present.

Keys to success:

- Apply tree marking principles
- Avoid dry, shallow, and saturated sites.
- Maintain some overhead shade during early regeneration phase to provide a competitive advantage over less tolerant competition.

Cautions:

- Excessive opening can cause epicormic branching and crown dieback.
- Maple regeneration can be very aggressive and will likely require tending if other species are desired on the same site.

Target Species: *Sugar maple*

	Designation	Conditions	Comments and Assumptions

Silviculture systems and harvest method

	Designation	Conditions	Comments and Assumptions
Clearcut with standards	High Probability	Objective is for low density of maple or able to protect adequate advanced regeneration to achieve higher density.	Application normally limited to stands with low pre-harvest maple composition or severely degraded maple stands. Narrow/small openings may improve success by limiting intolerant competition.
Clearcut - seedtree	High Probability	Objective is for low density of maple or able to protect adequate advanced regeneration to achieve higher density.	Application normally limited to stands with low pre-harvest maple composition or severely degraded maple stands.
Shelterwood - uniform	High Probability	Apply principles from the tree marking guide.	
Shelterwood - strip/group	High Probability	Apply principles from the tree marking guide.	Not a common practice when targeting maple regeneration.
Shelterwood - irregular	High Probability	Apply principles from the tree marking guide.	Application normally limited to sites where multi-aged structure is preferred and return harvest is unlikely.
Selection - individual	High Probability	Apply principles from the tree marking guide.	
Selection - group	High Probability	Apply principles from the tree marking guide.	Can be used to promote mid-tolerants within an uneven-aged matrix.

Target Species: *Sugar maple*

Pre-harvest treatments

	Designation	Conditions	Comments and Assumptions
Chemical	Low Probability		Damage and loss of maple very likely.
Prescribed Burn	Low Probability		Damage and loss of maple very likely.
Site Preparation	High Probability		Not normally required for maple as radical is able to penetrate litter.
Planting	High Probability		Maple not normally planted and advanced regeneration is often abundant.

Logging method

	Designation	Conditions	Comments and Assumptions
Cut-to-length	High Probability		
Tree length	High Probability		
Full tree	High Probability	Not acceptable for shelterwood removal harvests or uneven-aged management.	High risk of damage to regeneration. Careful logging can reduce damage to boles.

Target Species: *Sugar maple*

Site Preparation

	Designation	Conditions	Comments and Assumptions
Mechanical	High Probability		
Chemical	High Probability		Assumes chemical will be applied in a selective fashion or with an active ingredient and/or rate that is not damaging to sugar maple.
Prescribed Burn	High Probability	Timing of application and burn indices must be consistent with regeneration objectives.	Assumes adequate seed source (or sprout ability) and fire behaviour that will not consume seed and/or reduce sprouting ability.

Regeneration

	Designation	Conditions	Comments and Assumptions
Advance	High Probability		Primary method of recruitment to sapling/pole sizes - seedling bank cycles in understory.
Natural seed	High Probability		Primary method of regeneration.
Vegetative (coppice)	Not Recommended		
Planting	High Probability		Not a common practice as natural regeneration is normally sufficient.
Seeding	High Probability		Not a common practice as natural regeneration is normally sufficient.

Target Species: *Sugar maple*

Cleaning

	Designation	Conditions	Comments and Assumptions
Manual/mechanical	High Probability		Not a common practice.
Chemical	High Probability		Assumes chemical is applied in a selective fashion or with an active ingredient and/or rate that is not damaging.
Midstory/Improvement	High Probability		May be required to eliminate undesirable seed sources. Assumes stem selection will be consistent with a future sugar maple objective.

Spacing

	Designation	Conditions	Comments and Assumptions
PCT / crop tree	High Probability		Not a common practice.
Commercial thinning	High Probability		Not a common practice.

Suggested management approaches – sugar maple

Typical management approaches when sugar maple is present in the pre-harvest stand and selected as the management objective.

Option 1 – Single Tree Selection: Objective is the maintenance and improvement of an un-even aged stand of sugar maple - beech - hemlock.

- Normally applied to tolerant hardwood stands with a pre-harvest BA ≥ 24 m^2/ ha (varies by region), AGS ≥ 9 m^2/ha (or ≥ 7 m^2/ ha AGS in sawlog sized trees), an uneven aged-structure, and growing on deep, fresh silty sands and coarse loams.
- Marginal stands not quite meeting the above criteria may be successfully managed under the selection system but will likely require modifications such as lighter harvest in the initial cuts, a longer interval between cuts to compensate for slower growth rates of low quality trees (up to 35 years), and more cutting cycles to achieve desired quality/structure. These stands may be better suited to the shelterwood system.
- May also be applied to even aged stands on good sites which will develop into an un-even aged structure over time through harvest and improvement treatments.
- Harvest up to 1/3 of the basal area to a minimum retention of 18-22 m^2/ ha (varies by initial stand quality, stocking, site and region) (Leak et al. (1969), Marquis et al. (1992), and Nyland, (1987)). Harvest and retention decisions need to consider vigor and risk, stand structure targets (i.e. BA by size class), AGS improvement targets, species priority, and diversity objectives. Refer to the Ontario Tree Marking Guide (OMNR 2004) for further elaboration.
- Apply careful logging principles at all steps of the operation to minimize damage to the site, residual stems, and desirable advanced regeneration.
- Stand improvement to remove highly competitive, lower value mid-story species (e.g. iron wood, red maple, balsam fir, etc) and unmerchantable UGS stems of the target species is recommended either at time of harvest or with follow up treatments.

Option 2 – Group Selection: Objective is the maintenance and improvement of an un-even aged stand composed of sugar maple and other shade tolerants with a mid-tolerant species component.

- Incorporate group openings as part of regular selection management throughout the rest of the stand as described in option 1 to promote regeneration of mid-tolerant species within a stand dominated by sugar maple (e.g. red oak, yellow birch, basswood, white ash, black cherry, and white pine).
- Create groups in areas of higher UGS adjacent to mid-tolerant species seed trees, with particular regard for any areas of mid-tolerant advanced regeneration.
- Avoid locating groups in areas of smaller diameter AGS crop trees.
- Refer to example management approaches for other species for specific guidelines for group location, size, and renewal treatments.

- Number and arrangement of group openings should capture the best mid-tolerant regeneration opportunities and may range from 5% to 20% of total area, depending upon cutting cycle, regeneration objectives, and stand quality. The total volume cut should not exceed stand growth over a cutting cycle.
- In group openings and the immediately surrounding forest (within 10 to 20 m, particularly on the north side of the opening), all trees 2.5 cm dbh and larger should be cut or removed by planned skidding disturbance or scarification. Selective removal of non-crop tree species under 2.5cm will also be of benefit to regeneration.
- Assess regeneration of target species and consider planting or scarification where densities are low, competition is manageable and suitable nursery stock is available. Vigorous seedlings with a well-developed root system should be planted within operability constraints.
- Apply timely control of competition around regenerating stems (especially during first 5 years).
- In subsequent cuts careful logging to protect the regeneration is critical. If mid tolerant hardwoods have regenerated in the openings, the periphery of the openings may need to be expanded to release establishing regeneration.

Option 3 – Uniform Shelterwood: Objective is the regeneration of an even-aged sugar maple dominated stand.

- Normally applied to tolerant hardwood stands with a minimum component of sugar maple (≥30%) combined with other species adapted to even-aged management (Pw, Sw, Or, Ow, Bd, Hi, Aw, Cb, By) and generally less than 50% poplar-birch or less than 30% hemlock or beech.
- Applied on poorer quality tolerant hardwood sites, or on good quality sites with low overstory quality (i.e. AGS < 9 m^2/ ha (or < 7 m^2/ ha AGS in sawlog sizes))
- Typically two harvest cuts (regeneration and one removal cut) will be scheduled over a period of 5 to 15 years. When adequate density of advanced regeneration of desirable species (minimum 1 m tall) is present, consider moving straight to a final removal cut.
- Forest managers may choose to employ a first removal (release) cut in some situations, especially to promote the development of smaller sized trees.

Regeneration Cut

- Harvest from below to retain 50% to 60% crown closure (this would usually equate to a basal area in the range of 14 to 16 m^2/ha) removing UGS trees and undesirable seed sources. Heavier cuts will favor intolerant and/or mid tolerant hardwood regeneration if advanced maple regeneration is not plentiful.
- Trees to favor for retention in the regeneration cut are dominant - codominant crop trees with vigorous seed-producing crowns. Where no dominant trees of desirable species are available, spacing and seed source can be provided by intermediate trees.

- Seed is rarely limiting in maple stands with abundant seed occurring regularly. Retention of suitable crop trees of desired mid-tolerant species can increase species diversity of the new stand.
- Heavy mid-story of highly competitive, lower value species (e.g. ironwood) should be removed to meet overstory canopy closure objectives.
- Generally when sugar maple establishment is successful it tends to be abundant. Management should target >40% stocking with >12,500 sugar maple seedlings/ha (>5 stems in a 4m2 plot) measuring >0.6 m in height, typically 5-7 years after harvest (Leak et al (1987), Jacobs (1974), Tubbs (1977)). This should result in >2500 stems per ha measuring 5-10 cm at dbh at the late sapling stage of development (Tubbs, 1977).
- On sites with high competition (e.g. raspberry) the regeneration period may be delayed by up to 10 years as the maple establishes and grows to a competitive position.
- Site preparation is not normally required for maple as the large root radical can penetrate most litter layers and may in fact reduce regeneration potential.

Final Removal

- When regeneration has reached a minimum of 1 m with an acceptable density, remove the remaining overstory (Tubbs, 1977a). Delayed first removal will increase damage during harvest and risk suppression of regeneration as canopy fills in.
- Retain residual trees for wildlife habitat (e.g. trees with cavities) and ecological reasons (e.g veteran trees) as prescribed in Stand and Site Guide and groups of AGS polewood of desired crop tree species.
- Careful logging to protect the regeneration is critical. Minimize the number and width of extraction trails. Where feasible, scheduling a removal cut when the ground is frozen and covered with snow (ideally 30 cm+) will reduce permanent damage to regeneration.
- Some regeneration ingress following final removal will occur on some sites but should not be counted on to achieve desired densities.

Option 4 – Two-aged stands: Depending upon the species composition, the long-term objective may be the development of an even-aged or an uneven-aged tolerant hardwood stand.

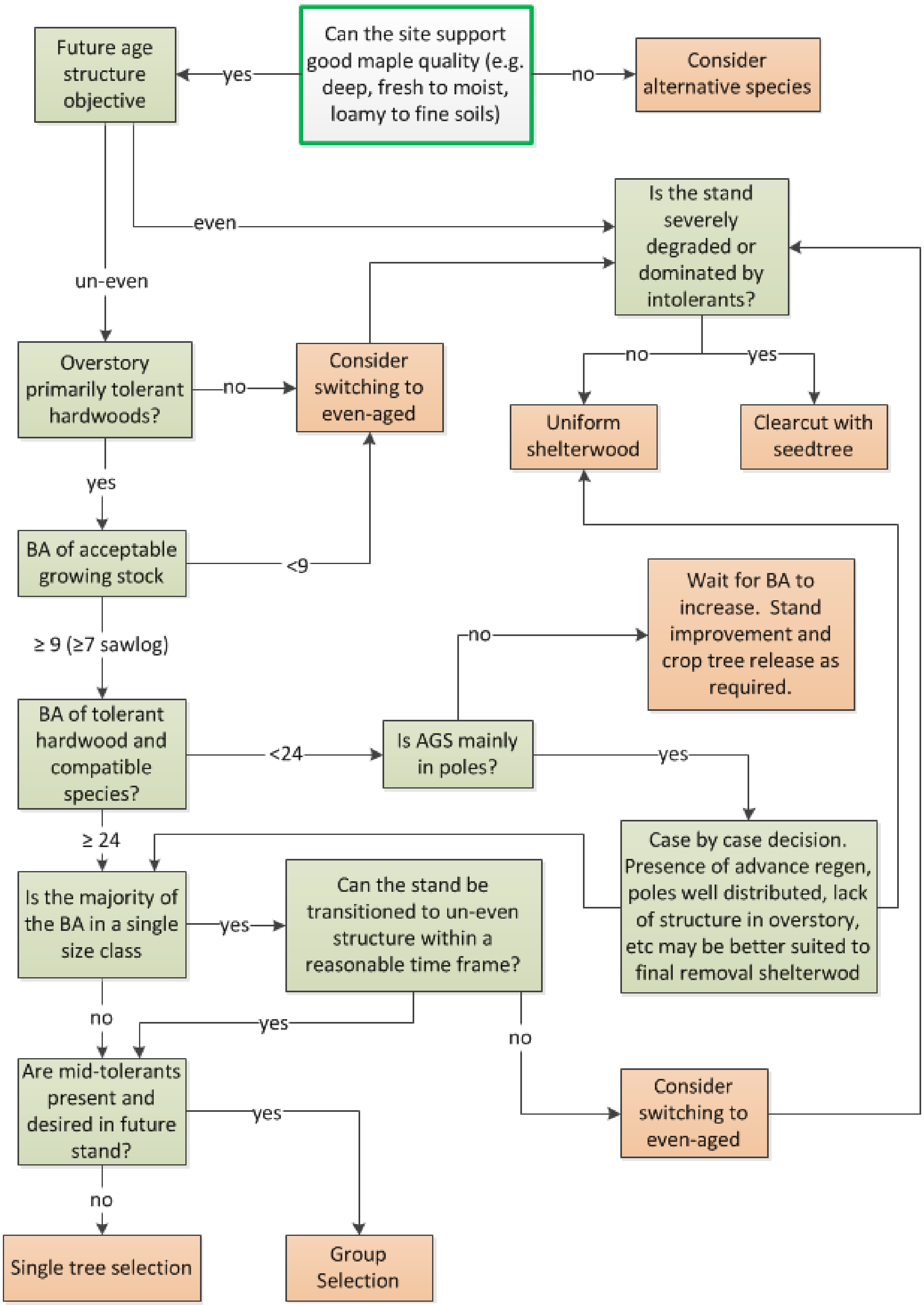
- Two-aged stands have typically developed from a previous high-grade harvest. The overstory of these stands consists of low quality intolerant, mid-tolerant and tolerant hardwoods, pine and/ or spruce. The understory is variable quality, moderately stocked (typically 6 to 15 m^2/ ha, 60%+ of which should be AGS) polewood and small log sized tolerant/mid-tolerant hardwoods, white pine, and/ or hemlock. Understory stocking may be uniform or patchy.

- There is a high degree of variability in these stands and the objective is to increase the percentage of AGS and uniformity of the stand while promoting the growth of the future crop trees. The principles to be applied in their management are:
    - A portion of the overstory should be removed and the understory AGS trees released.
    - Overall basal area removal of UGS stems is typically between 35% and 45% of initial stocking, depending upon stand density and quality, stocking and distribution of crop trees, and intolerant hardwood component. The combined residual crown closure of both strata will be between 50 and 70%.
    - Retain higher residual basal area or crown closure when the objective is the development of an uneven-aged stand of sugar maple, beech, and hemlock. Lower residual stocking levels are used when the objective is an even-aged stand with a higher component of mid-tolerant species.
    - On better sites, crop tree thinning of mid-tolerants in the understory is important to promote crown development.
    - Crop trees to be released should not be suppressed and flat topped. Target 150 to 250 crop trees per ha, depending upon age and diameter (Miller at al (2007), OMNR, (2000)).
    - Overstory UGS trees which are overtopping patches of understory crop trees should be removed.
    - The retention of minimum stocking levels (i.e. 12 to 16 m^2/ ha) to avoid excessive release of AGS crop trees in the understory is important for quality development in the residual stand. This will typically require the retention of some UGS stems.
    - AGS mid-tolerant hardwood, pine, hemlock and/or spruce seed trees should be retained at a regular spacing to provide opportunities for regeneration of these species.
    - Consider manual or selective chemical tending for timely control of competition around established seedlings.

Option 5 – Clearcut with Seed Trees: Objective is renewal of an even-aged intolerant hardwood forest with a minor sugar maple component

- Normally applied to stands dominated by intolerant hardwoods (poplar, white birch) with a minor component of sugar maple plus other common associates adapted to even-aged management (Pw, Pr, Sw, Or, Ow, Bd, Hi, By, Aw, Cb). Typically in this situation the combined basal area of sugar maple and all other compatible species is < 8 m^2/ha in sawlog-size classes or < 10 m^2/ ha in all size classes. Limit application in settled landscapes with low forest cover.
- May also be applied in stands with a higher sugar maple component where a large majority of sugar maple and associated species are exhibiting severe decline/mortality.
- Retain 15 to 35 healthy sugar maple and other seed trees per hectare as available at spacing of 15 to 25 meters.

Suggested decision key when determining the appropriate management approach for sugar maple (assumes maple is desired and present in pre-harvest stand).



5.1.3 Yellow Birch

Yellow birch (*Betula alleghaniensis*) is mid-tolerant of shade, occurs in almost pure, even-aged fire-origin stands, mixed with other hardwoods on upland sites and with hemlock, cedar, and balsam fir around lakes. It regenerates primarily from seed although sprouts from smaller stumps are not unheard of. Mineral or mixed organic/mineral soil required for germination and small radical can be inhibited by even a thin layer of matted litter (e.g. maple). Best growth is on moist lower slopes with deep loamy soils and a telluric water table. Concentrations of yellow birch are typically managed through the shelterwood system with lower densities or isolated pockets managed through seedtree or group selection prescriptions.

Keys to success:

- Choose fresh to moist deep loamy sites from middle to toe of slope.
- Time seedbed preparation (e.g. scarification) with a good seed year (male catkins on twigs in winter signal a seedcrop the following fall/winter). Dispersed skidding may provide adequate seedbed preparation on some sites.
- Regenerate in partial shade followed by gradual release. Maintain adequate light throughout stand development through crop tree release and thinning.

Cautions:

- Site damage and aggressive seedbed preparation on rich sites can stimulate seedbank (e.g. raspberry) and other competitors.
- Epicormic branching and crown dieback can occur in excessively opened stands.
- High incidence of deer or hare may lead to significant loss of regeneration.
- Shallow plate-type roots can lead to windthrow, particularly on shallow or saturated soils.

Target Species: *Yellow birch*

Silviculture systems and harvest method

	Designation	Conditions	Comments and Assumptions
Clearcut with standards	High Probability	1) Strip or small patch openings < 20 meters across 2) Minimum 50% mineral soil exposure OR objective is for low to moderate density of yellow birch regeneration.	Width and orientation of strip will influence success. Open conditions associated with wider strips will promote intolerant competitors.
Clearcut - seedtree	High Probability	Objective is for low density of yellow birch regeneration OR objective is moderate density of yellow birch regeneration and able to achieve a minimum of 50% mineral soil exposure.	Seed trees susceptible to dieback and early windthrow. Open conditions will promote intolerant competition.
Shelterwood - uniform	High Probability	1) Minimum 50% mineral soil exposure OR objective is for low to moderate density or yellow birch regeneration. 2)Apply principles from the tree marking guide.	
Shelterwood - strip/group	High Probability	Apply principles from the tree marking guide.	
Shelterwood - irregular	High Probability	1) Objective is for low to moderate density of yellow birch regeneration. 2) Apply principles from the tree marking guide.	Shade caused by extended or permanent retention of overstory will limit yellow birch regeneration to openings.
Selection - individual	Not Recommended		Inadequate light for long-term survival of regeneration.
Selection - group	High Probability	1) Objective is for low density of yellow birch regeneration. 2) Apply principles from the tree marking guide.	Larger groups (e.g. 2 tree heights) preferred when group expansion will not happen before next selection cutting cycle. Insufficient light for sapling development in matrix.

Target Species: *Yellow birch*

Pre-harvest treatments

	Designation	Conditions	Comments and Assumptions
Chemical	Low Probability		Not a common practice.
Prescribed Burn	Low Probability	Burn indices must be consistent with harvest and regeneration objectives.	Damage and loss of yellow birch very likely.
Site Preparation	High Probability		Harvest may be required shortly (1-2 yrs) after germination to provide adequate light levels for seedling development.
Planting	High Probability		Yellow birch not normally planted.

Logging method

	Designation	Conditions	Comments and Assumptions
Cut-to-length	High Probability		
Tree length	High Probability		
Full tree	High Probability	Not acceptable for shelterwood removal harvests or uneven-aged management.	High risk of damage to regeneration. Careful logging can reduce damage to boles.

Target Species: *Yellow birch*

Site Preparation

	Designation	Conditions	Comments and Assumptions
Mechanical	High Probability		Time site preparation for late summer or early fall, in advance of seed fall, to increase success.
Chemical	High Probability		Assumes chemical will be applied in a selective fashion or with an active ingredient and/or rate that is not damaging to yellow birch.
Prescribed Burn	High Probability	Timing of application and burn indices must be consistent with regeneration objectives.	

Regeneration

	Designation	Conditions	Comments and Assumptions
Advance	High Probability	Objective is for low to moderate density of yellow birch regeneration.	Yellow birch advanced regeneration not of sufficient quantity to establish dominant condition at a stand level, but can be significant in smaller areas.
Natural seed	High Probability		
Vegetative (coppice)	Not Recommended		Vegetative reproduction is rare and not reliable.
Planting	High Probability		Not a common practice
Seeding	High Probability		Not a common practice

Target Species: *Yellow birch*

	Designation	Conditions	Comments and Assumptions
Cleaning			
Manual/mechanical	High Probability		
Chemical	High Probability		Assumes chemical is applied in a selective fashion or with an active ingredient and/or rate that is not damaging.
Midstory/Improvement	High Probability		May be required to maintain desired light levels and eliminate undesirable seed sources. Assumes stem selection will be consistent with a future yellow birch objective.
Spacing			
PCT / crop tree	High Probability		Supressed yellow birch, with flat topped (two dimensional crown) crowns are unlikely to respond to release. Risk of windthrow and epicormic branching.
Commercial thinning	High Probability		Supressed yellow birch, with flat topped (two dimensional crown) crowns are unlikely to respond to release. Risk of windthrow and epicormic branching.

Suggested management approaches – yellow birch

Typical management approaches when yellow birch is present in the pre-harvest stand and selected as the management objective.

Option 1 – Uniform Shelterwood (two cut): Objective is the renewal of an even-aged yellow birch dominated forest

- Normally applied to yellow birch stands with a minimum component of yellow birch (≥ 30%) and composition of yellow birch plus other common associates adapted to even-aged management (Pw, He, Sw, Sr, Or, Bd, Hi, Aw, Cb) of ≥ 50%. Basal area of yellow birch is typically at least 8 to 10 m^2/ha and overall stand basal area ≥ 22 m^2/ha. Shade tolerant hardwoods (Mh, Be) typically compose less than 50% of BA.
- Depending upon initial stand stocking, site quality, and competition two harvest cuts are planned: a regeneration cut followed by a single removal cut 7 to 10 years after the regeneration cut.
- Stands designated for yellow birch management require regular observations of regeneration, and timely renewal treatments (i.e. site preparation and tending) and final removal cut.
- Trees to favor for retention in shelterwood harvests are dominant-codominant crop trees with vigorous seed-producing crowns. Where no dominant-codominant trees of desired species are available, spacing and seed source can be provided by intermediate trees.
- Priority crop tree species to retain are yellow birch, white pine, hemlock, red/white spruce, red oak, hickory, white ash, black cherry.

Regeneration Cut

- Retain 50% to 60% canopy closure post-harvest (this would usually equate to a basal area in the range of 12 to 16 m^2/ha) (Tubbs, 1977), favoring yellow birch seed trees for retention over other crop tree species.
- Heavy mid-story of undesirable tree species must be removed to meet overstory canopy closure objectives and provide adequate light for the growth of yellow birch regeneration. Heavy mid-story competition can eliminate yellow birch regeneration within a few years.
- Removal of leaf litter through prescribed burning, mechanical site preparation, or harvester or skidder activity is strongly recommended for establishment of new germinants – target 60% to 70% coverage of suitable seedbed (i.e. mineral soil, humus, well decayed logs/stumps).
- Timing of harvest and/or mechanical site preparation with a good seed year (about every three years) will increase probability of regeneration establishment. Good seed years can be predicted up to one year in advance by observing the development of male catkins.

- Prescribed burning and mechanical site preparation treatments should be planned for after leaf fall and before snow fall.
- Chemical site preparation to remove maple/beech seedling bank, and initial flush of seedbank (e.g. raspberry) will improve success. Chemical site preparation must occur prior to establishment of yellow birch germinants or seedlings to avoid mortality.
- Assess stocking and competitive position of yellow birch regeneration on a regular basis. Generally when yellow birch establishment is successful it tends to be abundant.
- Seedlings should attain a minimum height of 15 cm during their first year to prevent smothering or crushing by leaf fall (OMNR, 1983). Even so, significant mortality can be expected over the first 10 years.
- Management should target >40% stocking with >12,500 yellow birch seedlings/ha (>5 stems in a 4 m^2 plot) measuring >0.6 m in height, typically 5-7 years after harvest. (Leak et al (1987), Jacobs (1974), Tubbs (1977)). This should result in >2500 stems per ha measuring 5-10 cm at dbh at the late sapling stage of development (Tubbs 1977).
- Consider manual or selective chemical tending for timely control of competition around established seedlings.

Final Removal Cut

- Schedule final removal harvest when saplings reach ~2 m and exceed minimum stocking levels. Delayed removal may increase damage during harvest, and the vigour and amount of yellow birch regeneration will decline over time in the increasing shade environment, making them less responsive upon later release. Earlier removal (1 to 2 m height) can occur if competition is adequately controlled.
- Retain residual trees for wildlife habitat (e.g trees with cavities) and ecological reasons (e.g veteran trees) as prescribed in Stand and Site Guide and groups of AGS polewood of desired crop tree species.
- Careful logging to protect the yellow birch regeneration is critical. Minimize the number and width of extraction trails. Where feasible, scheduling a removal cut when the ground is frozen and covered with snow (ideally 30 cm+) will reduce permanent damage to regeneration.
- Consider thinning or crop tree release treatments as the stand continues to develop.

Option 2 – Group Selection: Objective is management of an all-aged tolerant hardwood forest with a yellow birch component

- Normally applied to stands with a lower component (<30%), or clumpy distribution, of yellow birch mixed with good quality tolerant hardwoods. May also be applied in settled landscapes with low forest cover.
- Groups are typically (but not always) applied in conjunction with a normal selection harvest throughout the rest of the stand.
- Create groups in areas of higher UGS adjacent to yellow birch seed trees, with particular regard for any areas of yellow birch advanced regeneration. Moist soils

with moving water (i.e. side and toe slope positions) are preferred locations for groups. These are sometimes referred to as “telluric” water tables.

- Avoid locating groups in areas of smaller diameter AGS crop trees.
- Group size should be a minimum of 20 meters (or tree height) in diameter crown edge to crown edge (30 meters from bole edge to bole edge) with larger (30-40 meters crown edge to crown edge) sizes preferred when return harvest for group expansion will not occur prior to the next selection entry. For more information on group opening size for minor species see the section: Mid-Tolerant and Intolerant Hardwoods: Minor Species (section 5.2.5).
- Number and arrangement of openings should capture the best yellow birch regeneration opportunities and may range from 5% to 20% of total area, depending upon cutting cycle, regeneration objectives and stand quality. The total volume cut should not exceed stand growth over a cutting cycle.
- In group openings and the immediately surrounding forest (within 10 to 20m, particularly on the north side of the opening), trees 2.5cm dbh and larger should be cut or removed by planned skidding disturbance or scarification. Selective removal of non-crop tree species under 2.5 cm will also be of benefit to regeneration.
- Removal of leaf litter and understory competition through prescribed burning, mechanical site preparation, or skidding during harvest will greatly improve success of establishment of new germinants – target 60% to 70% coverage of suitable seedbed (i.e. mineral soil, humus, well decayed logs/stumps).
- Assess regeneration of target species and consider planting or scarification where densities are low, competition is manageable, and suitable nursery stock is available. Vigorous seedlings with a well-developed root system should be planted within operability constraints. Avoid planting of yellow birch in groups located within areas of high deer populations.
- Apply timely control of competition around regenerating stems (especially during first 5 years).
- In subsequent cuts careful logging to protect the yellow birch regeneration is critical. Where feasible, schedule group expansion to maintain similar light levels to those suggested for uniform shelterwood.

Option 3 – Two-aged stands: Depending upon the species composition, the long-term objective may be the development of an even-aged yellow birch stand or an uneven-aged tolerant hardwood stand with a yellow birch component.

- Two-aged stands have typically developed from a previous high-grade harvest. The overstory of these stands consists of low quality intolerant, mid-tolerant and tolerant hardwoods, pine and/ or spruce. The understory is variable quality, moderately stocked (typically 6 to 15 m2/ Ha, 60%+ of which should be AGS) polewood and small log sized tolerant/mid-tolerant hardwoods, white pine, and/ or hemlock. Understory stocking may be uniform or patchy.

- There is a high degree of variability in these stands and the objective is to increase the percentage of AGS and uniformity of the stand while promoting the growth of the future crop trees. The principles to be applied in their management are:

    - A portion of the overstory should be removed and the understory AGS trees released.
    - Overall basal area removal of UGS stems is typically between 35% and 45% of initial stocking, depending upon stand density and quality, stocking and distribution of crop trees, and intolerant hardwood component. The combined residual crown closure of both strata will be between 50% and 70%.
    - Retain higher residual basal area or crown closure when the objective is the development of an uneven-aged stand of shade tolerant hardwoods with a yellow birch component. Lower residual stocking levels are used when the objective is an even-aged stand dominated by yellow birch.
    - On better sites, crop tree thinning of mid-tolerant trees in the understory is important to promote crown development.
    - Crop trees to be released should not be suppressed and flat topped. Crowns should be released on at least 3 sides. Target 150 to 250 crop trees per ha, depending upon age and diameter (Miller at al (2007), OMNR, (2000)).
    - Overstory UGS trees which are overtopping patches of understory crop trees should be removed.
    - The retention of minimum stocking levels (i.e. 12 to 16 m^2/ ha) to avoid excessive release of AGS crop trees in the understory is important for quality development in the residual stand. This will typically require the retention of some UGS stems.
    - AGS mid-tolerant hardwood, pine, hemlock and/or spruce seed trees should be retained at a regular spacing to provide opportunities for regeneration of these species.
    - Consider manual or selective chemical tending for timely control of competition around established seedlings.

Option 4 – Clearcut with Seed Trees: Objective is renewal of an even-aged intolerant hardwood forest with a minor yellow birch component

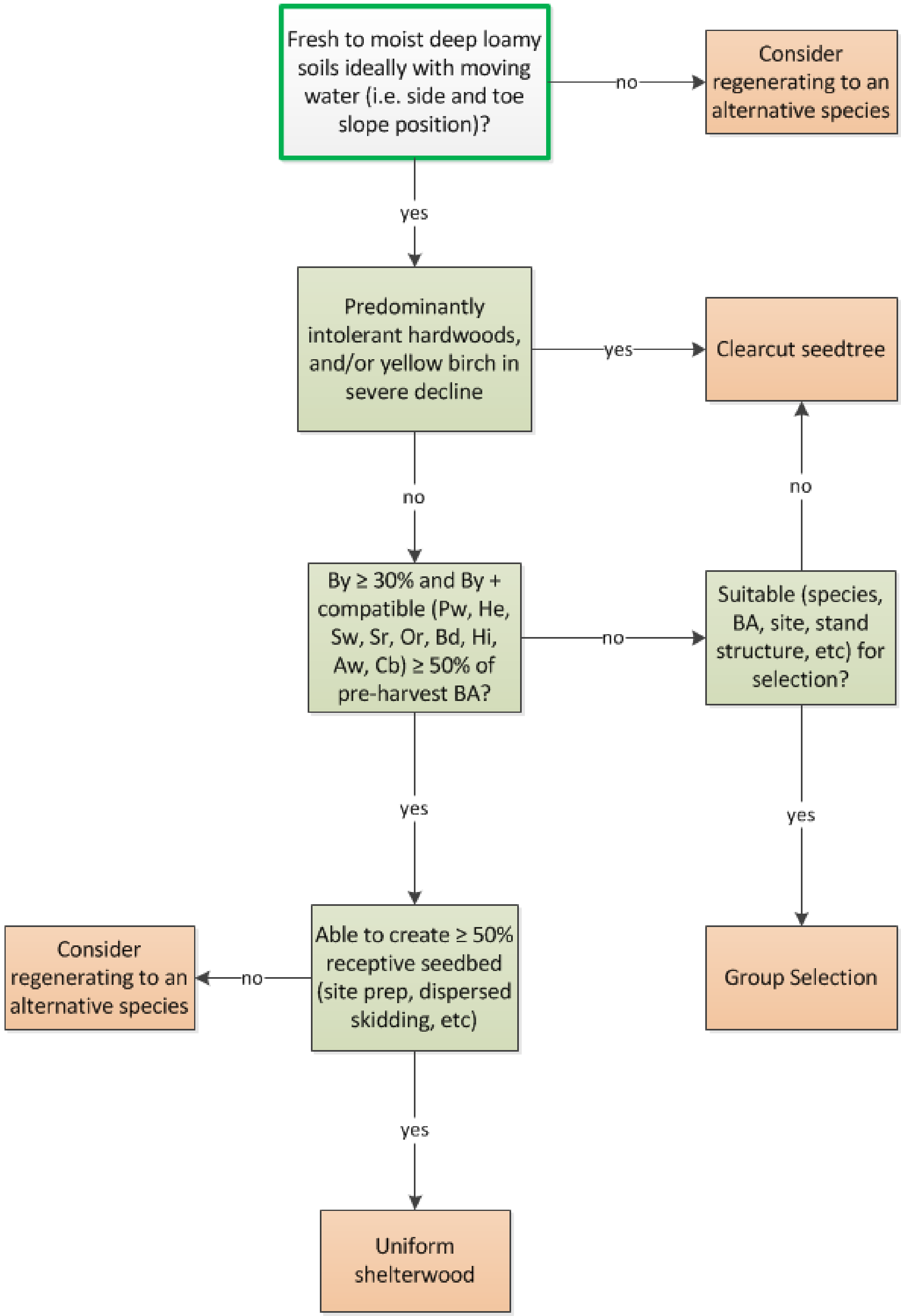
- Normally applied to stands dominated by intolerant hardwoods (poplar, white birch) with a minor component of yellow birch plus other common associates adapted to even-aged management (Pw, Sw, Or, Bd, Aw, Cb). Typically, in this situation the combined basal area of yellow birch and all other compatible species is < 8 m^2/ha in sawlog-size classes or < 10 m^2/ ha in all size classes. Limit application in settled landscapes with low forest cover.
- May also be applied in stands with a higher yellow birch component where a large majority of yellow birch and associated species are exhibiting severe decline/mortality.

- Retain 15 to 35 healthy yellow birch and other seed trees per hectare as available at spacing of 15 to 25 meters
- Timing of harvest and/or mechanical site preparation with a good seed year (about every three years) will increase probability of success. Good seed years can be predicted up to one year in advance by observing the development of male catkins.
- Open growing conditions combined with presence of fast growing intolerant (e.g. white birch and poplars, plus raspberries and shrubs) and tolerant (e.g. maples) hardwood regeneration will require early and regular competition control to release yellow birch regeneration.

Option 5 – Clearcut, Strip Progressive 3 Cut: Objective is renewal of an even-aged yellow birch forest

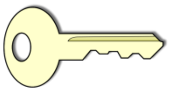
- Currently being used on a limited basis, an option considered in stands of the northern transitional forest where the site condition and quality of sugar maple suggests conversion to the better-adapted yellow birch (OMNR, 1998).
- For example, one SFL has applied this prescription in stands where current condition has a component of yellow birch in the overstory (By ≥ 10 m^2/ha), the development potential of producing high quality By sawlogs clearly exceeds that of Mh, and conditions are not suitable to harvest uniformly (shelterwood) across the site. The goal is to move stands toward the conditions of the By forest unit. Once there, these stands will be managed with uniform shelterwood principles (NFRM, 2009).
- Typically requires one more stand entry (3 cuts) than uniform shelterwood (2 cuts).
- Stands will require regular observations of regeneration, and timely renewal treatments.
- Strip width ranges from one to two tree heights (bole to bole). Each cut strip represents one third of total stand basal area.
- Release crowns of quality By/Or/Cb seed trees along perimeter of retained strips.
- Mineral soil exposure timed with a seed year is essential. If soil is not extensively disturbed during logging, follow-up site preparation will be required.
- Consider manual or selective chemical tending for timely control of competition around established seedlings.
- Implementation of the second and third strips is contingent on meeting the regeneration standard in the previously cut strips.
- Yellow birch seed trees are retained in the third strip.
- Retain residual trees for wildlife habitat (e.g. trees with cavities) and ecological reasons (e.g. veteran trees) as prescribed in Stand and Site Guide.

Suggested decision key when determining the appropriate management approach for yellow birch (assumes yellow birch is desired and present in pre-harvest stand).



5.1.4 White Birch

White birch (*Betula papyrifera*) is shade intolerant, can regenerate from both stump sprouts and seed, with seed origin stems being of better quality. White birch can tolerate a wide range of sites including dry and coarse soils but grows significantly better on fresh loamy sites. Early regeneration can be very dense with rapid self-thinning. White birch is normally managed through the clearcut silviculture system with complete, or nearly complete, overstory removal. White birch exhibits a moderate shade tolerance when young allowing for management through the shelterwood system if the final removal occurs relatively quickly. Competition on rich sites can significantly reduce survival of young birch.



Keys to success:

- Full or nearly full sunlight is required to survive past seedling/sapling stage
- Retain adequate seed trees within the block (or adjacent). Trees stressed from harvest may die quickly (1-2 growing seasons) but often produce copious amounts of seed.
- Exposed mineral soil.

Cautions:

- Avoid sites prone to excessive drying during drought periods
- Mature white birch can exhibit significant dieback when retained in a clearcut
- White birch is sensitive to root system disturbance
- Supressed white birch has limited/no ability to respond to release

Recommended reading:

- Proceedings for the Ecology and Management of White Birch Workshop. OMNR, (Chen et al 2000).
- Paper Birch Managers' Handbook for British Columbia. B.C. Ministry of Forests. Forest Science Program. FRDA Report 271. (BCMOF, 1997)

Target Species: *White birch*

Silviculture systems and harvest method

	Designation	Conditions	Comments and Assumptions
Clearcut with standards	High Probability		
Clearcut - seedtree	High Probability		
Shelterwood - uniform	High Probability		Return harvest may be required sooner than other species managed under the shelterwood system to maintain adequate light.
Shelterwood - strip/group	High Probability		Return harvest may be required sooner than other species managed under the shelterwood system to release regeneration and minimize losses from crown dieback of residual stems.
Shelterwood - irregular	High Probability	Objective is for low to moderate density of white birch regeneration.	Shade caused by extended or permanent retention of overstory will limit white birch regeneration to openings.
Selection - individual	Not Recommended		Insufficient light for sapling development.
Selection - group	High Probability	Objective is for low density of white birch regeneration.	Insufficient light for sapling development in matrix and density of groups dictates low density of white birch regeneration.

Target Species: *White birch*

Pre-harvest treatments

	Designation	Conditions	Comments and Assumptions
Chemical	High Probability	Chemical must be applied in a selective fashion or with an active ingredient and/or rate that retains birch seed source or stump sprout ability.	Not a common practice.
Prescribed Burn	High Probability	Burn indices must be consistent with harvest and regeneration objectives.	Relying primarily on stump sprouts for future stand.
Site Preparation	High Probability		Harvest may be required shortly (1-2 yrs) after germination to provide adequate light levels for seedling development. Root damage from heavy scarification may lead to crown dieback.
Planting	High Probability		White birch is not normally planted.

Logging method

	Designation	Conditions	Comments and Assumptions
Cut-to-length	High Probability		
Tree length	High Probability		
Full tree	High Probability	1) Rotation length must be greater than 80 years on very shallow soil ecosites (11 to 19 and 23 to 28). 2) Not acceptable for shelterwood removal harvests or	

Target Species: *White birch*

Site Preparation

	Designation	Conditions	Comments and Assumptions
Mechanical	High Probability		
Chemical	High Probability		Assumes chemical will be applied in a selective fashion or with an active ingredient and/or rate that is not damaging to white birch.
Prescribed Burn	High Probability	Timing of application and burn indices must be consistent with regeneration objectives.	Assumes adequate seed source (or sprout ability) and fire behaviour that will not consume seed and/or reduce sprouting ability.

Regeneration

	Designation	Conditions	Comments and Assumptions
Advance	High Probability	Objective is for low density of white birch regeneration.	White birch advanced regeneration not of sufficient quantity or quality to establish dominant condition.
Natural seed	High Probability		Seeds transport well over snow from within block and neighbouring stands. Seed trees retained within the block will increase success.
Vegetative (coppice)	High Probability		Stump sprouts alone may not be adequate for a birch dominant condition. Younger stands (<60 yrs) tend to sprout better than older stands.
Planting	High Probability		Not a common practice.
Seeding	High Probability		Not a common practice.

Target Species: *White birch*

	Designation	Conditions	Comments and Assumptions
Cleaning			
Manual/mechanical	High Probability		
Chemical	High Probability		Assumes chemical is applied in a selective fashion or with an active ingredient and/or rate that is not damaging.
Midstory/Improvement	High Probability		Assumes stem selection will be consistent with a future red oak stand.
Spacing			
PCT / crop tree	High Probability		Supressed white birch will not respond to release.
Commercial thinning	Low Probability		Supressed white birch will not respond to release. Stand level response to thinning is uncertain. Sudden exposure can lead to "scalding" and crown die-back.

Suggested management approach – white birch

Option 1 – Clearcut Natural (Seed): Objective is the renewal of an even-aged birch-dominated forest

- Normally applied to upland stands with a minimum white birch composition of 50%, and ideally above 70%, on a deep, dry to fresh, coarse loamy, soil.
- Limited suitability in late-successional birch stands that are showing visible signs of dieback. Limited suitability when aspen exceeds 20%, particularly if well distributed, as aspen will sucker prolifically and outcompete birch on most sites. Moderate pre-harvest densities of jack pine may lead to significant ingress of young jack pine.
- Harvest to provide a minimum of 70% full sunlight while retaining 20 to 30 (depending on crown size) well distributed white birch seed trees per hectare.
- Harvesting on frozen ground will minimize damage to root systems and reduce post-harvest crown dieback commonly displayed by white birch. Harvesting on dry unfrozen ground will improve available seedbed.
- Consider site preparation treatments if exposed seedbeds are lacking, ideally in late fall prior to a good seed year. On sites with moderate duff and slash, simple drags such as barrels and chains can be effective.
- Stump sprouts may also contribute to the future stand with younger (<60 years) stumps producing more frequently. Prescribed fire can further stimulate stump sprouting if done while birch is green (i.e. immediately after harvest).
- Allow three growing seasons prior to conducting a regeneration survey for seedling density, stocking, and survival. A high density of germinants does not guarantee a high density of seedlings as early mortality from competition and other factors can be very high.

5.1.5 American Beech

American beech (*Fagus grandifolia*) is very shade tolerant, is typically a late successional species, and commonly associates with sugar maple. Best growth is on fresh loams with a high humus content, but also found on sandy to fine loamy and clayey soils. Regeneration is from both seed and stump sprouts with seed falling in the vicinity of the parent tree. Germination can occur on a variety of substrates including thin hardwood litter provided adequate moisture is maintained. Beech can tolerate shade at all stages of development, particularly in the seedling and sapling phase, and responds well to release. Beech is typically managed through the selection silviculture system but is also consistent with shelterwood and clearcut systems when provided an early competitive advantage. Beech bark disease presents significant challenges to management of beech in Ontario.

Keys to success:
- Apply tree marking principles
- Maintain some overhead shade during early regeneration phase to provide a competitive advantage over intolerant competition.
- Avoid very dry, shallow, nutrient poor, or saturated sites.

Cautions:
- Open growing conditions may cause excessive drying of the seedbed inhibiting germination and establishment
- Beech bark disease and the associated scale insect is currently found in parts of Ontario and expected to expand across the range of beech over time. This disease presents significant challenges for management of beech at stand and landscape scales. Managers should apprise themselves of the latest knowledge and recommendations before proceeding with a management approach.

Recommended reading:
- Beech Bark Disease in Ontario: A Primer and Management Recommendations. (McLaughlin and Greifenhagen, 2012)
- Biology and Management of Beech Bark Disease. Michigan State Univeristy Extension Bulletin E-2746. (McCullough et al 2005)

Target Species: *American Beech*

Silviculture systems and harvest method

	Designation	Conditions	Comments and Assumptions
Clearcut with standards	Not Recommended		
Clearcut - seedtree	Not Recommended		
Shelterwood - uniform	High Probability	Apply principles from the tree marking guide.	
Shelterwood - strip/group	High Probability	Apply principles from the tree marking guide.	
Shelterwood - irregular	High Probability	Apply principles from the tree marking guide.	Application normally limited to sites where multi-aged structure is preferred and return harvest is unlikely.
Selection - individual	High Probability	Apply principles from the tree marking guide.	
Selection - group	High Probability	Apply principles from the tree marking guide.	Can be used to promote mid-tolerants within an uneven-aged matrix.

Target Species: *American Beech*

Pre-harvest treatments

	Designation	Conditions	Comments and Assumptions
Chemical	Low Probability		Damage and loss of beech very likely.
Prescribed Burn	Low Probability		Damage and loss of beech very likely.
Site Preparation	High Probability		Not a common practice. Mechanical disturbance encourages a proliferation of root suckers but they are often of very poor quality.
Planting	High Probability		Not a common practice.

Logging method

	Designation	Conditions	Comments and Assumptions
Cut-to-length	High Probability		
Tree length	High Probability		
Full tree	High Probability	Not acceptable for shelterwood removal harvests or uneven-aged management.	High risk of damage to regeneration. Careful logging can reduce damage to boles.

Target Species: *American Beech*

Site Preparation

	Designation	Conditions	Comments and Assumptions
Mechanical	High Probability		Not a common practice. Mechanical disturbance encourages a proliferation of root suckers but they are often of very poor quality.
Chemical	High Probability		Assumes chemical will be applied in a selective fashion or with an active ingredient and/or rate that is not damaging to American beech.
Prescribed Burn	Low Probability		Damage and loss of beech very likely.

Regeneration

	Designation	Conditions	Comments and Assumptions
Advance	High Probability		Primary method of recruitment to sapling/pole sizes - seedling bank cycles in understory.
Natural seed	High Probability		
Vegetative (coppice)	High Probability		
Planting	High Probability		Not a common practice as natural regeneration is normally sufficient.
Seeding	High Probability		Not a common practice as natural regeneration is normally sufficient.

Target Species: *American Beech*

Cleaning

	Designation	Conditions	Comments and Assumptions
Manual/mechanical	High Probability		Not a common practice.
Chemical	High Probability		Assumes chemical is applied in a selective fashion or with an active ingredient and/or rate that is not damaging.
Midstory/Improvement	High Probability		Assumes stem selection will be consistent with a future beech objective.

Spacing

	Designation	Conditions	Comments and Assumptions
PCT / crop tree	High Probability		Not a common practice.
Commercial thinning	High Probability		Not a common practice.

Suggested management approaches - beech.

Conventional management approach when American beech is present in the pre-harvest stand and maintenance of a beech component is a management objective.

Option 1 – Single Tree Selection: Objective is the maintenance of a beech component in an un-even aged tolerant hardwood stand.

- Normally applied to shade tolerant hardwood stands with a pre-harvest BA ≥ 24 m^2/ Ha (varies by region), an uneven aged-structure and growing on deep, fresh silty sands and coarse loams.
- Stands not meeting the above criteria may be successfully managed under the selection system but will likely require modifications such as lighter harvest in the initial cuts, a longer interval between cuts to compensate for slower growth rates of low quality trees, and more cutting cycles to achieve desired quality/structure.
- Beech will regenerate from seed on undisturbed leaf litter and from root suckers in low to moderate light conditions and fresh soil moisture regimes.
- Harvest up to 1/3 of the basal area to a minimum retention of 18-22 m^2/ ha (varies by initial stand quality, stocking, site and region). Harvest and retention decisions need to consider vigor and risk, stand structure targets (i.e. BA by size class), species priority, and diversity objectives. Refer to the Ontario Tree Marking Guide for further elaboration.
- Apply careful logging principles at all steps of the operation to minimize damage to the site, residual stems, and desirable advanced regeneration.
- Stand improvement to remove highly competitive, lower value mid-story species is recommended (e.g. iron wood, striped maple, etc) either at time of harvest or with follow up treatments.

Option 2 – Two-aged stands: The long-term objective may be the development of either an even-aged or uneven-aged tolerant hardwood stand with a beech component.

- Two-aged stands have typically developed from a previous high-grade harvest. The overstory of these stands consists of low quality intolerant, mid-tolerant and tolerant hardwoods, pine and/ or spruce. The understory is variable quality, moderately stocked (typically 6 to 15 m2/ ha, 60%+ of which should be AGS) polewood and small log sized tolerant/mid-tolerant hardwoods, white pine, and/ or hemlock. Understory stocking may be uniform or patchy.
- There is a high degree of variability in these stands and the objective is to increase the percentage of AGS and uniformity of the stand while promoting the growth of the future crop trees. The principles to be applied in their management are:
    - A portion of the overstory should be removed and the understory AGS trees released.
    - Overall basal area removal of UGS stems is typically between 35% and 45% of initial stocking, depending upon stand density and quality, stocking and

distribution of crop trees, and intolerant hardwood component. The combined residual crown closure of both strata will be between 50 and 70%.
    - Retain higher residual basal area or crown closure when the objective is the development of an uneven-aged tolerant hardwood stand. Lower residual stocking levels are used when the objective is an even-aged stand with a higher component of mid-tolerant species.
    - On better sites, crop tree thinning of mid-tolerants in the understory is important to promote crown development.
    - Overstory UGS trees which are overtopping patches of understory crop trees should be removed.
    - The retention of minimum stocking levels (i.e. 14 to 16 m^2/ha) to avoid excessive release of AGS crop trees in the understory is important for quality development in the residual stand. This will typically require the retention of some UGS stems.
    - AGS mid-tolerant hardwood, pine, hemlock and/or spruce seed trees should be retained at a regular spacing to provide opportunities for regeneration of these species.
    - Consider manual or selective chemical tending for timely control of competition around established seedlings.

Commentary on Beech Bark Disease (BBD) Complex

- Beech Bark Disease (BBD) is an invasive non-native insect-fungus complex caused by the beech scale (*Cryptococcus fagisuga*) and the canker fungus *Neonectria faginata*. The disease is causing decline and death of beech trees throughout most of its range in Ontario (McLaughlin and Greigenhagen, 2012).
- There is no control for beech bark disease and as the disease spreads throughout Ontario, beech trees will continue to decline.
- Three distinct phases of beech bark disease development can be observed across Ontario:
    - The Advancing Front, refers to stands in which beech scale populations have recently colonized unaffected beech trees. Larger, older trees support the building populations of beech scale.
    - The Killing Front is characterized by high populations of beech scale insects, *Neonectria* attacks, developing cankers and heavy tree mortality.
    - The Aftermath Forest, where disease has passed through and remains endemic. Large remnant trees will continue to decline and younger trees will become infected, disfigured and gradually decline.
- Rapid tree mortality (Killing Front) generally occurs 3 to 6 years after the scale insects infest an area and with the appearance of *Neonectria*. The rate of decline and mortality can take longer if the area is a great distance from other infected beech trees or the amount of fungal inoculum is low. Severe drought or other tree stressing events such as defoliation have been associated with *Neonectria* invasion. The Parry Sound

and Huntsville areas experienced the killing front in 2010, with approximately 50% beech tree mortality occurring within a 3 year period followed by significant additional damage caused by beech snap.

- BBD resistance vs BBD tolerance: Resistance to BBD is defined as resistance to the scale insect. If a tree in a heavily scale infested area has no scale on it, then it cannot become infected with BBD. In North America, 1% to 5% of trees exhibit resistance. Tolerance is the ability of a tree to limit the impact of *N. faginata* infection by preventing its radial and lateral spread by means of chemical and/or callus barriers.
- Residual and regenerating stands may be dominated by susceptible beech, capable of forming thickets that prevent the regenerating of other species and offering no economic and reduced ecological value as BBD continues to kill susceptible beech over time.

Managing Beech Bark Disease

The following general principles are based upon the cited documents from Michigan and Ontario and the knowledge and experience of Ontario silviculture scientists and practitioners.

General Principles for Managing Stands in all Phases of BBD Development

- In the absence of complete knowledge of the impacts of BBD throughout the range of beech and response of beech to different management options, forest managers will need to implement and evaluate a variety of silvicultural options to limit losses to BBD and maintain long-term forest health and biodiversity. The suggestions are intended as helpful advice but should not limit other options from being explored.
- The identification and retention of potentially resistant and tolerant trees is a top priority for conserving the genetic diversity of beech.
- Tree markers need to be aware of the importance of retaining a component of beech for wildlife (mast, cavities, stick nests) and diversity as per the Stand and Site Guide.
- Because of the serious concern with loss of beech for mast production, retention and regeneration of other mast producing species (e.g. oak, hickory) is critically important.
- Beech is often abundant as advanced seedling regeneration and as root sprouts from declining or dead stems. These seedlings/ sprouts are also susceptible to beech scale. Manual, mechanical and herbicidal methods may be considered to control advanced beech regeneration or beech root suckers in BBD-affected stands.
- Minimize harvesting injuries to beech root systems to reduce subsequent root sprouting.

Site Specific Guidelines

Factors that affect development of beech bark disease include species composition and density of stands, and the size, age and vigor of trees within a stand. Selecting a proper management strategy depends on the disease status of the stand, as well as the management objectives. Management guidelines are presented here for stands that are (1) not yet infested by beech scale, (2) within the Advancing Front, (3) within the Killing Front and (4) in the Aftermath Forest.

1) Stands Free of Beech Scale

If a stand is beyond the Advancing Front, consider the potential vulnerability of the stand when planning for thinning, harvesting or other silvicultural activities. When developing a prescription for an un-infested stand, it is important to consider how far the stand is from the Advancing Front. Current guidance is to **treat the stand as if it were part of the Advancing Front (Section 2) if the stand is within roughly 25-30 kilometers of a**

stand that is affected by beech scale. MNRF, will continue to monitor the development of BBD throughout Ontario, and information published by other jurisdictions to ensure that this guidance remains relevant.

Stands that are dominated by beech (i.e., more than 30 percent of basal area) will be highly vulnerable to damage, especially if large or decayed trees are abundant. On the other hand, if beech is a minor component of the overstory, effects on the stand will be less severe. Management guidelines are presented separately for these situations.

a) If beech is a minor component of the overstory:
Manage the stand according to the preferred normal silvicultural prescription, but consider the potential impacts of beech bark disease when setting stocking targets and species priorities.

b) If beech is a major component of the overstory:
If beech accounts for more than 30% of the basal area in a stand, effects of beech bark disease may be severe. Preventive management can reduce the susceptibility of the stand to the eventual beech scale invasion and reduce the vulnerability of the stand to beech bark disease. Appropriate actions will depend on the existing condition of the stand, the management objectives for the stand and the proximity of the stand to the Advancing Front.

- Consider reducing (but not eliminating) the amount of overstory beech present in the stand.
- Manage to maintain/ increase diversity in the stand by retaining a variety of tree species and where conditions are suitable, establishing group openings to provide opportunities for regenerating mid-tolerant species.
- In stands with marginal quality for selection management, the option of uniform shelterwood management should be considered.
- Retain vigorous beech trees with smooth bark. Vigorous trees and trees with smooth bark will have fewer sites suitable for beech scale establishment and may be more resistant to *Neonectria* invasion.

2) The Advancing Front

- Small numbers (around 1% to 5%) of beech may be resistant to infestation of the beech scale insect. **The retention and identification of potentially resistant trees is critical to the long-term recovery of the species.** Tree markers should specifically look for and identify for retention beech trees that have no beech scale or low numbers of scale, especially when these trees are growing near heavily infested trees. Resistant trees often have smooth bark, but this may not always be the case.

- Trees that are retained should not be excessively released (i.e. maintain sufficient stocking around the retained trees to protect from overexposure and potential dieback).
- In quality tolerant hardwood stands where losing all the beech would likely still leave sufficient stocking (i.e. ≤ 30% beech) single tree selection management is generally preferred. Prescriptions will typically discriminate against infested beech in favour of retention of potentially resistant beech or other AGS crop trees.
- Where conditions are suitable, group selection can be used to increase the percentage of mid-tolerant species' regeneration in the stand. Clumps or concentrations of infested beech are ideal areas to establish group openings. Further details on the implementation of group selection are provided in several other species' sections.
- In stands where losing all the beech would no longer allow sufficient stocking for selection management (i.e. beech >30%), uniform shelterwood management should be considered, because mortality from BBD will inevitably limit net growth in stand basal area under selection management. Beech generally does not regenerate well in stands where the canopy has been opened excessively such as shelterwood or clearcut (OMNR, 1998). See details of uniform shelterwood for other species for further direction.
- Mark for removal trees that are heavily infested with beech scale. Large, overmature trees with rough bark and trees with evidence of decay, broken tops or other injuries are likely to succumb to beech bark disease.
- Favour the retention of smaller more resistant size classes of beech

3) The Killing Front

Tree mortality usually starts soon after *Neonectria* invasion begins. You may find tar spots, clusters of tiny, red perithecia and patches of dead bark on infected trees. Beech scale may actually be less abundant on these trees because the scale insects will not survive on areas of wood that have been killed by *Neonectria*.

- In addition to trees which appear resistant to the beech scale insect, there may be beech trees which are tolerant of beech bark disease: these trees may survive for many years despite being infected. **The retention of both potentially resistant and tolerant trees is critical to the long-term recovery of the species.** In infected stands, tree markers should specifically look for and identify for retention potentially resistant and tolerant beech trees. Trees that are retained should not be excessively released (i.e. maintain sufficient stocking around the retained trees to protect from overexposure and potential dieback).
- Apply single tree selection, group selection or uniform shelterwood prescription (as described previously in section 2).
- Salvage dead or declining trees with thin crowns and yellowish foliage. These trees are often invaded by secondary decay fungi that can degrade wood within 2 to 3 years. Remove trees with sunken lesions or large patches of dead wood — these trees are likely to have defects.

- Prioritize harvest of trees that are heavily infested by beech scale and/or infected by *Neonectria.*

4) The Aftermath Forest

Aftermath forests are characterized by dense stands of infested beech sprouts and seedlings and a scattering of larger, residual trees in varying condition. Clumps of resistant or partially resistant trees may be present. Beech saplings grow quickly when overstory trees are killed and may be able to compartmentalize cankers. These trees, however, often have sunken lesions, patches of dead bark and deformities that lead to defects. Trees with convoluted bark are seldom killed outright by *Neonectria* but grow slowly and remain weak. These trees will have low value and volume.

- Consider whether the condition of the remaining trees would allow for a safe, viable harvest operation.
- Apply a silviculture system (e.g. selection/ shelterwood) appropriate to the amount of AGS material remaining in the stand.
- Prioritize harvest of trees that are heavily infested by beech scale and/or infected by *Neonectria*.
- Salvage dead and dying trees.
- Retain trees that are free of scales and *Neonectria* and trees with few scales, especially if the trees have smooth bark. Resistant trees will be very obvious in the aftermath forest.

Identifying potentially tolerant and resistant trees

Outside of the aftermath forest, it will be very difficult to identify tolerant or resistant trees with any certainty. The following photos (credit: Martin Streit) illustrate infected (left) and smooth bark healthy (right) trees referred to in the text. Smooth barked uninfected trees may have an increased chance of being resistant or tolerant, particularly when next to trees with heavy scale or neonectria cankers.

5.1.6 Lowland hardwood

The lowland hardwood group includes black ash, balsam poplar, green ash, white elm, red maple, silver maple, yellow birch and common associates growing on hydric substrates (e.g. ecosites 130-133). Common landform associations include flood plains, oxbow swamps, toe slopes, and localized depressions. The composition of individual stands can vary from single to multiple species with nearly pure stands (e.g. black ash or red maple) not uncommon. Substrates are typically deep, can be mineral or organic, and wet to saturated with seasonal standing water common. Species vary from intolerant (balsam poplar), to intermediate (e.g. green ash) to tolerant (e.g. red maple) of shade. Management approaches should be matched to species present but typically includes some form of partial harvesting.

Keys to success:

- Operate when substrate is frozen to avoid site damage.
- Protect desirable advance regeneration.

Cautions:

- Complete canopy removal can result in excessive/extended watering up and compromise regeneration objectives.
- High water table can lead to shallow rooting making these stands more prone to windthrow after partial harvest.
- The emerald ash borer insect is present at a number of locations in Ontario and expected to spread. This insect is known to cause complete mortality of ash stands and presents significant challenges for maintenance of ash at a stand and landscape scale. Managers should apprise themselves of the latest knowledge and recommendations before proceeding with a management approach.

Recommended reading:

- Preparing for emerald ash borer. (Streit et al 2012)
- Managing Ash in Farm Woodlots; some suggested prescriptions. (Williams and Schwann, 2012)

Target Species: ***Lowland Hardwood***

Silviculture systems and harvest method

	Designation	Conditions	Comments and Assumptions
Clearcut with standards	Not Recommended		
Clearcut - seedtree	Low Probability		
Shelterwood - uniform	High Probability		
Shelterwood - strip/group	High Probability		
Shelterwood - irregular	High Probability		Application normally limited to sites where multi-aged structure is preferred and return harvest is unlikely.
Selection - individual	High Probability	Apply principles from the tree marking guide.	Insufficient light for intolerant and mid-tolerant species.
Selection - group	High Probability	Apply principles from the tree marking guide.	

Target Species: *Lowland Hardwood*

Pre-harvest treatments

	Designation	Conditions	Comments and Assumptions
Chemical	Low Probability		Damage and loss of hardwoods very likely.
Prescribed Burn	Low Probability		Damage and loss of hardwoods very likely. Ground commonly saturated and not conducive to burning.
Site Preparation	Low Probability		Undesirable site damage very likely due to saturated ground conditions.
Planting	High Probability		Not a common practice.

Logging method

	Designation	Conditions	Comments and Assumptions
Cut-to-length	High Probability		
Tree length	High Probability		
Full tree	High Probability	Not acceptable for shelterwood removal harvests or uneven-aged management.	High risk of damage to regeneration. Careful logging can reduce damage to boles.

Target Species: *Lowland Hardwood*

Site Preparation

	Designation	Conditions	Comments and Assumptions
Mechanical	Low Probability		Undesirable site damage very likely due to saturated ground conditions.
Chemical	Low Probability		Assumes chemical will be applied in a selective fashion or with an active ingredient and/or rate that is not damaging to hardwoods.
Prescribed Burn	Low Probability		Assumes adequate seed source (or sprout ability) and fire behaviour that will not consume seed and/or reduce sprouting ability.

Regeneration

	Designation	Conditions	Comments and Assumptions
Advance	High Probability		Particularly when targeting shade tolerant species.
Natural seed	High Probability		Seedbed preparation likely to cause undesirable site damage on saturated sites.
Vegetative (coppice)	High Probability		
Planting	Low Probability		Not a common practice.
Seeding	High Probability		Not a common practice.

Target Species: *Lowland Hardwood*

Cleaning

	Designation	Conditions	Comments and Assumptions
Manual/mechanical	High Probability		
Chemical	Low Probability		Assumes chemical is applied in a selective fashion or with an active ingredient and/or rate that is not damaging to hardwoods.
Midstory/Improvement	High Probability		May be required to eliminate undesirable seed sources. Assumes stem selection will be consistent with a future lowland hardwood objective.

Spacing

	Designation	Conditions	Comments and Assumptions
PCT / crop tree	High Probability		Not a common practice.
Commercial thinning	Low Probability		Not a common practice.

Suggested management approaches – lowland hardwoods.

Lowland hardwood forests are typically dominated by major species red/silver/freeman maple, green/black ash and white elm. Depending upon geography and soil moisture minor species can include white cedar, yellow birch, hemlock, red/ white/ black spruce, bur oak, basswood, aspen spp, balsam poplar, eastern cottonwood, black willow, white birch, tamarack, balsam fir, white pine, and shagbark/ bitternut hickory. Additional species in southwestern Ontario can include swamp white oak, black walnut, tulip, hackberry and sycamore. **All management approaches must be evaluated in context of site sensitivity and hydrology as described in commentary which follows the main text.**

Option 1 – Group Selection: The objective is to manage for an uneven-aged lowland hardwood forest.

- Management objective is the maintenance or development of a lowland hardwood forest type with an uneven-aged structure that would have been caused by moderate wind and flood disturbances. Because of the preponderance of mid-tolerant species which dominate this forest type, this is often a mosaic of small to mid-sized even-aged patches throughout the stand.
- Group selection can be an effective means to develop or release mid-tolerant regeneration while maintaining areas of mature forest cover to minimize windthrow and changes to water levels.
- Also used in settled landscapes with low forest cover.
- Groups are typically (but not always) applied in conjunction with a single tree selection harvest throughout the rest of the stand.
- Remove 25% - 33% of the stand basal area to release AGS crop trees. Depending upon species composition and initial stand stocking, residual BA typically ranges from 22 m^2/ ha to 30 m^2/ ha.
- Residual stand structure should reflect a balance of size classes similar to shade tolerant hardwood management but will retain a higher residual basal area stocking typical of lowland hardwood forests.
- Group size should be a minimum of 20 meters in diameter crown edge to crown edge (30 meters from bole edge to bole edge) with maximum 30 meters crown edge to crown edge. For more information on group opening size for minor species see section 5.2.5.
- Number and arrangement of openings should be located to capture the best regeneration opportunities. The top priority is where desirable advanced regeneration is already established, while second priority is where adjacent seed trees are present. Openings may range from 5% to 20% of total area, depending upon species, cutting cycle, regeneration objectives and stand quality. The total volume cut should not exceed stand growth over a cutting cycle.
- Create groups in areas of higher UGS while avoiding areas of smaller diameter AGS crop trees.

- In group openings and the immediately surrounding forest (within 10 to 20 m), all trees 2.5 cm dbh and larger should be cut. Selective removal of non-crop tree species under 2.5 cm will also be of benefit to regeneration.
- Scattered tops resulting from harvest will act as a form of natural fencing creating a physical barrier and will help discourage browsing of established seedlings in stands containing low to moderate ungulate populations. Tops should be brushed down to approximately one meter in height to promote long-term decay of branches and nutrient cycling.
- Assess regeneration of target species and consider planting where densities are low, competition is manageable and suitable nursery stock is available. Vigorous seedlings with a well-developed root system should be planted within operability constraints. Most of the lowland hardwood species will coppice and this can form a significant and important component of the regeneration that becomes established.
- Apply timely control of competition around regenerating stems (especially during first 5 years).
- Where there are significant coppice clumps, long term value and health can be enhanced with coppice thinning treatments in the late sapling stage of growth. Thinning of coppice clumps of larger diameter stems can promote decay in the residuals due to slower rates of wound healing (for further information see commercial thinning section).
- In subsequent cuts careful logging to protect the regeneration is critical. If mid tolerant hardwoods have regenerated in the openings, the periphery of the openings may need to be expanded to release establishing regeneration.

Option 2 – Uniform Shelterwood (three cuts): Objective is the renewal of an even-aged lowland hardwood dominated forest

- Typically applied to even-aged stands or to uneven-aged stands with low overstory quality.
- Depending upon initial stand stocking and presence of advanced regeneration up to three harvests may be scheduled over a period of up to 30 years.
- Trees to favor for retention in shelterwood harvests are typically dominant-codominant crop trees with vigorous seed-producing crowns and wide spread, stable root systems.
- Priority crop tree species to retain are red/silver/freeman maple, bur oak, hemlock, white pine, spruce, white cedar, yellow birch, basswood and shagbark/bitternut hickory (note: at this time white elm and green/black ash are crop species that should be retained but with lower priority because of Dutch elm disease and the emerald ash borer, respectively (see further information in commentary section below)).
- A preparatory cut is not needed as most lowland hardwood species are regular seed producers.

Regeneration Cut

- Normally applied in stands 80+ years old, with little or very patchy distribution of advanced regeneration, and sufficient stocking of lowland hardwood species to meet post-harvest residual targets.
- Goal is to establish regeneration in partial shade where microclimatic conditions are moderated by tree cover and to limit changes to the water table and the development of competing species.
- Target 70% crown closure postharvest, thinned from below (remove approximately 25% to 33% of stand basal area). Depending upon species composition and initial stand stocking, residual BA typically ranges from 22 m2/ ha to 30 m2/ ha.
- Mid canopy trees must be removed to meet overstory canopy closure objectives and provide adequate light for the growth of regeneration.
- Assess regeneration of target species and consider planting where densities are low, competition is manageable and suitable nursery stock is available. Vigorous seedlings with a well-developed root system should be planted within operability constraints. Most of the lowland hardwood species will coppice and this can form a significant and important component of the regeneration that becomes established.
- Apply timely control of competition around established seedlings (especially during first 5 years).

First Removal (Release Cut)

- The goal of the release cut is to provide increased light conditions to enhance development of regeneration while providing control over the development of competing regeneration and the water table.
- Normally applied when regeneration is between 1m to 2m in height, stocked to FMP standards, and canopy closure exceeds 70%. This may include stands with adequate advanced regeneration and no previous shelterwood entry.
- The release cut will leave approximately 60% crown closure. Depending upon species composition and initial stand stocking, residual basal area typically ranges from 18 to 22 m^2/Ha.
- Forecast stocking of regeneration should anticipate some loss during harvest.
- Careful logging practices will be required to avoid damaging regeneration during harvest (e.g. minimize the number and width of extraction trails).
- Apply timely control of competition around established seedlings.
- Where there are significant coppice clumps, long term value and health can be enhanced with coppice thinning treatments in the late sapling stage of growth. Thinning of coppice clumps of larger diameter stems can promote decay in the residuals due to slower rates of wound healing (for further information see commercial thinning section).

Final Removal Cut

- Normally applied when regeneration reaches a minimum of 6 m in height and exceeds minimum stocking levels. This may include stands with adequate advanced regeneration and no previous shelterwood entry. Forecast stocking of regeneration should anticipate some loss during harvest.

- Retain residual trees for wildlife habitat (e.g. trees with cavities) and ecological reasons (e.g. veteran trees) as prescribed in Stand and Site Guide.
- Careful logging to protect the regeneration during harvest is critical. Minimize the number and width of extraction trails.

Irregular Shelterwood

- Irregular shelterwood may be an acceptable modification where the stand structure is not sufficient for uniform shelterwood or where the objective is to manage towards a multi-aged stand.

Commercial Thinning

- Younger stands (< 80 years old) may respond positively to light intensity thinning.
- Lowland hardwood stands are normally thinned from below to about 70 % crown closure.
- A crop tree approach is recommended with thinning focusing on the selection and release of AGS dominant and codominant crop trees (high vigour, well developed crowns). Target 150 to 250 crop trees per ha, depending upon age and diameter (Miller at al (2007), OMNR, (2000)).
- Fully stocked lowland hardwood stands can have basal areas of over 40 m^2/ha before harvest. Remove 25% to 33% of the stand basal area to release AGS crop trees while avoiding mortality from windfall, stem breakage and excessive development of epicormic branches.
- In thinning stands dominated by coppice growth, separation of clumps becomes inevitable. Losses to decay in residual stems can be mitigated by favoring thinning of u-shaped rather than v-shaped coppice connections, trimming stump faces on an angle (after cutting) to promote water run-off, and using shorter return cutting cycles to capture declining stems.

Commentary on Lowland Hardwood Management

Lowland hardwood forests are particularly sensitive sites because the hydrology of the site can be easily affected by access and harvest operations. The water table is typically at or close to ground level, and ponding and/or running water is typical. Root systems are shallow and trees prone to windthrow. Damage to the trees and site can occur easily if logging is carried out during the wetter/ frost-free seasons. For many of these sites harvesting is not feasible, or may only be possible during short time periods where the ground is frozen hard or extremely dry. At all times managers should be careful to avoid over-cutting lowland hardwood stands, which may lead to elevated water tables, an increased risk of windthrow and/or a conversion to non-forest cover, as well as off-site impacts related to drainage and habitat change.

Natural disturbances in lowland hardwood stands are typically flooding and/or wind throw. Moderate wind disturbances tend to kill mid story trees while super canopy trees and saplings have a lower probability of being killed. Analysis of black ash stands around L. Nipissing showed that individual trees were killed by flood events resulting in multi-aged stands in the majority of the stands studied (Townshend 2012). Group selection or single tree selection are silvicultural systems that most closely match the effects of the natural disturbances these tree species have adapted to. The uniform shelterwood and irregular shelterwood silvicultural systems create conditions similar to the more intense flood and wind disturbance events.

Commentary on Emerald Ash Borer (EAB)

Increasing tree species diversity in lowland hardwood forests can help to mitigate the impact of the EAB threat. After EAB infestations the death of the ash trees creates very open conditions in ash-dominated forests. If vigorous advanced regeneration of other tree species is present in the forest understory they will respond to the increase in light conditions and dominate the new forest. However if advanced regeneration is small or sparsely distributed, there is a significant risk that water tables may rise, windthrow may occur, and/ or herbaceous, brush or invasive species may take over.

Forest managers can control the location and size of canopy openings and the selection of residual trees to encourage the regeneration and growth of tree species other than ash. The documents “Preparing for Emerald Ash Borer (Streit, 2012)” and “Suggested Prescriptions for Managing Ash in Farm Woodlots (Williams and Schwan, 2011)” provide recommendations to help managers diversify ash forests and better withstand an outbreak of emerald ash borer.

5.1.7 White Ash

White ash (*Fraxinus americana*) is shade tolerant when young and progressively less tolerant with age. Best growth is on moderately well drained loams derived from a nutrient rich parent material. White ash has some tolerance for flooding but is more common on fresh to dry sites at the northern limits of its range. Regeneration is from both seed and stump sprouts. Suitable seedbed can vary (mineral soil, humus, leaf litter, etc) provided adequate moisture is maintained. Seedlings may take several (3-15) years to reach breast height but will grow relatively fast once established. Stump sprouts may be as few as one or two per stump and grow faster than seedlings. Light demands increase with age and moderate (e.g. 50%) to full light is required to reach pole size and larger. White ash is commonly managed through the shelterwood and selection silviculture systems as an associate with other species but can successfully regenerate in clearcuts when provided an early competitive advantage. The emerald ash borer insect presents significant challenges for perpetuation of ash in Ontario.

Keys to success:

- Early shade to maintain seedbed moisture and reduce competition
- Target existing regeneration for release.
- Maintain adequate light through successive canopy openings or removal.

Cautions:

- The emerald ash borer insect is present at a number of locations in Ontario and expected to spread. This insect is known to cause complete mortality of ash stands and presents significant challenges for maintenance of ash at a stand and landscape scale. Managers should apprise themselves of the latest knowledge and recommendations before proceeding with a management approach.

Recommended reading:

- Preparing for Emerald Ash Borer. (Streit et al. 2012)
- Managing Ash in Farm Woodlots; some suggested prescriptions. (Williams and Schwann, 2012)

Target Species: *White Ash*

Silviculture systems and harvest method

	Designation	Conditions	Comments and Assumptions
Clearcut with standards	Not Recommended		
Clearcut - seedtree	Not Recommended		
Shelterwood - uniform	High Probability	Apply principles from the tree marking guide.	
Shelterwood - strip/group	High Probability	Apply principles from the tree marking guide.	
Shelterwood - irregular	High Probability	Apply principles from the tree marking guide.	Application normally limited to sites where multi-aged structure is preferred and return harvest is unlikely.
Selection - individual	High Probability	Apply principles from the tree marking guide.	
Selection - group	High Probability	Apply principles from the tree marking guide.	

Target Species: *White Ash*

Pre-harvest treatments

	Designation	Conditions	Comments and Assumptions
Chemical	Low Probability		Damage and loss of ash very likely.
Prescribed Burn	Low Probability		Damage and loss of ash very likely.
Site Preparation	High Probability		Not a common practice
Planting	High Probability		Release will be required within a few (3-5) years to ensure survival. Not a common practice.

Logging method

	Designation	Conditions	Comments and Assumptions
Cut-to-length	High Probability		
Tree length	High Probability		
Full tree	High Probability	Not acceptable for shelterwood removal harvests or uneven-aged management.	High risk of damage to regeneration. Careful logging can reduce damage to boles.

Target Species: *White Ash*

Site Preparation

	Designation	Conditions	Comments and Assumptions
Mechanical	High Probability		
Chemical	High Probability		Assumes chemical must be applied in a selective fashion or with an active ingredient and/or rate that is not damaging to ash.
Prescribed Burn	High Probability	Timing of application and burn indices must be consistent with regeneration objectives.	Assumes adequate seed source and fire behaviour that will not consume seed.

Regeneration

	Designation	Conditions	Comments and Assumptions
Advance	High Probability		
Natural seed	High Probability		
Vegetative (coppice)	High Probability		
Planting	High Probability		Not a common practice.
Seeding	High Probability		Not a common practice.

Target Species: *White Ash*

Cleaning

	Designation	Conditions	Comments and Assumptions
Manual/mechanical	High Probability		
Chemical	High Probability		Assumes chemical is applied in a selective fashion or with an active ingredient and/or rate that is not damaging.
Midstory/Improvement	High Probability		May be required to eliminate undesirable seed sources. Assumes stem selection will be consistent with a future basswood objective.

Spacing

	Designation	Conditions	Comments and Assumptions
PCT / crop tree	High Probability		Not a common practice.
Commercial thinning	High Probability		Not a common practice.

Suggested management approaches - white ash

Option 1 – Selection harvest: Objective is the maintenance of a minor component of white ash in an uneven-aged matrix of tolerant hardwoods.

- Normally applied to tolerant hardwood stands with a pre-harvest BA ≥ 24 m^2/ ha (varies by region), AGS ≥ 9 m^2 /ha (or ≥ 7 m^2/ ha AGS in sawlog sized trees), an uneven aged-structure and growing on deep, fresh silty sands and coarse loams.
- Marginal stands not quite meeting the above criteria may be successfully managed under the selection system but will likely require modifications such as lighter harvest in the initial cuts, a longer interval between cuts to compensate for slower growth rates of low quality trees (up to 35 years), and more cutting cycles to achieve desired quality/structure. These stands may be better suited to the shelterwood system.
- May also be applied to even aged stands on good sites which will develop into an un-even aged structure over time through harvest and improvement treatments.
- Harvest up to 1/3 of the basal area to a minimum retention of 18-22 m^2/ ha (varies by initial stand quality, stocking, site and region) (Leak et al. (1969), Marquis et al. (1992), and Nyland (1987)). Harvest and retention decisions need to consider vigor and risk, stand structure targets (i.e. BA by size class), AGS improvement targets, species priority, and diversity objectives. Refer to the Ontario Tree Marking Guide for further elaboration.
- Identify and opportunistically release suitable white ash crop trees in all size classes.
- Apply careful logging principles at all steps of the operation to minimize damage to the site, residual stems, and desirable advanced regeneration.
- Stand improvement to remove highly competitive, lower value mid-story species is recommended (e.g. iron wood, red maple, balsam fir, etc) either at time of harvest or with follow up treatments.

Option 2 – Group Selection: Objective is management of an uneven-aged tolerant hardwood forest with a white ash component.

- Normally applied to stands with white ash (e.g. 10-20%), particularly with clumpy distribution, mixed with good quality tolerant hardwoods.
- Create groups in areas of higher UGS adjacent to white ash seed trees, with particular regard for any areas of white ash advance regeneration.
- Group size should be a minimum of 20 meters (bole edge to bole edge) in diameter with larger (30-40 m) sizes preferred when return harvest for group expansion will not occur prior to the next selection entry. Large openings will promote intolerants and likely require competition control. Number and arrangement of openings should capture the best ash regeneration opportunities without exceeding 10% by area.
- In group openings all trees 2.5 cm dbh and larger should be felled. Selective removal can occur for non-crop tree species under 2.5 cm.

- Site preparation is not normally required for ash germination/establishment but may improve coverage.
- Apply timely control of competition around regenerating stems (especially during first 5 years).
- In subsequent cuts careful logging to protect the white ash regeneration is critical. Where feasible, schedule group expansion to maintain adequate light levels (~50%).

5.1.8 Butternut

Butternut (*Juglans cinerea*) is a common yet not abundant tree that typically inhabits the southern portions of the Great Lakes–St. Lawrence forest. It is an endangered species on the Species at Risk in Ontario (SARO) List. Its main threat is an introduced fungal disease, butternut canker, but premature harvests may also be affecting recovery.

Butternut grows best on well-drained, fertile soils in shallow valleys or on gradual slopes. Although young trees may withstand competition from the side, butternut does not survive under shade from above. It must be in the overstory to thrive and is classified as shade intolerant. Good seed crops occur every 2-3 years and seed falls within the vicinity of the parent tree unless it is further transported by rodents or water. Germination typically occurs in the spring following seed fall but seed can remain viable in the ground for 2 years. The species is fast growing and also has the ability to reproduce vegetatively through stump sprouting from young trees/saplings.

Because butternut is intolerant of shade, forest harvesting can be used to regenerate the species, but indiscriminate harvesting of butternut itself may remove potentially resistant genetic material.

Keys to success:

- The Forest Gene Conservation Association is collecting information on the location and health of butternut trees in Ontario to find healthy trees to obtain seed for planting and cloning material for a disease tolerance breeding program. Please contact them if you have butternut trees and wish to help.

Cautions:

- Naturally occurring butternut trees of any size and age are protected under the Endangered Species Act
- Some butternut removal may be allowed under Ontario Regulation 242/08. The regulation requires that an MNRF designated Butternut Health Assessor (BHA) assess the tree(s) and submit a BHA report for approval by the local MNRF district manager.

Recommended reading:

- Butternut Tree: A Landowner’s Resource Guide http://www.fgca.net
- Endangered Species Act, 2007
- Ontario Regulation 242/08 http://www.e-laws.gov.on.ca/html/regs/english/elaws_regs_080242_e.htm

5.1.9 Balsam Poplar

Balsam Poplar (*Populus balsamifera*) is shade intolerant, regenerates from root suckers, buried branches, and seed, and is typically clonal. Balsam poplar can be a pioneer species on a wide range of sites but is more typically found on imperfectly drained soils. An ability to produce adventitious roots allows it to tolerate low lying areas with seasonally inundated soils. Regeneration from suckering can be very dense with rapid self-thinning. Regeneration from seed is less common but can be significant when moist mineral soil is available in spring for extended periods (e.g. active floodplains). Balsam poplar is typically even-aged but can exhibit wide age ranges (50+ yrs.) on flood plain sites.

Keys to success:

- Target deep, moist and wet sites where balsam poplar is already present.
- Ensure full or nearly full sunlight
- Adequate distribution of parent root system or sustained moist mineral soil with seed source

Cautions:

- Retention of mature balsam poplar will supress suckering ability
- Cool soils (shade from brush, slash, etc.) can significantly delay suckering
- Wet soils associated with balsam poplar are more prone to site disturbance
- Competition from brush, grass, etc. can be significant on rich sites and increases with even moderate site disturbance.
- Herbicides that translocate may affect unsprayed neighbours through shared roots

Target Species: *Balsam Poplar*

Silviculture systems and harvest method

	Designation	Conditions	Comments and Assumptions
Clearcut with standards	High Probability		Narrow strips/patches will limit growth/survival at edges - opening should be greater than 2 tree heights across.
Clearcut - seedtree	High Probability		
Shelterwood - uniform	Low Probability		Inadequate light for long-term survival of regeneration.
Shelterwood - strip/group	Low Probability		Inadequate light for long-term survival of regeneration.
Shelterwood - irregular	Low Probability		Inadequate light for long-term survival of regeneration.
Selection - individual	Not Recommended		Inadequate light for long-term survival of regeneration.
Selection - group	Low Probability		Inadequate light for long-term survival of regeneration.

Target Species: *Balsam Poplar*

Pre-harvest treatments

	Designation	Conditions	Comments and Assumptions
Chemical	High Probability	Objective is for low to moderate density of balsam poplar.	Application rates, droplet size, active ingredient, etc must be tailored to regeneration objectives.
Prescribed Burn	High Probability	Burn indices must be consistent with harvest and regeneration objectives.	Not a common practice.
Site Preparation	Not Recommended		Seedbed conditions are difficult to maintain and pre-harvest stand unlikely to have adequate light for regeneration.
Planting	Not Recommended		Pre-harvest stand unlikely to have adequate light for seedling/cutting survival.

Logging method

	Designation	Conditions	Comments and Assumptions
Cut-to-length	High Probability		Large quantities of slash may reduce soil temperatures and suckering ability. Thick concentrations of slash should be treated to ensure adequate coverage of regeneration.
Tree length	High Probability		Large quantities of slash may reduce soil temperatures and suckering ability. Thick concentrations of slash should be treated to ensure adequate coverage of regeneration.
Full tree	High Probability	Rotation length must be greater than 80 years on very shallow soil ecosites (11 to 19 and 23 to 28).	

Target Species: *Balsam Poplar*

Site Preparation

	Designation	Conditions	Comments and Assumptions
Mechanical	High Probability		
Chemical	High Probability		Assumes chemical will be applied in a selective fashion or with an active ingredient and/or rate that is not damaging to poplar.
Prescribed Burn	High Probability	Timing of application and burn indices must be consistent with regeneration objectives.	Burn indices must be carefully considered to avoid killing poplar root systems. Burn should occur prior to suckering.

Regeneration

	Designation	Conditions	Comments and Assumptions
Advance	High Probability	Objective is for low density of balsam poplar	A combination of open stand and active substrate may lead to some advanced regeneration.
Natural seed	High Probability		Sustained moisture in seedbed is critical through germination and early development.
Vegetative (coppice)	High Probability		Primary method of regeneration.
Planting	High Probability		Not a common practice.
Seeding	High Probability		Not a common practice.

Target Species: *Balsam Poplar*

Cleaning

	Designation	Conditions	Comments and Assumptions
Manual/mechanical	High Probability		
Chemical	High Probability		Assumes chemical is applied in a selective fashion or with an active ingredient and/or rate that is not damaging.
Midstory/Improvement	High Probability		Assumes stem selection will be consistent with a future poplar objective.

Spacing

	Designation	Conditions	Comments and Assumptions
PCT / crop tree	High Probability		Not a common practice.
Commercial thinning	High Probability		Not a common practice.

Suggested management approach - balsam poplar

Managing for pure balsam poplar stands is not common because it is often found in mixed stands (with trembling aspen, black spruce, balsam fir, white spruce and white birch) and pockets of pure balsam poplar are typically bypassed. A management approach is described when balsam poplar is present in the pre-harvest stand and targeting balsam poplar dominated mixedwood regeneration.

Option 1 – Clearcut Natural (Coppice): Objective is the renewal of an even-aged balsam poplar dominated mixedwood forest

- Commonly applied to stands with a minimum balsam poplar composition of 30% with deep, moist to wet fine loamy and clayey soils and deep, fresh clay soils, coarse loamy, fine loamy, silty, or clayey soils.
- Harvest of most poplar and a moderate level of soil disturbance will promote root suckering and stump sprouting. Mixing of the soil may bury branch fragments capable of producing aerial shoots. Partial harvest that leaves too many living poplar trees will supress suckering through auxin effect.
- Limited suitability in areas with extensive soil compaction and/or disturbance (i.e. summer harvested sites with fine textured soils) and/or severe machine-related root damage (severing) which contributes to reduced root suckering.
- Allow two growing seasons prior to conducting a survey for regeneration density and stocking.
- Low lying sites should be harvested only when frozen. Site disturbance can lead to a prolonged grass (e.g. calamagrostis) or brush dominated condition.

5.1.10 Large-toothed Aspen

Large-toothed aspen (*Populous grandidentata*) and trembling aspen are very similar in their silvics and response to management. The direction for trembling aspen (section 5.1.11) applies equally to large-toothed aspen. Although very similar, it is important to note large-toothed aspen canopies may provide better light conditions for regeneration and development of other species due to a later leaf flush in spring and rapid leaf response to summer drought and other stresses.

5.1.11 Trembling Aspen

Trembling aspen (*Populus tremuloides*) is shade intolerant, regenerates prolifically from root suckers, and is strongly clonal. Best growth is on loamy nutrient rich soils, particularly those with a calcium component derived from limestone or other calcareous parent material. Aspen will tolerate dry sites, grows poorly if at all on saturated sites, and exhibits best growth on fresh and moist sites. Early regeneration is typically in the 10’s or 100’s of thousand per hectare with rapid self-thinning. Regeneration from seed is possible but unreliable in a natural setting. Aspen is normally managed through the clearcut silviculture system with complete, or nearly complete, overstory removal to stimulate root suckering and provide full sunlight for good growth of suckers.

Keys to success:

- Full or nearly full sunlight
- 30% or greater aspen composition pre-harvest
- Loamy, fresh/moist, deep sites

Cautions:

- Compacted soils can significantly reduce growth and survival
- Retention of mature aspen may reduce the density of sucker initiation through a chemical auxin effect.
- Avoid dry or saturated sites
- On very rich sites, high shrub and grass cover can suppress sucker initiation and compete strongly with new suckers.
- Herbicides that translocate may affect unsprayed neighbours through shared roots
- Even small amounts of aspen pre-harvest, particularly if well distributed, can hamper regeneration of other species.
- Heavy thinning in young aspen can lead to sun scald and increased incidence of hypoxylon canker.

Target Species: *Trembling Aspen*

Silviculture systems and harvest method

	Designation	Conditions	Comments and Assumptions
Clearcut with standards	High Probability		Narrow strips/patches will limit growth/survival at edges - opening should be greater than 2 tree heights across.
Clearcut - seedtree	Not Recommended		Aspen regeneration from seed is unreliable.
Shelterwood - uniform	Low Probability		Inadequate light for long-term survival of regeneration.
Shelterwood - strip/group	Low Probability		Inadequate light for long-term survival of regeneration.
Shelterwood - irregular	Low Probability		Inadequate light for long-term survival of regeneration.
Selection - individual	Not Recommended		Inadequate light for long-term survival of regeneration.
Selection - group	Low Probability		Inadequate light for long-term survival of regeneration.

Target Species: *Trembling Aspen*

Pre-harvest treatments

	Designation	Conditions	Comments and Assumptions
Chemical	High Probability	Objective is for low to moderate density of aspen.	Application rates, droplet size, active ingredient, etc must be tailored to regeneration objectives.
Prescribed Burn	High Probability	Burn indices must be consistent with harvest and regeneration objectives.	Damage and loss of some aspen is likely. Spring burning may decrease suckering ability.
Site Preparation	Not Recommended		Seedbed conditions are difficult to maintain and pre-harvest stand unlikely to have adequate light for regeneration.
Planting	Not Recommended		Pre-harvest stand unlikely to have adequate light for seedling/cutting survival.

Logging method

	Designation	Conditions	Comments and Assumptions
Cut-to-length	High Probability		Large quantities of slash may reduce soil temperatures and suckering ability. Thick concentrations of slash should be treated to ensure adequate coverage of regeneration.
Tree length	High Probability		Large quantities of slash may reduce soil temperatures and suckering ability. Thick concentrations of slash should be treated to ensure adequate coverage of regeneration.
Full tree	High Probability	Rotation length must be greater than 80 years on very shallow soil ecosites (11 to 19 and 23 to 28).	

Target Species: *Trembling Aspen*

Site Preparation

	Designation	Conditions	Comments and Assumptions
Mechanical	High Probability		
Chemical	High Probability		Assumes chemical will be applied in a selective fashion or with an active ingredient and/or rate that is not damaging to aspen.
Prescribed Burn	High Probability	Timing of application and burn indices must be consistent with regeneration objectives.	Burn indices must be carefully considered to avoid killing aspen root systems. Burn should occur prior to suckering.

Regeneration

	Designation	Conditions	Comments and Assumptions
Advance	Not Recommended		Aspen can regenerate under a full canopy, but due to low light, suckers do not usually survive more than a few years. Pre-harvest suckers, if released, are not high enough density to form future stand.
Natural seed	Low Probability		Regeneration from seed is possible but unreliable in a natural setting.
Vegetative (coppice)	High Probability		Primary method of regeneration.
Planting	Low Probability		Not a common practice.
Seeding	Low Probability		Not a common practice.

Target Species: *Trembling Aspen*

	Designation	Conditions	Comments and Assumptions
Cleaning			
Manual/mechanical	High Probability		
Chemical	High Probability		Assumes chemical is applied in a selective fashion or with an active ingredient and/or rate that is not damaging.
Midstory/Improvement	High Probability		Assumes stem selection will be consistent with a future aspen objective.
Spacing			
PCT / crop tree	High Probability		Not a common practice.
Commercial thinning	High Probability		Not a common practice.

Suggested management approach – trembling aspen

Option 1 – Clearcut Natural (Coppice): Objective is the renewal of an even-aged aspen-dominated forest

- Normally applied to upland stands with a minimum trembling aspen composition of 30% and ideally above 50% with deep, fresh to moist, coarse loamy, fine loamy, silty, or clayey soils.
- Limited suitability in late-successional aspen stands where the pre-harvest understory is well established with species such as grass and beaked hazel as they compete for root space and maintain sub-optimal soil temperatures for coppice reproduction.
- Limited suitability in areas with extensive soil compaction and/or disturbance (i.e. summer harvested sites with fine textured soils) and/or severe machine-related root damage (severing) which contribute to reduced root suckering. Site disturbance in moist soils can promote native grasses that can cool soils and suppress suckering.
- Harvest all stems (excepting those required for diversity targets) to create open light conditions. Harvesting in fall/winter (i.e. leaf off) will provide an increase in number and vigor of first year suckers, which can be useful on very competitive sites, otherwise the effect is transient.
- Removing thick shrubs and advance growth balsam fir will improve soil warmth and provide space for aspen suckers.
- Allow two growing seasons prior to conducting a regeneration survey for sucker density and stocking.

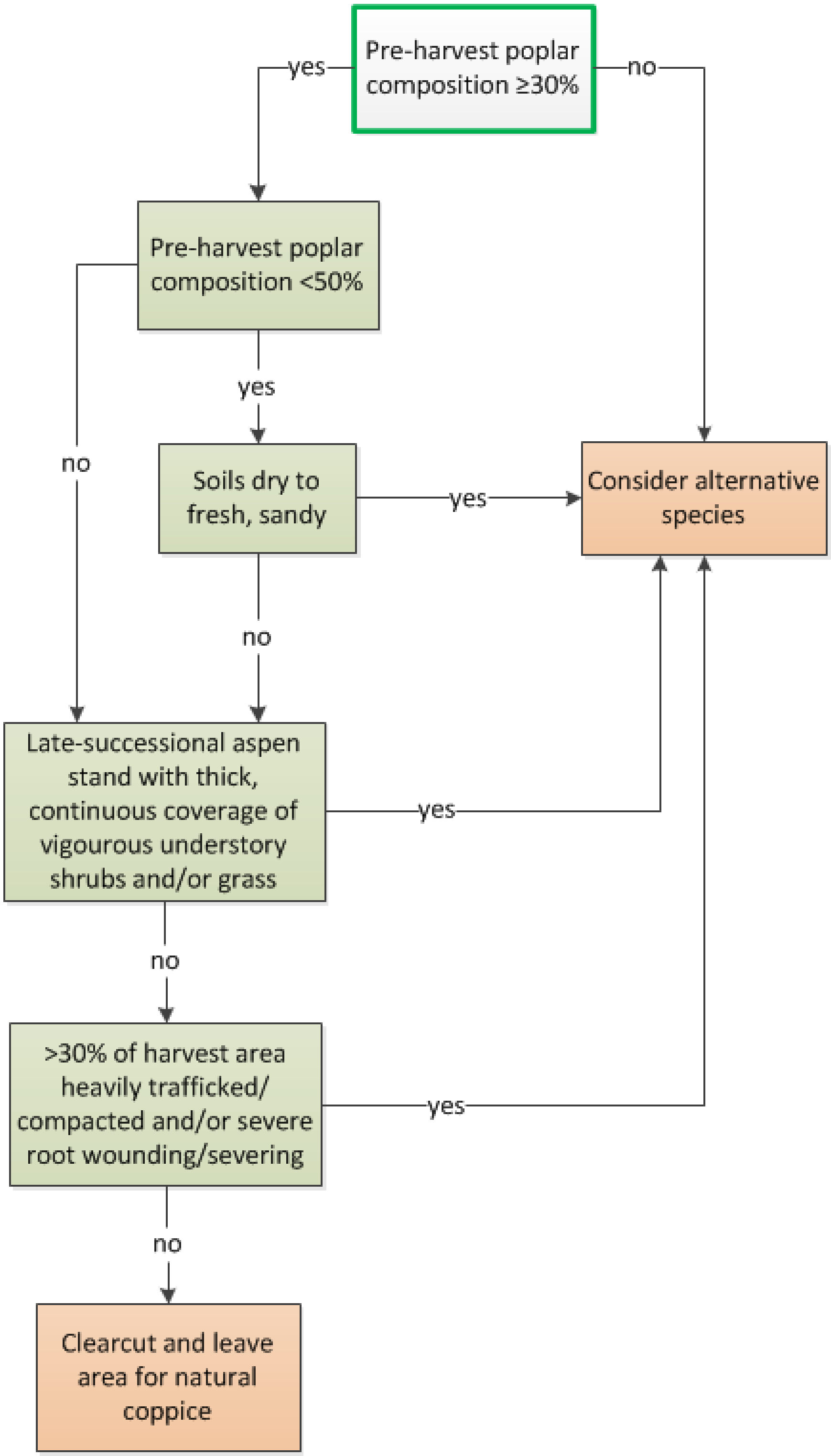
Option 2 – Clearcut natural with pre-harvest herbicide: Objective is the renewal of a moderate density of aspen mixed with other species.

- This approach has been applied experimentally at operational scales. For suggested approach, timing, active ingredient, and expected outcomes refer to Man et al. 2011a and Man et al. 2011b.

Man, R., J.A. Rice, L. Freeman, and S. Stuart. 2011a. Effects of pre- and post-harvest spray with glyphosate and partial cutting on growth and quality of aspen regeneration in a boreal mixedwood forest. For. Ecol. and Manage. 262: 1298-1304.

Man, R., J.A. Rice, and G.B. MacDonald. 2011b. Early effect of pre- and post-harvest herbicide application and partial cutting in regenerating aspen - jack pine mixtures in northeastern Ontario. CJFR 41: 1082-1090.

Suggested decision key when determining the appropriate management approach for trembling aspen (assumes even-aged aspen regeneration objective).



5.1.12 Black Cherry

Black cherry (*Prunus serotina*) exhibits moderate shade tolerance when young but requires full or nearly full sunlight to develop past the sapling stage. Best growth is on moist, rich, well-drained loamy soils and favours cool sites such as north and east facing slopes. Seeds fall within the vicinity of the tree, can remain viable in the soil for multiple years (but not decades as previously thought), and produces good crops every 3 to 4 years. Seedling banks can be a significant source of future regeneration after release. Stump sprouts are common but often have poor form and develop early rot. Cherry is typically managed through large group openings centered on concentrations of cherry, but good regeneration can occur in clearcuts when cherry is provided an early advantage over competition.

Keys to success:

- Select moist north and east facing slopes.
- Ensure timely expansion of small to medium openings to maintain adequate light. Use large openings when return harvest (e.g. surrounding forest is on a selection cycle) is unlikely.
- Consider manual tending to provide a competitive advantage over aggressive competitors.

Cautions:

- In non-bumper years rodents will significantly reduce seed availability.
- Shallow root system creates windthrow hazard, particularly after partial harvest.
- Epicormic branching and crown dieback can occur in excessively opened stands.

Target Species: *Black cherry*

Silviculture systems and harvest method

	Designation	Conditions	Comments and Assumptions
Clearcut with standards	Low Probability	Objective is for low density of cherry AND able to protect adequate advanced regeneration.	New seedlings will be outcompeted by advanced regeneration (e.g. maple) and intolerants. Narrow strips/patches will limit growth/survival at edges - opening should be greater than 1 tree heights across.
Clearcut - seedtree	Low Probability	Objective is for low density of cherry AND able to protect adequate advanced regeneration.	New seedlings will be outcompeted by advanced regeneration (e.g. maple) and intolerants.
Shelterwood - uniform	High Probability	Apply principles from the tree marking guide.	Final removal will be required relatively early to maintain adequate light levels.
Shelterwood - strip/group	High Probability	Apply principles from the tree marking guide.	Final removal will be required relatively early to maintain adequate light levels.
Shelterwood - irregular	High Probability	1) Objective is for low density of black cherry regeneration. 2) Apply principles from the tree marking guide.	Application normally limited to sites where multi-aged structure is preferred and return harvest is unlikely. Regeneration will be limited to openings.
Selection - individual	Not Recommended		Inadequate light for long-term survival of regeneration.
Selection - group	High Probability	1) Objective is for low density of black cherry regeneration. 2) Apply principles from the tree marking guide.	Groups will need expansion if less than 2 tree heights in width.

Target Species: *Black cherry*

Pre-harvest treatments

	Designation	Conditions	Comments and Assumptions
Chemical	High Probability		Used to clean understory (e.g. maple) prior to harvest. Advanced cherry growth will likely be lost.
Prescribed Burn	High Probability	Burn indices must be consistent with harvest and regeneration objectives.	Cherry not typically managed through prescribed fire but some regeneration is possible.
Site Preparation	High Probability		Harvest likely required shortly (1-2 yrs) after germination to provide adequate light levels for seedling development.
Planting	High Probability		Harvest likely required shortly after planting to provide adequate light levels for seedling survival.

Logging method

	Designation	Conditions	Comments and Assumptions
Cut-to-length	High Probability		
Tree length	High Probability		
Full tree	High Probability	Not acceptable for shelterwood removal harvests or uneven-aged management.	High risk of damage to regeneration. Careful logging can reduce damage to boles.

Target Species: *Black cherry*

Site Preparation

	Designation	Conditions	Comments and Assumptions
Mechanical	High Probability		
Chemical	High Probability		Assumes chemical will be applied in a selective fashion or with an active ingredient and/or rate that is not damaging to cherry.
Prescribed Burn	High Probability	Timing of application and burn indices must be consistent with regeneration objectives.	

Regeneration

	Designation	Conditions	Comments and Assumptions
Advance	High Probability		Additional regeneration may be required to achieve higher densities.
Natural seed	High Probability		
Vegetative (coppice)	High Probability		Stumps sprouts typically have poor form and high incidence of rot.
Planting	High Probability	Low browse pressure or browse control measures in place.	Not a common practice
Seeding	High Probability		Not a common practice

Target Species: *Black cherry*

	Designation	Conditions	Comments and Assumptions
Cleaning			
Manual/mechanical	High Probability		
Chemical	High Probability		Assumes chemical is applied in a selective fashion or with an active ingredient and/or rate that is not damaging.
Midstory/Improvement	High Probability		May be required to maintain desired light levels and eliminate undesirable seed sources. Assumes stem selection will be consistent with a future cherry stand.
Spacing			
PCT / crop tree	High Probability		Risk of windthrow and epicormic branching.
Commercial thinning	High Probability		Risk of windthrow and epicormic branching.

Suggested management approaches – black cherry.

Option 1 – Group Selection: Objective is management of an uneven-aged tolerant hardwood forest with a black cherry component.

- Normally applied to stands with a cherry component (e.g. 10%-30%), particularly with clumpy distribution, mixed with good quality tolerant hardwoods.
- Create groups in areas of higher UGS, centered on a black cherry tree, to take advantage of the seed bank. Areas with advance regeneration of maple should be avoided if the maple cannot be treated (e.g. herbicide) prior to harvest.
- Cherry trees are relatively short-lived. Medium trees with vigorous crowns are more likely to survive to the next cutting cycle than large (e.g. 50 cm+) trees with weak crowns.
- Group size should be a minimum of 25 m in diameter (crown edge to crown edge) with larger (40-50m) sizes preferred when return harvest for group expansion will not occur prior to the next selection entry. Large openings will promote intolerants and may require competition control. Smaller openings (e.g. 15 meters) can be effective in establishing regeneration but will require earlier group expansion to maintain adequate light. Number and arrangement of openings should capture the best cherry regeneration opportunities without exceeding 10% by area.
- In group openings all trees 2.5 cm dbh and larger should be felled. Selective removal can occur for non-crop tree species under 2.5 cm.
- Site preparation is not normally required, as mineral soil exposure is not necessary, but light mixing may help to increase soil temperatures and stimulate germination. Site preparation should be avoided on highly competitive sites (e.g. raspberry).
- Apply timely control of competition around regenerating stems (especially during first 5 years).
- When cherry stems are approximately 1 m, and definitely before 2 m, full or nearly full sunlight should be provided through group expansion.
- In subsequent cuts careful logging to protect the black cherry regeneration is critical.

Option 2 – Uniform Shelterwood (two cut): Objective is the renewal of an even-aged black cherry dominated forest

- Normally applied to stands with a minimum component of black cherry (> = 30%) and composition of black cherry plus other common associates adapted to even-aged management (Pw, Pr, He, Sr, Sw, Or, Ow, Hi, Aw, By) of ≥ 50%. Shade tolerant hardwoods (Mh, Be, Bd) typically compose less than 50% of BA.
- Depending upon initial stand stocking, site quality, and competition, two cuts - a regeneration and a single removal cut - will be scheduled over a period of 7-10 years.

- Stands designated for black cherry management require regular observations of regeneration, and timely return harvest. If the regeneration cut is light, or the canopy/midstory closes in quicker than expected, a first removal may be required to get the seedlings past the 15cm stage.
- Trees to favor for retention in shelterwood harvests are dominant-codominant crop trees with vigorous seed-producing crowns. Where no dominant trees are available, spacing and seed source can be provided by intermediate trees of desirable species.
- Priority crop tree species to retain are black cherry, red/white oak, yellow birch, white/red pine, hemlock, red/white spruce, hickory, white ash.

Regeneration Cut

- Retain 50% to 60% canopy closure post-harvest (this would usually equate to a basal area in the range of 14 to 16 m^2/ha).
- Heavy mid-story and understory of undesirable tree species must be removed to meet overstory canopy closure objectives and provide adequate light for the growth of regeneration. Heavy competition can eliminate black cherry regeneration within a few years.
- Site preparation is not normally required, as mineral soil exposure is not necessary, but light mixing may help to increase soil temperatures and stimulate germination. The benefits of site preparation should be balanced against the potential for stimulating competition (e.g. raspberry) on fresh/moist fine textured soils.
- Chemical site preparation to remove maple/beech seedling bank, and initial flush of seedbank (e.g. raspberry) will improve success. Chemical site preparation must be timed to avoid mortality to black cherry germinants or seedlings. Where feasible, pre-harvest spray can be used to remove maple advance regeneration.
- Assess stocking and competitive position of black cherry regeneration on a regular basis.
- Consider manual or selective chemical tending for timely control of competition around established seedlings.

Final Removal Cut

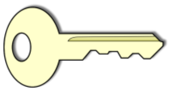
- Schedule final removal harvest when seedlings are approximately 1-2m and exceed minimum FMP stocking levels. Delayed removal may increase damage during harvest, and the vigour and amount of black cherry regeneration will decline over time in the increasing shade environment, making them less responsive upon the later release.
- Early removal will encourage growth of competition before black cherry is of adequate height/development to out compete.
- Retain groups of AGS polewood/ small sawlogs of desired crop tree species.
- Careful logging to protect the regeneration is critical. Minimize the number and width of skid trails. Where feasible, scheduling a removal cut when the ground is frozen and covered with snow (ideally 30 cm+) to reduce permanent damage to regeneration.
- Consider thinning or crop tree release treatments as the stand continues to develop.

Option 3 – Clearcut: Objective is regeneration of an even-aged stand with low densities of black cherry.

- Normally applied to stands with a moderate black cherry component (e.g. 20-40%), mixed with poor quality hardwoods. Avoid sites with trembling aspen, particularly if well distributed, as aspen can out out-grow cherry on favorable sites. Areas with advance regeneration of maple should be avoided if the maple cannot be reduced prior to (e.g. herbicide) or during harvest.
- Site preparation is not normally required, as mineral soil exposure is not necessary, but light mixing may help to increase soil temperatures and stimulate additional germination. The benefits of site preparation should be balanced against the potential for stimulating competition (e.g. raspberry) on fresh/moist fine textured soils.
- Advance regeneration should be surveyed prior to harvest and the logging plan adjusted to avoid skidding through any concentrations.
- Seed trees are of limited silvicultural utility as seedbank is normally adequate and advance. Further, seedlings originating from seed falling after harvest, particularly after a delay for stratification, will be behind competition and unlikely to survive.
- Consider controlling competition around regenerating stems (especially during first 5 years) when competition is significant. Stump sprouts from red maple and other aggressive competitors should be evaluated for potential over-topping of black cherry regeneration over time, and addressed early.

5.1.13 Red Oak

Red oak (*Quercus rubra*) is mid-tolerant of shade and can grow on a wide range of sites from dry rocky ridges to moist lower slopes. Best growth is on fresh-moist well drained soils on middle to lower slope positions but it is often found on dry sites including ridges and shallow rocky areas. It regenerates from both acorns and stump sprouts with smaller diameters sprouting better than larger ones. Acorns require access to mineral soil to successfully establish. Clipped/damaged/burned seedlings normally re-sprout and can be equal or greater vigour than the parent seedling. Stands of red oak are typically managed through the shelterwood system while isolated concentrations may be managed through group selection.



Keys to success:

- Time renewal efforts with a good seed year and ensure incorporation of acorns into the substrate – planting may be required.
- Early and regular vegetation management to maintain sufficient light
- Regenerate in partial shade followed by release to full or nearly full sunlight.
- Consider prescribed fire, clipping, or other seedling treatments.

Cautions:

- In non-bumper years deer, rodents, etc. will significantly reduce acorn availability.
- Repeated browse of seedlings can affect form and survival and competitiveness.
- Susceptible to epicormic branching following heavy release.
- Stump sprouts originating above the root collar are prone to decay.

Recommended reading:

- Regeneration of red oak (*Quercus rubra* L.) using shelterwood systems: Ecophysiology, silviculture and management guidelines. OFRI Forest Research Information Paper 126 (Dey and Parker, 1996).

Target Species: *Red oak*

Silviculture systems and harvest method

	Designation	Conditions	Comments and Assumptions
Clearcut with standards	High Probability	Supplemental regeneration required when objective is moderate or high density of oak regeneration.	Application normally limited to stands with very low pre-harvest oak composition or oak in severe decline. Very low density of oak regeneration likely without supplemental regeneration.
Clearcut - seedtree	High Probability	Supplemental regeneration required when objective is moderate or high density of oak regeneration.	Application normally limited to stands with low pre-harvest oak composition or oak in severe decline. Very low density of oak regeneration likely without supplemental regeneration.
Shelterwood - uniform	High Probability	Apply principles from the tree marking guide.	
Shelterwood - strip/group	High Probability	Apply principles from the tree marking guide.	
Shelterwood - irregular	High Probability	1) Objective is for low to moderate density of red oak regeneration. 2) Apply principles from the tree marking guide.	Application normally limited to sites where multi-aged structure is preferred and return harvest is unlikely. Regeneration will be limited to openings.
Selection - individual	Not Recommended		Inadequate light for long-term survival of regeneration.
Selection - group	High Probability	1) Objective is for low density of red oak regeneration in a stand dominated by tolerant hardwoods. 2) Apply principles from the tree marking guide.	Insufficient light for sapling development in matrix. Deer browse pressure likely to be higher than uniform shelterwood.

Target Species: *Red oak*

Pre-harvest treatments

	Designation	Conditions	Comments and Assumptions
Chemical	High Probability		Used to clean understory (e.g. maple) prior to harvest. Advanced oak growth will likely be lost.
Prescribed Burn	High Probability	Burn indices must be consistent with harvest and regeneration objectives.	Not a common practice.
Site Preparation	High Probability		Harvest may be required shortly (1-2 yrs) after germination to provide adequate light levels for seedling development.
Planting	High Probability		Harvest may be required shortly after planting to provide adequate light levels for seedling survival.

Logging method

	Designation	Conditions	Comments and Assumptions
Cut-to-length	High Probability		
Tree length	High Probability		
Full tree	High Probability	Not acceptable for shelterwood removal harvests or uneven-aged management.	High risk of damage to regeneration. Careful logging can reduce damage to boles.

Target Species: *Red oak*

Site Preparation

	Designation	Conditions	Comments and Assumptions
Mechanical	High Probability		Schedule before seedfall in a good seed year.
Chemical	High Probability		Assumes chemical will be applied in a selective fashion or with an active ingredient and/or rate that is not damaging to oak.
Prescribed Burn	High Probability	Timing of application and burn indices must be consistent with regeneration objectives.	Can stimulate oak re-sprouting.

Regeneration

	Designation	Conditions	Comments and Assumptions
Advance	High Probability	Objective is for low to moderate density of red oak regeneration.	Red oak advanced regeneration not normally of sufficient quantity to establish dominant condition.
Natural seed	High Probability		Acorn incorporation either through timing of harvest / SIP or designed treatments may improve success.
Vegetative (coppice)	High Probability		Stump sprouts may require thinning. Seedling sprouts can be very vigorous.
Planting	High Probability		Repeated browsing of oak seedlings may affect form, survival and competitiveness. Planted stock is prone to rodent girdling.
Seeding	High Probability		

Target Species: *Red oak*

Cleaning

	Designation	Conditions	Comments and Assumptions
Manual/mechanical	High Probability		Anticipate at least one cleaning on poor sites with multiple cleanings likely on more competitive sites.
Chemical	High Probability		Assumes chemical is applied in a selective fashion or with an active ingredient and/or rate that is not damaging.
Midstory/Improvement	High Probability		May be required to maintain desired light levels and eliminate undesirable seed sources. Assumes stem selection will be consistent with a future red oak stand.

Spacing

	Designation	Conditions	Comments and Assumptions
PCT / crop tree	High Probability		
Commercial thinning	High Probability		

Suggested management approaches - red oak

The following options present typical management approaches when red oak is present in the pre-harvest stand and selected as the management objective.

Option 1 – Uniform Shelterwood (two or three cut): Objective is the renewal of an even-aged red oak-dominated forest

- Normally applied to red oak stands with a minimum component of oak (≥30% of BA) and composition of red oak plus other common associates adapted to even-aged management (Pw, Pr, He, Sr, Sw, Ow, Hi, Aw, Cb, By) of ≥ 50% of BA. Shade tolerant hardwoods (Mh, Be, Bd) typically compose less than 50% of BA.
- Stands with a composition of red oak plus common associates of 30% to 50% of BA can be managed with either uniform shelterwood (option 1) or group selection (option 2) depending upon management objectives, species composition, site condition, oak distribution (uniform or patchy) and advanced regeneration. Regenerating even-aged oak forests using uniform shelterwood can be challenging under these conditions except on low competition ecosites and/or with intensive silvicultural inputs.
- Depending upon initial stand stocking, advanced regeneration and competition, two to three harvest cuts (a regeneration cut and one or two removal cuts) will be scheduled over a period of 15 to 30 years. Stands designated for oak management require regular observations of regeneration, and timely renewal treatments and removal cuts.
- Trees to favor for retention in shelterwood harvests are dominant-codominant crop trees with vigorous seed-producing crowns. Trees which have historically produced good acorn crops are most likely to produce good crops in the future.
- Priority crop tree species to retain are red/white oak, white/red pine, hemlock, red/white spruce, hickory, white ash, black cherry and yellow birch.

Regeneration Cut

- When the potential for understory competition is high and there is little advanced red oak regeneration greater than 50 to 100 cm height (normally associated with a root collar caliper of at least 0.5 cm and preferably 0.75 cm), retain at least 70% canopy closure after the regeneration cut (this would usually equate to a basal area in the range of 18 to 20 m^2/ha) (Dey and Parker, 1996). This maximizes potential acorn production, allows 20% to 30% of full sunlight to penetrate to the forest floor which is required to initiate red oak regeneration growth, and increases the duration of vegetation control treatments by reducing the vigor of competing species (Dey et al, 2012; Parker and Dey, 2008). Control of competition is extremely important in these stands. Without vegetation control there is almost no chance that these stands will regenerate to red oak.
- If the potential for understory competition is low or has been significantly reduced by vegetation management treatments, or if planting of oak/ pine seedlings is scheduled, the overstory could be reduced to 50 to 60 per cent canopy closure in the initial regeneration cut. (Dey and Parker, 1996). This would usually equate to a basal area between 12 to 16 m^2/ha

- At lower oak crown closures selection of good seed producers (large crowns, history of production, etc) becomes increasingly important.
- Timing of harvest and/or site preparation with a good seed year will increase probability of success.
- Best results will occur if harvest occurs after the acorns have fallen to the ground or during the late summer/fall of the same year after acorns have matured. Machine traffic from harvesting after acorns have fallen can help incorporate them into mineral soil.
- Acorn germination is best in mineral soil. Removal of thick duff through prescribed burning or mechanical site preparation will improve establishment. These treatments also have positive effects on control of competition, although further competition control is usually required in subsequent years. Site preparation treatments are most effective when done prior to seed fall, usually before October.
- For regeneration cuts a heavy mid-story (e.g. maple, ironwood) must be removed to meet overstory canopy closure objectives and provide adequate light for the growth of red oak regeneration. Mid story competition can eliminate oak regeneration in a few years. Herbicide application to cut stumps at the time of cutting is a good way of preventing sprouting of undesirable regeneration that would be strong competitors with oak.
- Assess stocking and competitive position of oak regeneration on a regular basis. Bear in mind that oak seed crops are extremely irregular. Consider mechanical or chemical site preparation, prescribed burning and/ or planting where oak seedling densities are low and if competition is anticipated to be abundant. Vigorous oak seedlings with a well-developed root system should be planted within operability constraints. Acorn sowing may be an option but predation by wildlife and insects may limit success.
- Oak seedlings that are suppressed by dense competition for any substantial period of time will generally not survive. Apply timely control of competition around established seedlings, using manual tending, selective chemical tending or prescribed burning (note that red oak seedlings < 2 years old will likely be killed by prescribed burning).
- Coppice stump sprouts from smaller oak stems (i.e. < 25 cm dbh) have been shown to be important contributors to stocking of the new forest, but should not be relied upon as the primary source of regeneration.

First Removal (Release Cut)

- Where overstory canopy closure is impeding regeneration growth and target species regeneration has reached ~50cm to 100 cm in height (normally associated with a root collar caliper of at least 0.5 cm and preferably 0.75 cm) and exceeds minimum stocking levels, schedule a first removal (release) harvest. Be prepared to perform a first removal cut within five years of the first substantial acorn crop or planting, providing that timely vegetation control treatments have occurred. Delayed first removal may increase damage during harvest, and the vigour and amount of oak regeneration will decline over time in the increasing shade environment, making them less responsive upon the later release.
- Retain 50% canopy closure after the release cut. This would usually equate to a basal area in the range of 12 to 14 m^2/ha. This will allow 40% to 50% of full sunlight to

penetrate to the forest floor to allow red oak regeneration to develop to its full potential while still maintaining limits over the growth of competing vegetation (Dey et al, 2012; Parker and Dey, 2008). The residual overstory will also moderate temperature extremes, reducing frost damage.

- Continue regular observations of the regeneration throughout this stage of management.
- Treatments to control competing vegetation may still be required after the release cut.
- Careful logging to protect the oak regeneration is critical. Minimize the number and width of extraction trails. Where feasible, scheduling a release cut when the ground is frozen and covered with snow (ideally 30 cm+) will reduce permanent damage to regeneration.
- In areas where oak regeneration meets the desired standards but occurs in a patchy distribution, release cutting by creating group openings in areas of regeneration (group shelterwood) has been successful but usually only when additional tending treatments are used to release oak regeneration, both within and outside the group openings.

Final Removal Cut

- Schedule final removal harvest when target species regeneration reaches ~2m (normally associated with a root caliper of at least 1.5cm and preferably 2.0 cm or more) and exceeds minimum stocking levels. Retain residual trees for wildlife habitat (e.g trees with cavities) and ecological reasons (e.g. veteran trees) as prescribed in Stand and Site Guide, and groups of AGS polewood of desired crop tree species.
- The probability of red oak saplings expressing dominance in the new stand after final removal changes drastically as they develop in size. For example in a moderate quality oak site a red oak sapling with basal diameter of 1.5 cm has a 13% probability of achieving dominance after a final removal cut without further intervention. This increases to 21% probability for an oak sapling with basal diameter of 2.0 cm and 46% probability for an oak sapling with basal diameter of 4.0 to 5.0 cm. (Loftis, 1990).
- Using Loftis 1990 as a guide, on a site index 70 (metric 21m) site it would take 1000 1.5 cm diameter oak seedlings at the time of final overstory removal to achieve 125 crop trees/ha, which should result in a relatively pure stand of oak at stand maturity (Dey, 2013).
- Careful logging to protect the oak regeneration is critical. Minimize the number and width of extraction trails. Where feasible, scheduling a final removal cut when the ground is frozen and covered with snow (ideally 30 cm+) will reduce permanent damage to regeneration.
- Oak regeneration should be monitored between the final removal cut and the point of crown closure to assess the need and benefit for crop tree release of oak and other desired species (see Miller et al, 2007).

Option 2 – Group Selection: Objective is management of an all-aged tolerant hardwood forest with a red oak component

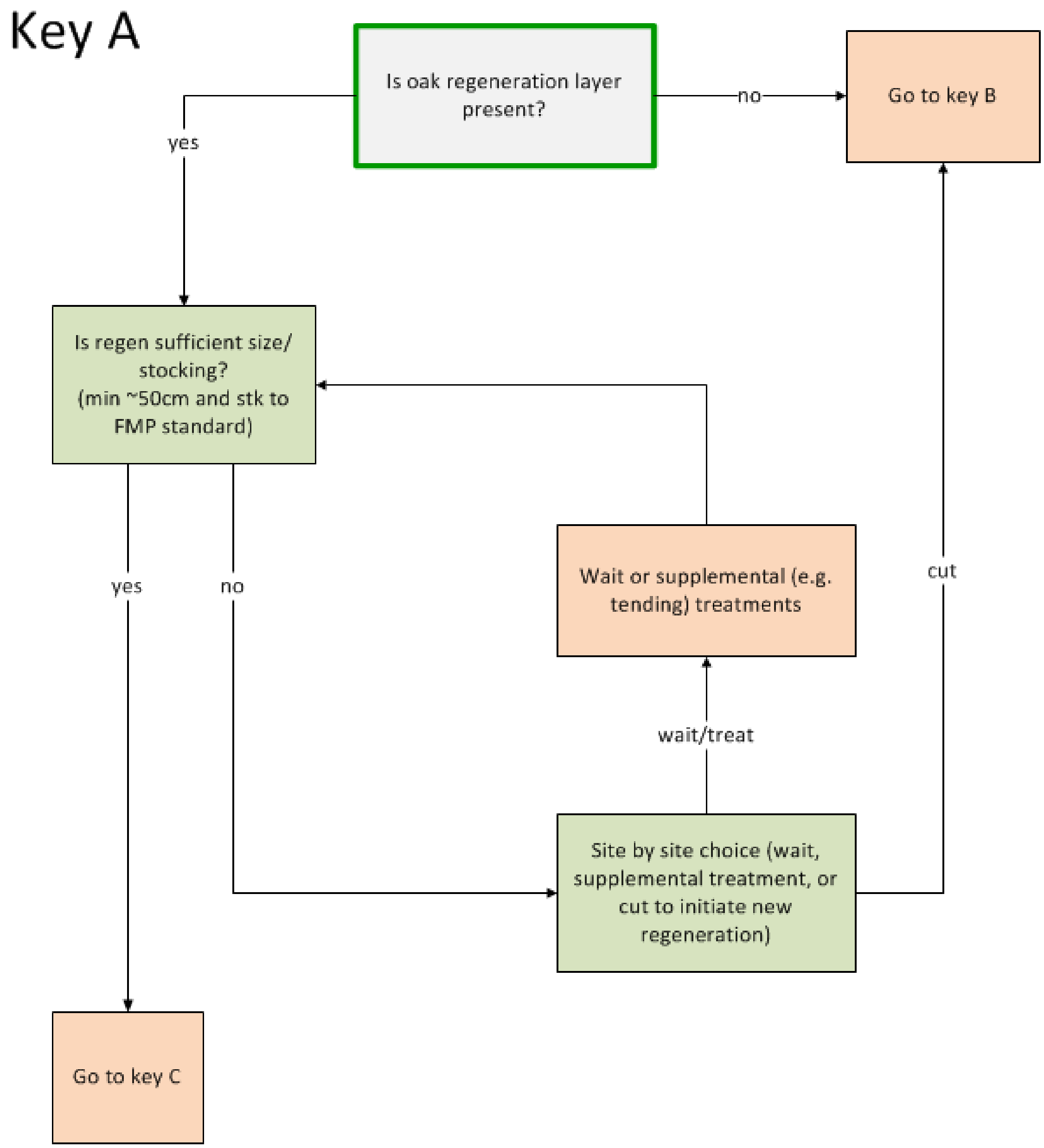
- Normally applied to stands with a lower component (<30% of BA) of red oak mixed with good quality tolerant hardwoods or in settled landscapes with low forest cover. May also be applied to red oak dominated forests on deeper soils where a previous harvest under the selection system has occurred and has resulted in the development of a well-stocked mid-canopy of shade tolerant crop species.
- Groups are typically (but not always) applied in conjunction with a normal selection harvest throughout the rest of the stand.
- Create groups in areas of higher UGS adjacent to oak seed trees, with particular regard for areas of oak advanced regeneration. South and west aspects are preferred locations for groups.
- Avoid locating groups in areas of smaller diameter AGS crop trees.
- Group size should be a minimum of 20 meters (or tree height) in diameter crown edge to crown edge (30 m from bole edge to bole edge) with larger (30-40meters crown edge to crown edge) sizes preferred on north/ east aspects or when return harvest for group expansion will not occur prior to the next selection entry. For more information on group opening size for minor species see the section: Mid-Tolerant and Intolerant Hardwoods: Minor Species.
- Number and arrangement of openings should capture the best oak regeneration opportunities and may range from 5% to 20% of total area, depending upon cutting cycle, regeneration objectives and stand quality. The total volume cut should not exceed stand growth over a cutting cycle.
- In group openings and the immediately surrounding forest (within 10 to 20m, particularly on the north side of the opening), all trees 2.5cm dbh and larger should be cut or removed by planned skidding disturbance or scarification. Selective removal of non-crop tree species under 2.5cm will also be of benefit to regeneration.
- To the extent feasible the ground inside the group should be cleared of felled stems to facilitate follow-up treatment and reduce competition for oak. However in situations of moderate deer or moose populations, leaving tops in the group openings may prove beneficial as a physical barrier to browsing. Herbicide application to cut stumps at the time of cutting is a good way of preventing sprouting of undesirable regeneration that would be strong competitors with oak.
- Assess oak regeneration and consider planting where densities are low and competition is manageable. Vigorous oak seedlings with a well-developed root system should be planted within operability constraints. Apply timely control of competition around regenerating stems (especially during first 5 years). Avoid planting of red oak in groups located within areas of high deer populations.
- In subsequent cuts careful logging to protect the oak regeneration is critical. Where feasible, schedule group expansion to maintain similar light levels to those suggested for uniform shelterwood.

Option 3 – Clearcut with Seed Trees: Objective is renewal of an even-aged intolerant hardwood forest with a red oak component

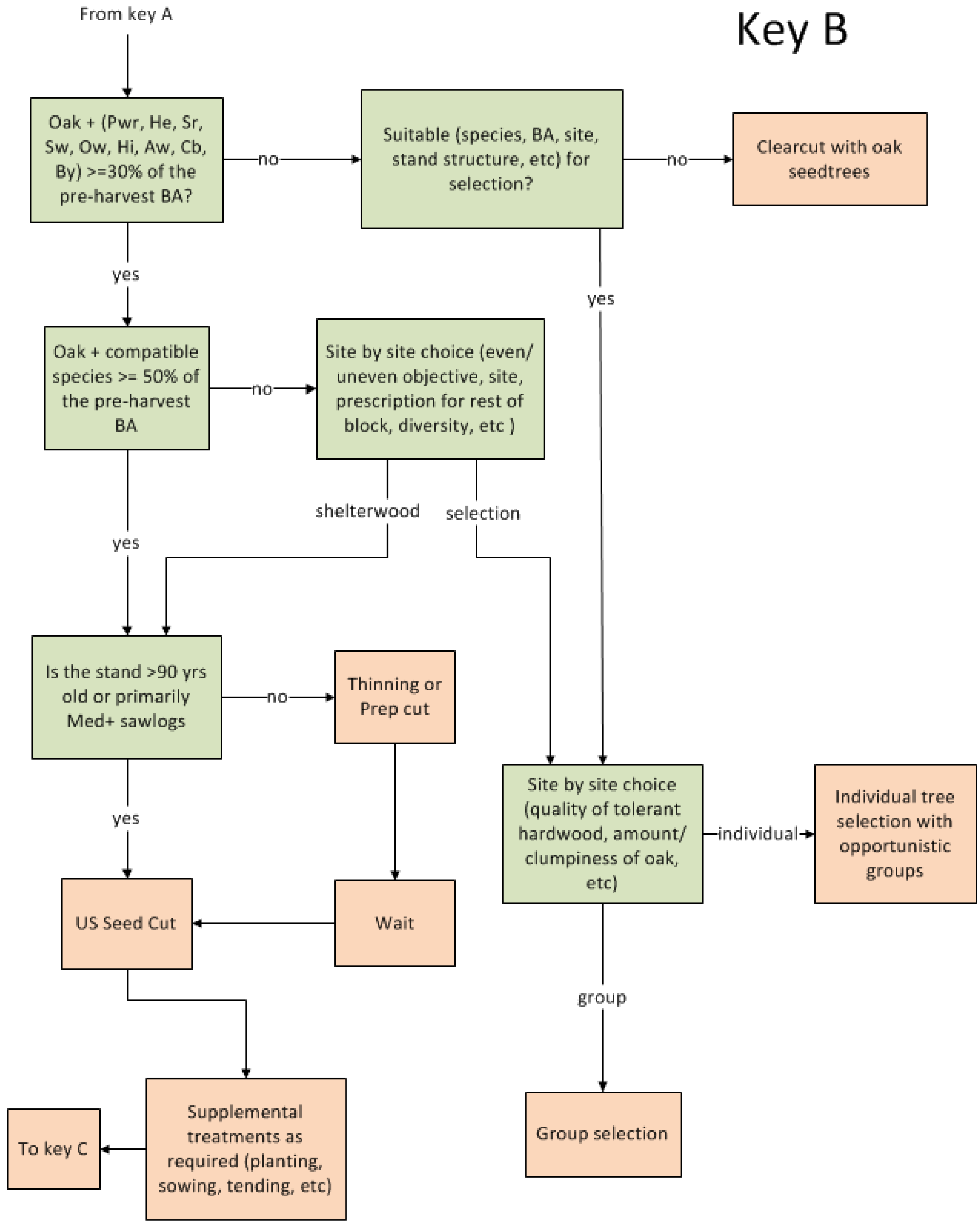
- Normally applied to stands dominated by intolerant hardwoods (poplar, white birch) with a minor component of red oak plus other common associates adapted to even-aged management (Pw, Pr, He, Sr, Sw, Ow, Hi, Aw, Cb, By). Typically in this situation the combined basal area of oak and all other compatible species is < 8 m2/ha in sawlog-size classes or < 10 m^2/ Ha in all size classes. Limit application in settled landscapes with low forest cover.

- May also be applied in stands with a higher oak component where a large majority of oak and associated species are exhibiting severe decline/mortality
- Retain 15 to 35 healthy red oak and other seed trees per hectare as available at spacing of 15 to 25 meters.
- Advanced oak regeneration or planting will be required to achieve a future component of oak. Vigorous oak seedlings with a well-developed root system should be planted within operability constraints.
- Open growing conditions combined with presence of aggressive intolerant hardwood suckers will require early and regular competition control.

Suggested decision key when determining the appropriate management approach for red oak (assumes red oak is desired and present in the pre-harvest stand).

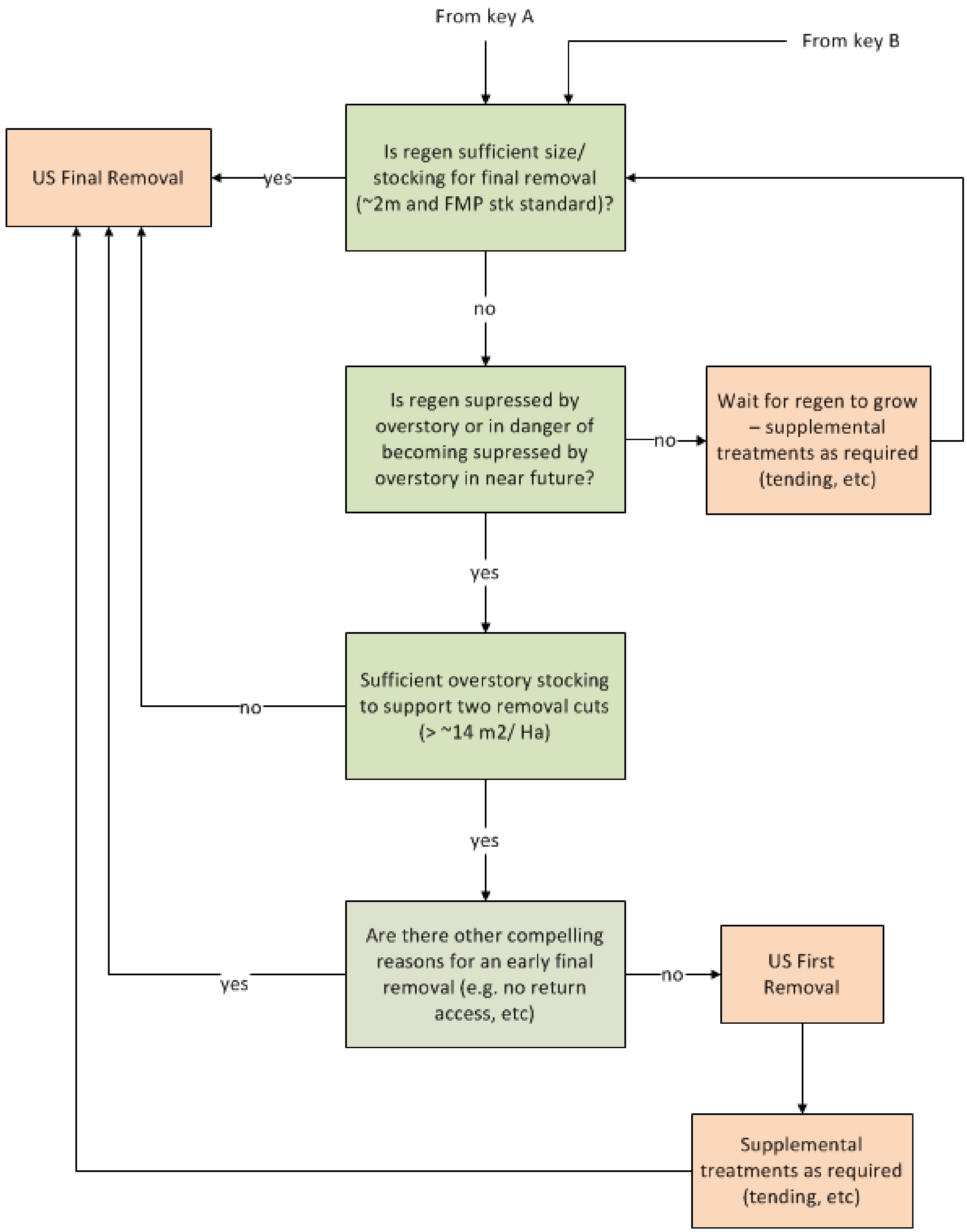


Suggested decision key when determining the appropriate management approach for red oak (part B).



Suggested decision key when determining the appropriate management approach for red oak (part C).

Key C



5.1.14 Basswood

American basswood (*Tilia americana*) is tolerant of shade, does not occur in pure stands, and is considered a nitrogen demanding species. Common sites include fresh to moist sandy and silty loams on north and east facing slopes, but it can occur on coarse soils, rock ridges, and very moist lower slopes with telluric drainage. Regeneration is from both seed and stump sprouting. Ideal seedbed is well decomposed humus with consistent moisture. Stump sprouts are normally of good quality, present an opportunity to out compete commonly associated maple seedlings after release, and are often the dominant form of regeneration. Shade will improve initial survival of seedlings but growth is limited without a moderate opening of the canopy. Basswood shade tolerance progresses contrary to many associates with larger trees being more tolerant than seedlings and saplings. Basswood is typically managed through selection and shelterwood silviculture systems but can successfully regenerate in clearcuts, particularly from stump sprouts.

Keys to success:

- Choose nutrient rich cool moist sites.
- Provide early shade to moderate seedbed conditions and reduce intolerant competition.
- Consider thinning stump sprouts before reaching pole size.

Cautions:

- Best growth is on rich sites but competition can be severe if basswood is not provided a head start.
- Open growing conditions (i.e. low densities) can lead to short trunks with wide crowns.

Target Species: *Basswood*

Silviculture systems and harvest method

	Designation	Conditions	Comments and Assumptions
Clearcut with standards	Not Recommended		
Clearcut - seedtree	Not Recommended		
Shelterwood - uniform	High Probability	Apply principles from the tree marking guide.	
Shelterwood - strip/group	High Probability	Apply principles from the tree marking guide.	Use narrow strips (e.g. 1/2 tree height) and/or additional seed trees if seed origin basswood is preferred.
Shelterwood - irregular	High Probability	Apply principles from the tree marking guide.	Application normally limited to sites where multi-aged structure is preferred and return harvest is unlikely.
Selection - individual	High Probability	Apply principles from the tree marking guide.	
Selection - group	High Probability	Apply principles from the tree marking guide.	Where possible center small to medium groups on concentrations of basswood regeneration or mature basswood marked for removal.

Target Species: *Basswood*

Pre-harvest treatments

	Designation	Conditions	Comments and Assumptions
Chemical	Low Probability		Damage and loss of basswood very likely.
Prescribed Burn	Low Probability		Damage and loss of basswood very likely.
Site Preparation	High Probability		Light scarification more likely to achieve desirable (i.e. humus) seedbed conditions.
Planting	High Probability		Release will be required within a few (3-5) years to ensure survival. Not a common practice.

Logging method

	Designation	Conditions	Comments and Assumptions
Cut-to-length	High Probability		
Tree length	High Probability		
Full tree	High Probability	Not acceptable for shelterwood removal harvests or uneven-aged management.	High risk of damage to regeneration. Careful logging can reduce damage to boles.

Target Species: *Basswood*

Site Preparation

	Designation	Conditions	Comments and Assumptions
Mechanical	High Probability		
Chemical	High Probability		Assumes chemical will be applied in a selective fashion or with an active ingredient and/or rate that is not damaging to basswood.
Prescribed Burn	High Probability	Timing of application and burn indices must be consistent with regeneration objectives.	Assumes adequate seed source (or sprout ability) and fire behaviour that will not consume seed and/or reduce sprouting ability.

Regeneration

	Designation	Conditions	Comments and Assumptions
Advance	High Probability		
Natural seed	High Probability		
Vegetative (coppice)	High Probability		Prolific stump sprouter
Planting	High Probability		Not a common practice.
Seeding	High Probability		Not a common practice.

Target Species: *Basswood*

	Designation	Conditions	Comments and Assumptions
Cleaning			
Manual/mechanical	High Probability		
Chemical	High Probability		Assumes chemical is applied in a selective fashion or with an active ingredient and/or rate that is not damaging.
Midstory/Improvement	High Probability		May be required to eliminate undesirable seed sources. Assumes stem selection will be consistent with a future basswood objective.
Spacing			
PCT / crop tree	High Probability		Not a common practice.
Commercial thinning	High Probability		Not a common practice.

Suggested management approaches - basswood.

Option 1 – Single Tree Selection: Objective is the maintenance and improvement of an un-even aged tolerant hardwood stand with a basswood component.

- Normally applied to tolerant hardwood stands with a pre-harvest BA ≥ 24 m^2/ ha (varies by region), AGS ≥ 9 m^2 /ha (or ≥ 7 m^2/ ha AGS in sawlog sized trees), an uneven aged-structure and growing on deep, fresh silty sands and coarse loams.
- Marginal stands not quite meeting the above criteria may be successfully managed under the selection system but will likely require modifications such as lighter harvest in the initial cuts, a longer interval between cuts to compensate for slower growth rates of low quality trees (up to 35 years), and more cutting cycles to achieve desired quality/structure. These stands may be better suited to the shelterwood system.
- May also be applied to even aged stands on good sites which will develop into an un-even aged structure over time through harvest and improvement treatments.
- Harvest up to 1/3 of the basal area to a minimum retention of 18-22 m^2/ ha (varies by initial stand quality, stocking, site and region) (Leak et al. (1969), Marquis et al. (1992), and Nyland (1987)). Harvest and retention decisions need to consider vigor and risk, stand structure targets (i.e. BA by size class), AGS improvement targets, species priority, and diversity objectives. Refer to the Ontario Tree Marking Guide for further elaboration.
- Apply careful logging principles at all steps of the operation to minimize damage to the site, residual stems, and desirable advanced regeneration.
- Stand improvement to remove highly competitive, lower value mid-story species is recommended (e.g. iron wood, striped maple, etc) either at time of harvest or with follow up treatments.

Option 2 – Group Selection: Objective is the maintenance and improvement of an un-even aged shade tolerant hardwood stand with a basswood component.

- Normally applied to stands with a lower component (<30%), or clumpy distribution, of basswood mixed with good quality tolerant hardwoods.
- Incorporate group openings as part of regular selection management throughout the rest of the stand, as described in option one, to promote regeneration of basswood within a shade-tolerant hardwood stand.
- Create groups in areas of higher UGS adjacent to basswood seed trees, with particular regard for any areas of basswood advanced regeneration.
- Avoid locating groups in areas of smaller diameter AGS crop trees.
- Group size should be 20 m (or tree height) in diameter bole edge to bole edge

- Number and arrangement of group openings should capture the best basswood regeneration opportunities and may range from 5% to 20% of total area, depending upon cutting cycle, regeneration objectives and stand quality. The total volume cut should not exceed stand growth over a cutting cycle.
- In group openings and the immediately surrounding forest (within 10 to 20 m, particularly on the north side of the opening), all trees 2.5cm dbh and larger should be cut or removed by planned skidding disturbance or scarification. Selective removal of non-crop tree species under 2.5cm will also be of benefit to regeneration.
- Assess regeneration and consider planting where densities are low, competition is manageable and suitable nursery stock is available. Vigorous seedlings with a well-developed root system should be planted within operability constraints.
- Apply timely control of competition around regenerating stems (especially during first 5 years).
- In subsequent cuts careful logging to protect the regeneration is critical. If basswood seedlings have regenerated in the openings, the periphery of the openings may need to be expanded to release establishing regeneration.

5.1.15 Other hardwood group

This broad group includes oaks (white, bur, etc.), hickories (bitternut, shagbark, etc.), black walnut, ironwood, tulip tree, sassafras, green ash, and others. This guide provides only limited information for these species. Refer to section 5.3.5 for suggested group selection opening size when targeting regeneration of these species. When managing for these species the silviculturalist is encouraged to use the best available information, including that found in the *Silviculture Guide to Managing Southern Ontario Forests* (OMNR, 2000), and the *Tree Marking Guide* (OMNR, 2004). Consultation with other experienced practitioners is strongly encouraged.

5.1.16 Balsam Fir

Balsam fir (*Abies balsamea*) is very tolerant of shade, is more common in mixed and late successional forests, and highly susceptible to fire and periodic spruce budworm infestations. It can occur on a wide range of soils including mineral and organic/mineral transitions but exhibits limited growth on dry, nutrient poor (e.g. pure sand), or saturated sites. Balsam fir will germinate on almost any substrate that remains moist, but loamy mineral soil with an organic component provides the best chance for establishment. Light demands are very modest and advance regeneration is common under a wide variety of canopy conditions. Regeneration densities can be very high with severe inter-specific competition. High heat and surface drying associated with open growing conditions can be lethal to young seedlings. Balsam fir responds well to release, may exhibit some stress when moved from full shade to full sun, and can produce enough shade to significantly limit regeneration of other species on the same site. Competition from herbs, woody shrubs and hardwood stems can be significant (e.g. smothering) but rarely kills established (i.e. 15cm+) seedlings. Balsam fir is rarely targeted for regeneration but often forms an undesirable component of the future stand in many species mixes and all silviculture systems. Efforts to actively supress balsam fir include prescribed fire, motor-manual cleaning, blading, trampling with machinery/bunches during extraction, and 'mowing' when a live head harvester is available.

Keys to success:

- Select fresh to moist sites with abundant natural regeneration.
- Provide exposed mineral soil when additional regeneration is desired.
- Protect existing advance regeneration through careful logging practices.
- Manage competing vegetation (aspen, maple, etc) to maintain dominant canopy position.

Cautions:

- Susceptible to periodic spruce budworm epidemics (stand replacing mortality).
- Tendency toward early and rapid breakup of mature stems.
- Balsam fir can act as a ladder fuel and may limit the ability to use prescribed ground fires on sites with advance balsam fir regeneration
- Once established, balsam fir can be hard to get rid of

Target Species: *Balsam Fir*

Silviculture systems and harvest method

	Designation	Conditions	Comments and Assumptions
Clearcut with standards	High Probability	Objective is for low to moderate density of balsam fir or relying on advanced regen and/or supplemental planting.	
Clearcut - seedtree	High Probability	Objective is for low to moderate density of balsam fir or relying on advanced regen and/or supplemental planting.	
Shelterwood - uniform	High Probability	Apply principles from the tree marking guide.	
Shelterwood - strip/group	High Probability	Apply principles from the tree marking guide.	
Shelterwood - irregular	High Probability	Apply principles from the tree marking guide.	Application normally limited to sites where multi-aged structure is preferred and return harvest is unlikely.
Selection - individual	High Probability	Apply principles from the tree marking guide.	
Selection - group	High Probability	Apply principles from the tree marking guide.	

Target Species: *Balsam Fir*

Pre-harvest treatments

	Designation	Conditions	Comments and Assumptions
Chemical	High Probability		Not a common practice.
Prescribed Burn	Not Recommended		Fire will eliminate mature seed source and advanced regeneration.
Site Preparation	High Probability		May not be necessary as advanced regeneration is common.
Planting	High Probability		Not a common practice.

Logging method

	Designation	Conditions	Comments and Assumptions
Cut-to-length	High Probability		
Tree length	High Probability		
Full tree	High Probability	1) Rotation length must be greater than 80 years on very shallow soil ecosites (11 to 19 and 23 to 28). 2) Not acceptable for shelterwood removal harvests or	High risk of damage to regeneration. Can be used to reduce undesirable balsam fir advanced regeneration.

Target Species: *Balsam Fir*

Site Preparation

	Designation	Conditions	Comments and Assumptions
Mechanical	High Probability		
Chemical	High Probability		
Prescribed Burn	Not Recommended		Fire will eliminate mature seed source and advanced regeneration.

Regeneration

	Designation	Conditions	Comments and Assumptions
Advance	High Probability		
Natural seed	High Probability		
Vegetative (coppice)	Not Recommended		Vegetative reproduction uncommon on typical Ontario sites.
Planting	High Probability		Not a common practice.
Seeding	High Probability		Not a common practice.

Target Species: *Balsam Fir*

Cleaning

	Designation	Conditions	Comments and Assumptions
Manual/mechanical	High Probability		
Chemical	High Probability		
Midstory/Improvement	High Probability		Assumes stem selection will be consistent with a future balsam fir objective.

Spacing

	Designation	Conditions	Comments and Assumptions
PCT / crop tree	High Probability		Not a common practice.
Commercial thinning	High Probability		Not a common practice.

Suggested management approach – balsam fir

Option 1 – Clearcut Natural Advance Regeneration: Objective is the renewal of an even-aged balsam fir-dominated (>50% composition) mixedwood forest

- Ideally prescribed in upland boreal mixedwood stands dominated by trembling aspen, balsam fir, white spruce, white birch and/or black spruce with deep, fresh to moist, and coarse loamy, silty, or fine loamy soils with a well-developed understory of advance balsam fir regeneration.
- Protect regeneration during harvest by harvesting in winter, directional felling of trees, and restricting machine traffic to defined corridors.
- Anticipate natural seeding to supplement regeneration densities where there are mature balsam fir residual seed bearing trees and where mineral soil has been disturbed.
- Anticipate coppice of trembling aspen where it existed in the pre-harvest overstory and where open growing conditions exist with uncompacted soils.
- Allow five growing seasons prior to surveying for seedling establishment. If necessary, schedule tending (e.g., herbicide) to control competing vegetation prior to FTG age.
- Supplemental treatments (e.g., fill planting with black and/or white spruce) will most likely be required to meet a conifer-dominated mixedwood regeneration objective.

5.1.17 Eastern Larch

Eastern larch (*Larix laricina*) is shade intolerant, is often a pioneer species, and occupies a very wide range of sites from upland gravel to lowland peats. It is most common on wet organic soils, exhibits best growth on moist well-drained loamy soils and it may succumb to drought on very coarse or shallow soils. In peatlands, rich substrates (i.e. woody vs sphagnum peat), and moving (i.e. aerated) water provide better growth than bogs. Regeneration is from both layering and seed with seed being the most common. Suitable seedbeds include mineral soil, moist organic, and sphagnum mounds. Early losses from damping off associated with aggressive sphagnum, fluctuating water levels, shade, and herbaceous competition can be significant. Larch requires full or nearly full sunlight at all stages of development from seedling to mature tree. As such it is best suited to the clearcut silviculture system but individual trees are known to regenerate in larger shelterwood openings, along skid trails and landings.

Keys to success:

- Full or nearly full sunlight.
- Retain well dispersed individual seed trees.

Cautions:

- Larch will establish on a very wide range of sites but growth is optimized on a narrower range.
- Although very fast growing on an individual stem basis, low densities required to provide adequate light do not translate into equally high stand level volumes.
- Repeated defoliation from larch sawfly can lead to mortality.

Recommended reading:

- A Study of Some of the Factors Affecting the Natural Regeneration of Tamarack (Larix laricina) in Minnesota (Duncan, 1954)

Target Species: *Eastern Larch*

Silviculture systems and harvest method

	Designation	Conditions	Comments and Assumptions
Clearcut with standards	High Probability	Objective is for low to moderate density of larch or relying on supplemental planting.	Narrow strips/patches will limit growth/survival at edges - opening should be greater than 2 tree heights across.
Clearcut - seedtree	High Probability		Suggested retention of ~25 trees per hectare well distributed.
Shelterwood - uniform	Low Probability		Insufficient light for seedling development. Regeneration in openings, sides of trail, etc possible.
Shelterwood - strip/group	Not Recommended		Insufficient light for seedling development.
Shelterwood - irregular	Not Recommended		Insufficient light for seedling development.
Selection - individual	Not Recommended		Insufficient light for seedling development.
Selection - group	Low Probability		Insufficient light for development past sapling stage.

Target Species: *Eastern Larch*

Pre-harvest treatments

	Designation	Conditions	Comments and Assumptions
Chemical	High Probability	Chemical must be applied in a selective fashion or with an active ingredient and/or rate that is not damaging to larch.	Not a common practice.
Prescribed Burn	High Probability	Burn indices must be consistent with harvest and regeneration objectives.	Loss of some mature stems is likely
Site Preparation	Low Probability		Pre-harvest stand unlikely to have adequate light for seedling survival.
Planting	High Probability		Pre-harvest stand unlikely to have adequate light for seedling survival.

Logging method

	Designation	Conditions	Comments and Assumptions
Cut-to-length	High Probability		
Tree length	High Probability		
Full tree	High Probability	Rotation length must be greater than 80 years on very shallow soil ecosites (11 to 19 and 23 to 28).	

Target Species: *Eastern Larch*

Site Preparation

	Designation	Conditions	Comments and Assumptions
Mechanical	High Probability		
Chemical	High Probability		Assumes chemical will be applied in a selective fashion or with an active ingredient and/or rate that is not damaging to larch.
Prescribed Burn	Not Recommended		Fire will eliminate mature seed source and advanced regeneration.

Regeneration

	Designation	Conditions	Comments and Assumptions
Advance	High Probability	Objective is for low density of larch regeneration.	
Natural seed	High Probability		
Vegetative (coppice)	Not Recommended		Larch does not form stump or root sprouts.
Planting	High Probability		Not a common practice
Seeding	High Probability		Not a common practice

Target Species: *Eastern Larch*

Cleaning

	Designation	Conditions	Comments and Assumptions
Manual/mechanical	High Probability		
Chemical	High Probability		Assumes chemical is applied in a selective fashion or with an active ingredient and/or rate that is not damaging.
Midstory/Improvement	High Probability		Assumes stem selection will be consistent with a future larch stand.

Spacing

	Designation	Conditions	Comments and Assumptions
PCT / crop tree	High Probability		Not a common practice.
Commercial thinning	High Probability		Not a common practice.

Suggested management approach – eastern larch

Option 1 – Clearcut Natural Seed: Objective is the renewal of an even-aged larch-dominated forest

- Ideally applied to lowland stands that have a minimum larch composition of 30% (with black spruce as the predominant associate) with organic, nutrient poor soils where sphagnum moss and peat dominate the forest floor and where there is a low potential for post-harvest competition (e.g., alder, grass).
- Aim for a residual seed bearing tree density of 25 stems/ha (Johnston and Brittain 1983). Due to its moderate wind firmness, retain individual dominant and co-dominant seed trees with well-established crowns.
- Mechanical SIP (i.e., winter shearblading) may be required to remove or reduce layers of living sphagnum and feathermoss and/or reduce competition. SIP is ideally scheduled to occur as soon after harvest as possible or within one year of harvest to take advantage of seeding potential from cone-bearing slash. Mixing/rutting of soil may improve success of larch.
- Allow five growing seasons prior to surveying for seedling establishment. If necessary, schedule tending (e.g., herbicide) to control competing vegetation prior to FTG age.
- Supplemental treatments (e.g., fill planting or direct seeding with black spruce) may be required to meet regeneration objectives.

5.1.18 White Spruce

White spruce (*Picea glauca*) is tolerant of shade, is more common in mixed and late successional forests, and rarely forms pure stands. White spruce can tolerate a wide range of site and climatic conditions but grows best on fresh to moist nutrient rich soils including telluric, shoreline, and floodplain sites. Regeneration is exclusively from seed on a wide variety of seedbeds including rotting logs, feathermoss, and exposed mineral soil. Thick (5+cm) litter layers, particularly if exposed and prone to drying out, will limit establishment. Good seed years typically occur every 2 to 6 years, may be as long as 10 to 12 years in some locations, with a poor seed year always following a good one. White spruce tolerates low light levels for long periods and responds well to eventual release. White spruce is managed through both the shelterwood (particularly when mixed with other shelterwoodable species) and clearcut silviculture systems including intensively managed plantations.

Keys to success:

- Avoid dry sandy sites.
- Planting is normally required to achieve moderate to high densities
- Time site preparation with a good seed year when not planting
- Avoid low lying ‘frost pockets’ that lack cold air drainage when moderating cover (e.g. shelterwood) cannot be retained.
- Manage competition to maintain adequate light for sustained growth

Cautions:

- Shallow rooting habit creates a wind throw risk in partial harvest areas.
- Shoot elongation may be very limited for the first few years following planting.
- Avoid sites with high incidence of tomentosous root rot.
- Prescribed fire may climb low crowns and kill mature spruce

Target Species: *White Spruce*

Silviculture systems and harvest method

	Designation	Conditions	Comments and Assumptions
Clearcut with standards	High Probability	Objective is for low density of white spruce or relying on advanced regeneration and/or supplemental planting.	
Clearcut - seedtree	High Probability	Objective is for low density of white spruce or relying on advanced regeneration and/or supplemental planting.	Windthrow risk for retained spruce.
Shelterwood - uniform	High Probability	Apply principles from the tree marking guide.	
Shelterwood - strip/group	High Probability	Apply principles from the tree marking guide.	
Shelterwood - irregular	High Probability	Apply principles from the tree marking guide.	Application normally limited to sites where multi-aged structure is preferred and return harvest is unlikely. Development beyond sapling/pole stage will be limited to
Selection - individual	Not Recommended		
Selection - group	High Probability	1) Objective is for low to moderate density of white spruce regeneration. 2) Apply principles from the tree marking guide.	Insufficient light for sapling development in matrix and density of groups dictates low density of white spruce regeneration.

Target Species: *White Spruce*

Pre-harvest treatments

	Designation	Conditions	Comments and Assumptions
Chemical	High Probability		Not a common practice.
Prescribed Burn	High Probability	Burn indices must be consistent with harvest and regeneration objectives.	Low crowns and presence of ladder fuels (e.g. balsam fir) may lead to loss of mature trees and future seed source.
Site Preparation	High Probability		Not a common practice
Planting	High Probability		Not a common practice.

Logging method

	Designation	Conditions	Comments and Assumptions
Cut-to-length	High Probability		
Tree length	High Probability		Long log lengths increase the risk of damage while skidding.
Full tree	High Probability	Not acceptable for shelterwood removal harvests or uneven-aged management.	Long log lengths increase the risk of damage while skidding.

Target Species: *White Spruce*

Site Preparation

	Designation	Conditions	Comments and Assumptions
Mechanical	High Probability		
Chemical	High Probability		
Prescribed Burn	High Probability	Timing of application and burn indices must be consistent with regeneration objectives.	Advanced regeneration will be eliminated.

Regeneration

	Designation	Conditions	Comments and Assumptions
Advance	High Probability		
Natural seed	High Probability		Seedbed preparation will increase success. May require supplemental planting to achieve higher densities.
Vegetative (coppice)	Not Recommended		White spruce does not regenerate vegetatively.
Planting	High Probability		
Seeding	High Probability		Not a common practice.

Target Species: *White Spruce*

	Designation	Conditions	Comments and Assumptions
Cleaning			
Manual/mechanical	High Probability		
Chemical	High Probability		
Midstory/Improvement	High Probability		May be required to maintain desired light levels and eliminate undesirable seed sources. Assumes stem selection will be consistent with a future white spruce stand.
Spacing			
PCT / crop tree	High Probability		
Commercial thinning	High Probability		Refer to best management practices in Appendix 4.

Suggested management approaches – white spruce

The following example management approaches are described when white spruce is present in the pre-harvest stand and when targeting a white spruce component in a future mixedwood regeneration scenario.

Option 1 – Clearcut Plant: Objective is the renewal of an even-aged conifer dominated forest with a white spruce component

- Normally applied to upland stands where white spruce existed in the pre-harvest stand. Planting white spruce is commonly practiced on sites with deep, dry to moist, and coarse to fine loamy soils.
- Mechanical SIP may be required to increase the number and distribution of suitable planting spots and control advance balsam fir regeneration that may outcompete white spruce seedlings for available resources. Manual SIP (i.e., screefing) is typical on clay-textured soils susceptible to frost heaving, sites with no mechanical SIP access, and sites with thin "duff" layers (>10 cm). Chemical SIP may also be applied on high competition sites.
- As white spruce rarely forms pure stands, it may be mixed in with other species (e.g., black spruce) during planting. White spruce may compose between 30 and 50% of the planted trees. Planting densities will vary significantly depending on site conditions and the range of management intensities identified in the FMP.
- Planted seedlings can tolerate some competition, particularly moderate shade, but growth may be reduced when competition is severe. "Veg press" associated with thick fall/winter matting of dead herbaceous growth, can smother smaller seedlings before they become fully established. On competitive sites, survey for tending the year following planting and schedule a release (e.g., broadcast herbicide) as required.
- Consider harvest blocks where access to conduct future surveys and regeneration (fill-planting) and tending (e.g., pre-commercial thinning) treatments will be feasible.

Option 2 – Clearcut Plant: Objective is the renewal of an even-aged spruce-aspen mixedwood forest

- Normally applied to upland stands where white spruce and trembling aspen existed in the pre-harvest stand. Planting white spruce is commonly practiced on sites with deep, dry to moist, and coarse to fine loamy soils.
- Mechanical SIP may be required to increase the number and distribution of suitable planting spots and control and advance balsam fir regeneration that may outcompete white spruce seedlings for available resources. Manual SIP (i.e., screefing) is typical on clay-textured soils susceptible to frost heaving, sites with poor mechanical SIP access, and sites with thin "duff" layers (>10 cm).
- White spruce is planted with wide spacing (e.g., 5 m spacing or 400 stems/ha) alongside aspen regeneration by suckering.
- Planted seedlings require early competition control to promote early dominance over adjacent aspen regeneration. Survey for tending the year of planting and if necessary, schedule release (e.g., directed or spot herbicide treatments) as early as one year post-planting.

- Consider harvest blocks where access to conduct future surveys and tending will be feasible.

Option 3 – Clearcut Natural Seed: Objective is the renewal of an even-aged mixedwood forest with a white spruce component

- Normally applied to upland stands that have a white spruce composition of greater than 30% and where there is a relatively low potential for post-harvest competition. Harvesting should be scheduled to occur before seed release in a mast (cone crop) year.
- Windfirm individual white spruce trees or groups of white spruce trees mixed with other species should be retained as seed bearing trees. Retain at least 5 mature trees/ha with large crowns as seed trees. Seed trees need to represent the genetic diversity of the pre-harvest stand.
- Any white spruce advance growth should be protected during harvest to supplement seeding regeneration.
- Mechanical SIP is likely required to ensure sufficient coverage and distribution of a receptive seedbed. Exposed mineral soil, mineral soil with an organic layer less than 5 cm thick, and rotting logs are suitable seedbeds for white spruce. SIP is ideally scheduled to occur during the summer of a mast year just prior to seed release (August to September). Seedbed quality diminishes quickly after 3 years.
- Allow five growing seasons prior to surveying for seedling establishment. If necessary, schedule tending as early as two growing seasons after seeding. Directed tending is practical when spruce regeneration will be supplemented by natural aspen suckering, whereas broadcast herbicide tending is suitable where a future conifer dominated mixedwood stand is desired.
- Supplemental regeneration treatments (e.g., fill planting) may be required to meet regeneration objectives.

Option 4 – Uniform Shelterwood: Objective is the renewal of an even-aged white spruce dominated mixedwood forest

- Normally applied to upland mixedwood stands with a hardwood dominated overstory and a conifer understory with few other species that would normally be associated with a shelterwood approach (e.g. Pw, Pr, He, Or, By, etc). This system may be desired to protect spruce regeneration from exposure and competition from shade intolerant species with a broadleaf canopy.
- When white spruce is growing with other species adapted to even-aged management (Pw, Pr, He, Sr, Sw, Ow, Hi, Aw, Cb, By) totaling >=18 m^2 refer to the white pine uniform shelterwood suggested management approach.
- A regeneration cut is conducted to reduce BA to 9 – 14 m^2/ha. Mature aspen are retained as a nurse crop. Any white spruce advance growth should be protected during harvest to supplement future regeneration.
- Mechanical SIP may be required to increase the number and distribution of suitable planting spots and control advance balsam fir regeneration that may outcompete white spruce seedlings for available resources. Manual SIP (i.e., screefing) is typical on clay-textured soils susceptible to frost heaving, sites with no mechanical SIP access, and sites with thin “duff” layers (>10 cm). Chemical

SIP of the understory (ground application) may also be applied on high competition sites.

- The use of large planting stock is suggested. As white spruce rarely forms pure stands, it may be mixed in with other species with similar shade tolerances during planting. Planting densities will vary significantly depending on site conditions and the range of management intensities identified in the FMP.
- Planted seedlings require early competition control for adequate sunlight and suitable growing conditions. Survey for tending the year of planting and if necessary, schedule release (e.g., ground application of herbicide) as early as one year post-planting.
- When regeneration is 2 – 3 years old, conduct a final cut of the overstory canopy to achieve >70% full sunlight conditions. If a final cut is not operationally feasible, the broadleaf canopy can be modified (e.g., strip herbicide treatment) to achieve >70% full sunlight conditions.

5.1.19 Black Spruce

Black spruce (*Picea mariana*) is tolerant to mid tolerant of shade, regenerates from both seed and layers, and can be even, multi, or uneven aged. Black spruce can occupy a very wide range of sites from shallow till over bedrock to deep sands, loams, clays, and wet organics - best growth is on fresh to moist silty loams. It can be a significant component of successional forests on upland sites, but it is most common in pure or nearly pure stands on wet soils including deep clays and peats. Black spruce will germinate on a variety of substrates (mineral, mixed mineral, humus, sphagnum, etc) where adequate moisture is maintained. Layering is quite common on organic sites with site richness (poor), stand structure (open) and amount of woody brush (low) influencing the presence of layers. Black spruce will grow in as little as 30% sunlight and optimally in 60% or better light. Black spruce is most commonly managed through the clearcut silviculture system but it’s shade tolerance makes it well suited to shelterwood and selection. Typical harvest patterns include the retention of small to medium stems and concentration of machinery on narrow travel corridors to retain advance regeneration and avoid disturbance of the forest floor.

Keys to success:

- Harvest wet sites on frozen soil, using high floatation tires, or other modifications, to minimize potential for site damage.
- Plant or direct seed when natural regeneration is unlikely to meet objectives.
- Manage vegetation to maintain adequate light.
- Protect advance regeneration using careful logging techniques (e.g. CLAAG – careful logging around advance growth, HARP – harvest with advance regeneration protection).
- Augment natural regeneration with planting.

Cautions:

- Fast growing sphagnum can over-top germinants and may not be a suitable seedbed.
- High risk of wind throw in partial harvest areas, particularly on sites with a high water table.

Recommended reading:

- Direct seeding black spruce and jack pine: A field guide for northern Ontario. (Adams et al 2005)

Target Species: *Black spruce*

Silviculture systems and harvest method

	Designation	Conditions	Comments and Assumptions
Clearcut with standards	High Probability	Bog/swamp ecosites (126-133): no conditions All other ecosites: objective is for low density of black spruce or relying on advanced regen and/or supplemental planting/seeding.	Assumes appropriate seedbed conditions are maintained/created for bog/swamp ecosites. Retention of larch or cedar can lead to significant ingress and compromise forest unit targets.
Clearcut - seedtree	High Probability	Bog/Swamp ecosites (126-133): no conditions All other ecosites: objective is for low to moderate density of black spruce or relying on advanced regen and/or supplemental planting/seeding..	Assumes appropriate seedbed conditions are maintained/created for bog/swamp ecosites. Retention of larch or cedar can lead to significant ingress and compromise forest unit targets.
Shelterwood - uniform	High Probability		Increased risk of windthrow.
Shelterwood - strip/group	High Probability		Increased risk of windthrow.
Shelterwood - irregular	High Probability		Increased risk of windthrow. Application normally limited to sites where multi-aged structure is preferred and return harvest is unlikely.
Selection - individual	High Probability		Stand structure, site type, trail coverage, machine size, etc need careful consideration.
Selection - group	High Probability		Suggested group size of 1-2 tree heights well distributed and covering <20% of stand. Stand structure, site type, trail coverage, machine size, etc need careful consideration.

Target Species: *Black spruce*

Pre-harvest treatments

	Designation	Conditions	Comments and Assumptions
Chemical	High Probability		Not a common practice.
Prescribed Burn	High Probability	Burn indices must be consistent with harvest and regeneration objectives.	Low crowns, shallow roots, and presence of ladder fuels (e.g. balsam fir) may lead to loss of mature trees and future seed source. Majority of advanced regeneration will be lost.
Site Preparation	High Probability		Not a common practice
Planting	High Probability		Not a common practice.

Logging method

	Designation	Conditions	Comments and Assumptions
Cut-to-length	High Probability		
Tree length	High Probability		
Full tree	High Probability	1) Rotation length must be greater than 80 years on very shallow soil ecosites (11 to 19 and 23 to 28). 2) Not acceptable for shelterwood removal harvests or	

Target Species: *Black spruce*

Site Preparation

	Designation	Conditions	Comments and Assumptions
Mechanical	High Probability		
Chemical	High Probability		
Prescribed Burn	High Probability	Timing of application and burn indices must be consistent with regeneration objectives.	Majority of advanced regeneration will be lost.

Regeneration

	Designation	Conditions	Comments and Assumptions
Advance	High Probability		Moderately open canopy and low density of shrubs increases the likelihood of layers on bog sites. Upland advanced regeneration more likely with increased time since fire.
Natural seed	High Probability		
Vegetative (coppice)	Not Recommended		Black spruce will layer to produce advanced regeneration, but does not regenerate from coppice.
Planting	High Probability		
Seeding	High Probability		

Target Species: *Black spruce*

	Designation	Conditions	Comments and Assumptions
Cleaning			
Manual/mechanical	High Probability		
Chemical	High Probability		
Midstory/Improvement	High Probability		Not normally required in black spruce stands. May be used to adjust species composition to achieve purity objectives.
Spacing			
PCT / crop tree	High Probability		
Commercial thinning	High Probability		Narrow crown architecture makes response to thinning uncertain. Refer to best management practices in Appendix 4.

Suggested management approaches – black spruce

Alternative management approaches are summarized below when black spruce is present in the pre-harvest stand and when targeting pure black spruce or black spruce dominated regeneration. Conditions within a harvest block (species composition, post-harvest competition, moisture regime, etc.) can be quite variable and may require stratification into separate treatment units. Treatment units should be of a minimum size to facilitate efficient renewal, tending, and future harvests. This may require sub-optimal treatment of some areas based on a pragmatic approach to the whole.

Option 1 – Clearcut Natural Seed: Objective is the renewal of an even-aged black spruce-dominated forest

- Normally applied to lowland stands that have a minimum black spruce composition of 70% (with larch as the predominant associate) with nutrient poor organic soils where sphagnum moss and peat dominate the forest floor and where there is a low potential for post-harvest competition. Applied to stands where advance regeneration is irregular and patchy or absent.
- Group residual seed bearing trees to increase windfirmness and longevity. Groups should be 10-15 m in diameter and 80-90 m apart. Group seed trees need to represent the genetic diversity of the pre-harvest stand. Retained larch trees will provide a seed source for larch regeneration which may impact the future composition objectives of the stand.
- Winter harvest may increase amount of cone-bearing slash on the ground.
- Mechanical SIP (i.e., winter shearblading) may be required to remove or reduce layers of living sphagnum and feathermoss. SIP is ideally scheduled to occur as soon after harvest as possible or within one year of harvest to take advantage of seeding potential from cone-bearing slash.
- Allow five growing seasons prior to surveying for seedling establishment. If necessary, schedule tending (e.g., herbicide) as early as two growing seasons after seeding.
- Direct seeding or tree planting may be required to meet regeneration objectives. Schedule direct seeding to occur within one year post-harvest.

Option 2 – Clearcut Direct Seed: Objective is the renewal of an even-aged black spruce-dominated forest

- Normally applied to lowland stands that have a minimum black spruce composition of 50% (with larch as the predominant associate) with organic, nutrient poor soils where sphagnum moss and peat dominate the forest floor and where there is a low potential for post-harvest competition. Applied to stands where advance regeneration is irregular and patchy or absent and where natural seeding is not expected to meet regeneration objectives.

- Mechanical SIP (i.e., winter shearblading) may be required to remove or reduce layers of living sphagnum and feathermoss. SIP is ideally scheduled to occur as soon after harvest as possible or within one year of harvest to take advantage of seeding potential from cone-bearing slash.
- Schedule sowing of seed to occur in the late winter or early spring following harvest and after the completion of SIP operations (if conducted). A seeding rate of 50,000 – 100,000 seeds/ha is commonly applied, dependent upon 1) seed viability, 2) receptive seedbed coverage and distribution, and 3) anticipated ingress from natural seed sources (Adams *et al*. 1998).
- Ensure origin (seed zone) of seed corresponds to the geographic area it is being applied in.
- Anticipate natural seeding to supplement regeneration densities where cone-bearing slash is present.
- Allow five growing seasons prior to surveying for seedling establishment. If necessary, schedule tending (e.g., herbicide) to control competing species (e.g., alder) prior to FTG age.
- Supplemental treatments (e.g., fill planting) may be required to meet regeneration objectives.

Option 3 – Clearcut Natural Advance Regeneration: Objective is the renewal of an even-aged black spruce-dominated forest

- Normally applied to open, lowland stands dominated by black spruce (with larch and cedar as the predominant associates) with organic soils where sphagnum moss and peat dominate the forest floor and sufficient stocking of advance regeneration (primarily from layers) is present. The potential for advance regeneration is also high in black spruce dominated stands on shallow soils over bedrock. Mature and overmature stands with stocking or crown closure less than 70% are good candidates for this treatment.
- Protect regeneration during harvest by harvesting in winter on frozen ground, directional felling of trees, and restricting machine traffic to defined corridors.
- Anticipate natural seeding to supplement advance regeneration density where residual seed bearing trees, cone bearing slash, and adequate receptive seedbed (sphagnum moss and peat) are present.
- Allow 2-3 growing seasons prior to surveying for seedling establishment. If necessary, schedule tending (e.g., herbicide) to control competing species (e.g., alder) prior to FTG age.
- Supplemental treatments (e.g., direct seeding, tree planting) may be required to meet regeneration objectives.

Option 4 – Clearcut Plant: Objective is the renewal of an even-aged black spruce-dominated forest

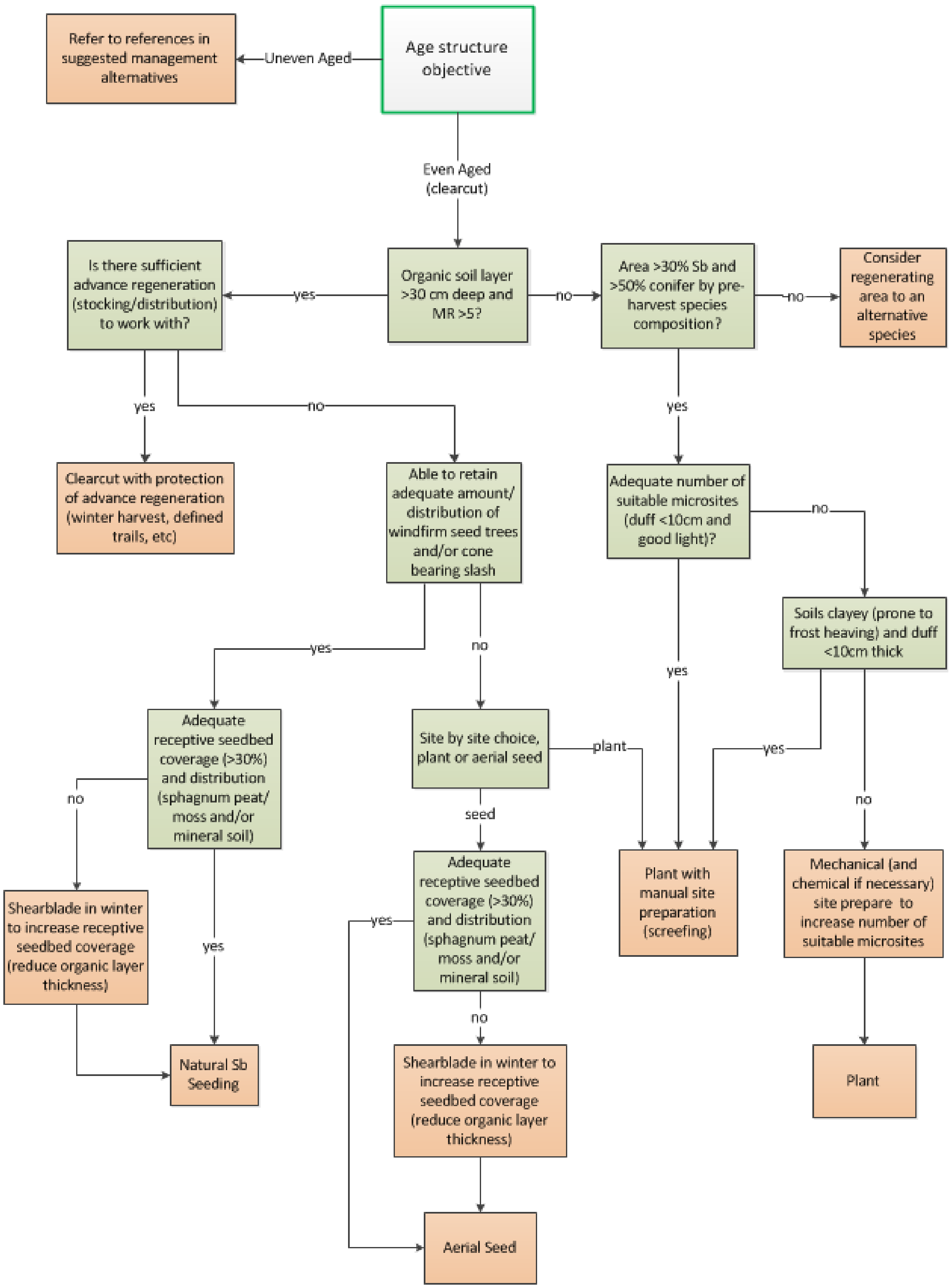
- Normally applied to upland stands with a minimum black spruce composition of 30% and conifer composition of >50%. Planting black spruce is a common treatment on a wide range of upland sites from very shallow to deep, dry to moist, and coarse to fine-textured soils. Commonly used to convert a hardwood or mixedwood site to a conifer dominant condition.
- Even moderate pre-harvest densities of jack pine, particularly when slash is well distributed over disturbed substrate, can lead to significant jack pine ingress, which can quickly overtop black spruce.
- Planting is may be required on some organic sites where there is insufficient natural advance regeneration (i.e., stands with stocking or crown closure greater than 70%), inadequate seed source or seedbed, or high potential for post-harvest competition.
- Mechanical SIP may be required to increase the number and distribution of suitable planting spots. Density regulation begins with SIP and can setup future commercial thin. Manual SIP (i.e., screefing) is typical on very shallow, organic, or clay-textured soils susceptible to frost heaving, sites with poor mechanical SIP access, and sites with thin "duff" layers (>10 cm). Chemical SIP may also be applied on high competition sites.
- Planting densities should consider the desired future forest condition (composition, piece size, etc), planned future treatments (e.g. thinning), and typically range from 800 to 2,200 stems/ha. Crop planning tools such as density management diagrams can help match regeneration density to future targets. Expected natural ingress, extent of non-plantable spots (e.g. bedrock), and intended future composition will all influence the chosen density.
- Planted seedlings require early competition control for full sunlight and open growing conditions. Survey for tending the year of planting and if necessary, schedule release (e.g., herbicide) as early as one year post-planting.

Option 5 – Uneven-aged management: Objective is the maintenance/creation of an uneven-aged black spruce-dominated forest

- To date, there have been few operational experiences with uneven-aged silviculture systems in boreal Ontario. Some practices, such as Harvesting with Advance Regeneration Protection (HARP) in lowland black spruce forests do retain some structure, but typical diameter limits (e.g. 10-12cm) and significant trail coverage result in the bulk of the future growing stock coming from new regeneration and creating a largely even-aged condition.
- A number of research studies are available as inspiration for a possible operational approach to uneven-aged black spruce management (e.g. Groot, 2014). Different

studies have taken different approaches and their effectiveness in achieving an un-even aged condition, or feasibility in an operational setting, have not been evaluated in this guide.

Suggested decision key when determining the appropriate management approach for black spruce.



5.1.20 Red Spruce

Red spruce (*Picea rubens*) is tolerant of shade, long lived, and the least common conifer species in Ontario. It can grow on a wide range of sites when moisture is adequate, grows well on fresh to moist sandy loams, and is considered acidophilous (only grows on acidic soils). Regeneration occurs almost exclusively from seed with good seed years occurring every 3 to 8 years. Germination and establishment can occur on a range of substrates (mineral, mixed mineral, logs, humus, etc) when adequate moisture and moderate temperatures are maintained - drying for even short periods of time can cause failure. Soil disturbance will encourage root establishment into mineral soil, reducing the risk of drying out. Seedlings can survive in as little as 10% full sunlight but require 50% or better light for optimal growth. Once established, seedlings/saplings can remain supressed for decades and still respond well to release, although older trees may require up to 5 years to show increased growth. Red spruce rarely forms pure stands in Ontario and is typically managed based on associated species through the selection and shelterwood silviculture systems. Even small concentrations of red spruce are ecologically significant and should be stratified for retention or a red spruce specific prescription.

Keys to success:

- Maintain overstory shade until seedlings are well established into mineral soil
- Organic layer disturbance through frost free harvest or site preparation
- Mark for retention whenever possible.

Cautions:

- Hardwood litter, ferns, etc can smother small germinants.
- Germinants may show initial success when established in thick humus but will perish at the first signs of drought.

Target Species: ***Red Spruce***

Silviculture systems and harvest method

	Designation	Conditions	Comments and Assumptions
Clearcut with standards	Not Recommended		Open growing conditions lead to excessive drying and/or severe competition.
Clearcut - seedtree	Not Recommended		Open growing conditions lead to excessive drying and/or severe competition.
Shelterwood - uniform	High Probability	Apply principles from the tree marking guide.	Fulltree logging may cause excessive damage to regeneration.
Shelterwood - strip/group	High Probability	Apply principles from the tree marking guide.	Control of competing vegetation, particularly hardwoods, is critical to success.
Shelterwood - irregular	High Probability	Apply principles from the tree marking guide.	Application normally limited to sites where multi-aged structure is preferred and return harvest is unlikely.
Selection - individual	High Probability	Apply principles from the tree marking guide.	
Selection - group	High Probability	Apply principles from the tree marking guide.	Suggested group size of 1/2 tree height well distributed and covering <20% of stand.

Target Species: *Red Spruce*

Pre-harvest treatments

	Designation	Conditions	Comments and Assumptions
Chemical	High Probability		Not a common practice.
Prescribed Burn	High Probability	Burn indices must be consistent with harvest and regeneration objectives.	Low crowns, shallow roots, and presence of ladder fuels (e.g. balsam fir) may lead to loss of mature trees and future seed source.
Site Preparation	High Probability		Not a common practice
Planting	High Probability		Not a common practice.

Logging method

	Designation	Conditions	Comments and Assumptions
Cut-to-length	High Probability		
Tree length	High Probability		Long log lengths increase the risk of damage while skidding.
Full tree	High Probability	Not acceptable for shelterwood removal harvests or uneven-aged management.	May cause excessive damage to regeneration.

Target Species: *Red Spruce*

Site Preparation

	Designation	Conditions	Comments and Assumptions
Mechanical	High Probability		
Chemical	High Probability		
Prescribed Burn	High Probability	Timing of application and burn indices must be consistent with regeneration objectives.	Low crowns, shallow roots, and presence of ladder fuels (e.g. balsam fir) may lead to loss of mature trees and future seed source.

Regeneration

	Designation	Conditions	Comments and Assumptions
Advance	High Probability		
Natural seed	High Probability		
Vegetative (coppice)	Not Recommended		
Planting	High Probability		
Seeding	High Probability		Not a common practice.

Target Species: *Red Spruce*

	Designation	Conditions	Comments and Assumptions
Cleaning			
Manual/mechanical	High Probability		
Chemical	High Probability		
Midstory/Improvement	High Probability		May be required to eliminate undesirable seed sources. Assumes stem selection will be consistent with a future hemlock stand.
Spacing			
PCT / crop tree	High Probability		Not a common practice.
Commercial thinning	High Probability		Not a common practice.

Suggested management approaches – red spruce

The ecological characteristics and adaptations of red spruce are similar to those of hemlock. The suggested management approaches for hemlock provide a reasonable starting point for red spruce. Refer to section 5.2.25.

5.1.21 Jack Pine

Jack pine (*Pinus banksiana*) is intolerant of shade, regenerates exclusively from seed, and is adapted to stand replacing fires. It can tolerate a wide range of sites from thin soils over bedrock to deep silts/clays, performs best on fresh well-drained loams, but is found most often on deep dry to fresh sands where fire return interval tends to be lower and competition is not as severe. Jack pine seed banks in the canopy and logging slash (serotinous cones) and requires high temperatures to release the seed. Germination occurs on mineral or burned seedbeds where adequate moisture is present. Spring droughts can lead to delayed germination with some seed germinating the following year. Hardwood and herbaceous litter can smother small germinants, and seedlings are sensitive to even moderate competition. Rapid early growth and high initial densities leads to early stem exclusion and self-thinning. Jack pine responds well to release if not significantly supressed (i.e. good live crown ratio) and is commonly thinned at multiple development stages. Jack pine is managed through the clearcut silviculture system and is typically planted or artificially seeded.

Keys to success:

- Provide full or nearly full sunlight through overstory removal.
- Site preparation to improve microsite and control competing vegetation
- Plant or direct seed when natural regeneration is unlikely to meet objectives.
- Early vegetation management to maintain adequate light.

Cautions:

- Avoid nutrient rich highly competitive sites.
- Incidence of cronartium rust can increase on clay sites.
- Susceptible to windthrow and snow damage following thinning.

Recommended reading:

- Direct seeding black spruce and jack pine: A field guide for northern Ontario. (Adams et al 2005)

Target Species: *Jack Pine*

Silviculture systems and harvest method

	Designation	Conditions	Comments and Assumptions
Clearcut with standards	High Probability		Narrow strips/patches will limit growth/survival at edges - opening should be greater than 2 tree heights across.
Clearcut - seedtree	High Probability		May require site preparation and/or supplemental planting to achieve density objective
Shelterwood - uniform	Not Recommended		Insufficient light for seedling development.
Shelterwood - strip/group	Not Recommended		Insufficient light for seedling development.
Shelterwood - irregular	Not Recommended		Insufficient light for seedling development.
Selection - individual	Not Recommended		Insufficient light for seedling development.
Selection - group	Low Probability		Insufficient light for seedling development.

Target Species: *Jack Pine*

Pre-harvest treatments

	Designation	Conditions	Comments and Assumptions
Chemical	High Probability		Not a common practice.
Prescribed Burn	High Probability	Burn indices must be consistent with harvest and regeneration objectives.	Presence of ladder fuels (e.g. balsam fir) may lead to loss of mature trees and future seed source.
Site Preparation	Low Probability		Pre-harvest stand unlikely to have adequate light for seedling development
Planting	Low Probability		Pre-harvest stand unlikely to have adequate light for seedling development

Logging method

	Designation	Conditions	Comments and Assumptions
Cut-to-length	High Probability		
Tree length	High Probability		
Full tree	High Probability	Rotation length must be greater than 80 years on very shallow soil ecosites (11 to 19 and 23 to 28).	

Target Species: *Jack Pine*

Site Preparation

	Designation	Conditions	Comments and Assumptions
Mechanical	High Probability		
Chemical	High Probability		
Prescribed Burn	High Probability	Timing of application and burn indices must be consistent with regeneration objectives.	Burned seedbeds that eliminate most of the duff/litter layer are ideal for germination. Advanced regeneration will be eliminated.

Regeneration

	Designation	Conditions	Comments and Assumptions
Advance	Low Probability		Advanced regeneration is insufficient to produce a pj stand without supplemental regeneration (e.g. planting).
Natural seed	High Probability		Seedbed preparation will increase success. Effective seed source must be retained (standing trees, cones in slash, etc) following harvest.
Vegetative (coppice)	Not Recommended		Jack pine does not regenerate by coppice.
Planting	High Probability		
Seeding	High Probability		

Target Species: *Jack Pine*

	Designation	Conditions	Comments and Assumptions
Cleaning			
Manual/mechanical	High Probability		
Chemical	High Probability		
Midstory/Improvement	High Probability		Not normally required in jack pine stands. May be used to adjust species composition to achieve purity objectives.
Spacing			
PCT / crop tree	High Probability		Susceptible to snow damage following thinning.
Commercial thinning	High Probability		Refer to best management practices in Appendix 4. Susceptible to windthrow and snow damage following thinning.

Suggested management approach – jack pine

Option 1 – Clearcut Aerial Broadcast Seed: Objective is the renewal of an even-aged jack pine-dominated forest

- Normally applied to upland stands with a minimum jack pine composition of 50% and conifer composition of >70% (e.g. black spruce) with shallow to deep, dry to fresh, sandy or coarse loamy soils where there is low potential for post-harvest competition from hardwoods, shrubs, and herbs.
- Mechanical SIP is usually required to increase receptive seedbed distribution and coverage and is especially critical on sites with heavier slash loads and thicker organic layers. SIP is ideally scheduled to occur as soon after harvest as possible or within one year of harvest to take advantage of natural ingress from cone-bearing slash and initial lower coverage of competing vegetation postharvest. Moderate site preparation that results in a uniform distribution of mineral soil exposure with roughly 12 - 25% coverage of ground area is common.
- Schedule sowing of seed to occur in the late winter or early spring following harvest and after the completion of SIP operations. A seeding rate of 25,000 – 50,000 seeds/ha is commonly applied, dependent upon 1) seed viability, 2) receptive seedbed coverage, and 3) distribution and anticipated ingress from natural seed sources. Refer to Adams et al 2005 for details.
- Ensure origin (seed zone) of seed is appropriate for the geographic area it is being applied in.
- Anticipate natural ingress to supplement regeneration density where cone-bearing slash is present. Increased break-off of branches associated with winter harvest will increase ingress through slash/cone retention.
- Allow two growing seasons prior to surveying for seedling establishment. If necessary, schedule tending (i.e. herbicide) as early as two growing seasons after seeding.
- Ideally applied in areas where access to conduct future surveys and regeneration (fill-planting) and tending (pre-commercial thinning) treatments will be feasible.

Option 2 – Clearcut Plant: Objective is the renewal of an even-aged jack pine-dominated forest

- Normally applied to upland stands with a minimum jack pine composition of 30% and conifer composition of >50% (predominantly black spruce). Planting jack pine is a common treatment on sites with deep, dry to fresh, and fine-textured soils (fine loamy, silty) where the potential for post-harvest competition from hardwoods (Po, Bw), shrubs (raspberry, beaked hazel, mountain maple, alder, pin cherry), and herbs (grass) is moderate to high.

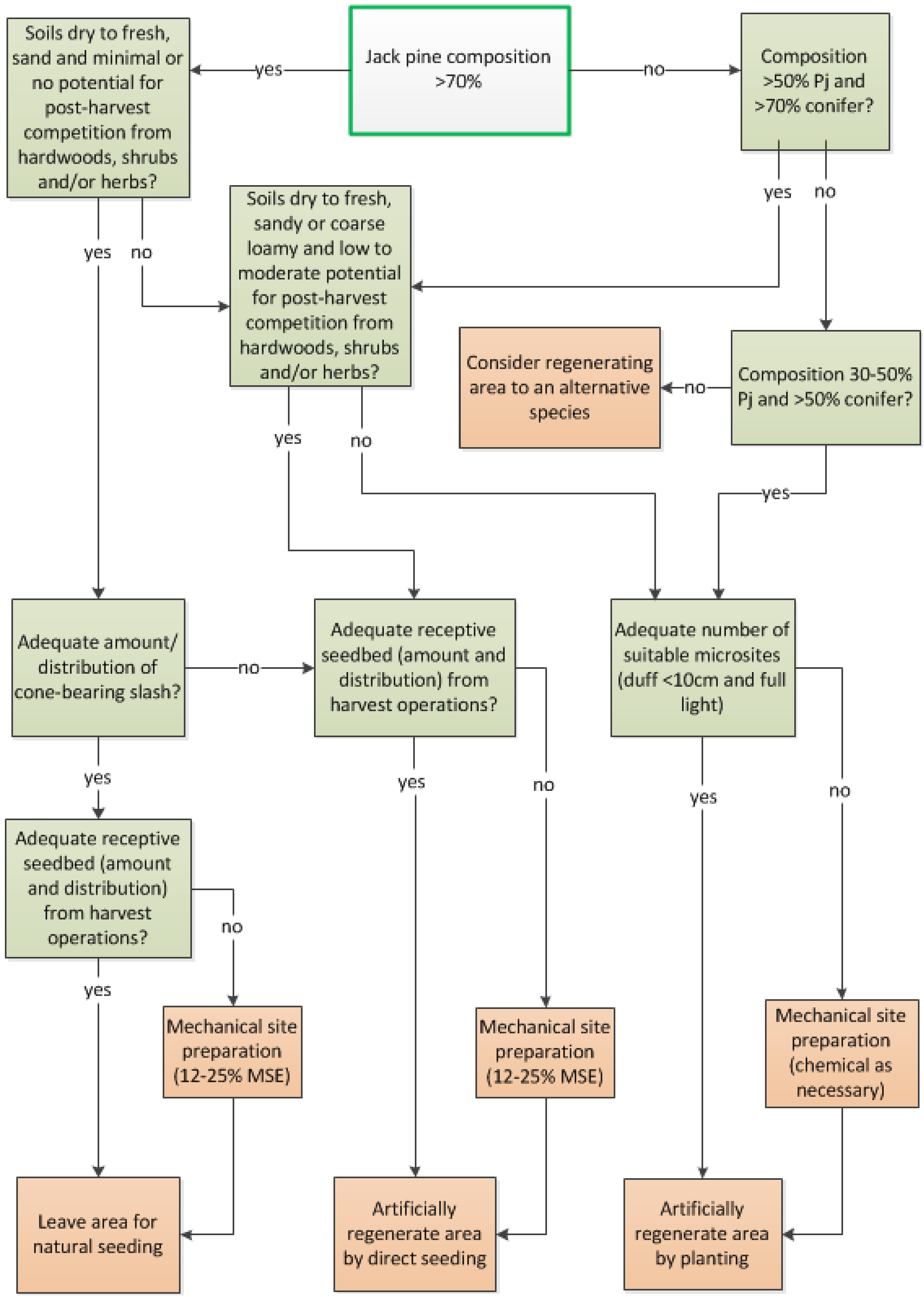
- Mechanical SIP is usually required to increase the number and distribution of suitable planting spots. Manual SIP (screefing) is typical on sites with fine-textured soils susceptible to frost heaving, sites with poor mechanical SIP access, and sites with thin "duff" layers (>10 cm). Chemical SIP may also be applied on high competition sites.
- Site preparation can help to set the stand up for future density regulation.
- Areas to be planted ideally have all-season access to facilitate cost-effective planting operations.
- Planting densities should consider the desired future forest condition (composition, piece size, etc), planned future treatments (e.g. thinning), and typically range from 800 to 2,100 stems/ha. Crop planning tools such as density management diagrams can help match regeneration density to future targets. Expected natural ingress, extent of non-plantable spots (e.g. bedrock), and intended future composition will all influence the chosen density. Increased break-off of branches associated with winter harvest will increase ingress through slash/cone retention. Low planting densities without ingress or natural regeneration of other species will lead to low heavy branching limiting future product potential.
- Planted seedlings require early competition control for full sunlight and open growing conditions. Survey for tending the year of planting and if necessary, schedule release (i.e. herbicide) as early as one year post-planting for overwinter crop (spring plant) seedlings and two years for current crop (summer plant) seedlings.
- The planting of jack pine is a common practice used to reclaim roadsides, gravel and borrow pits.

Option 3 – Clearcut Natural Ingress: Objective is the renewal of an even-aged jack pine-dominated forest

- Normally limited to stands with a pure to nearly pure component of jack pine (>70% species composition) with dry to fresh, sandy soils where there is no or minimal potential for post-harvest competition from hardwoods, shrubs, and herbs.
- Scarification is ideally scheduled to occur as soon after harvest as possible to take advantage of seed that will be released from cone-bearing slash and initial lower coverage of competing vegetation postharvest. Scarification with drags will increase receptive seedbed coverage and distribute cone-bearing slash. Light to moderate scarification that results in a uniform distribution of mineral soil exposure with roughly 12 - 25% coverage of ground area is common. Increase break-off of branches associated with winter harvest will increase ingress through slash/cone retention.

- Post-harvest seed supply typically includes an adequate amount and uniform distribution of cone-bearing slash in the treatment area and 10 - 25 well distributed seed trees per hectare.
- Supplemental planting may be required to achieve target densities and stocking.
- Allow two growing seasons prior to surveying for seedling establishment. If necessary, schedule tending (i.e. herbicide) as early as two growing seasons post-harvest.

Suggested decision key when determining the appropriate management approach for jack pine.



5.1.22 Red Pine

Red pine (*Pinus resinosa*) is mid to intolerant of shade, with light requirements increasing with age, and is adapted to frequent ground fires. Red pine can tolerate very dry and poor sites, occurs primarily on deep coarse textured soils (e.g. glacial outwash), with improved growth on fresher sites with a silt/loam component. Red pine prefers acidic soils - sites with moderate to strongly alkaline c-horizon soils have been associated with increased risk of decline. Good seed years are every 3 to 7 years (bumper every 10 to 12) with little seed in the intervening years. Lateral roots extend well beyond the limit of the crown, can send tap and sinker roots very deep into the soil, and commonly graft with roots of other red pine. Red pine is managed through both the shelterwood (particularly when mixed with other shelterwoodable species) and clearcut silviculture systems including intensively managed plantations. Environmental conditions under red pine plantations may be well suited to long-term conversion to hardwoods, white pine, and other mixes.

Keys to success:

- Prepared seedbed (mineral or humus/mineral mix) timed with a good seed year.
- Early, aggressive, and frequent vegetation management
- Regular thinning in high density plantations to avoid stagnation

Cautions:

- Avoid shallow ridge tops, alkaline, or high water table sites.
- Red pine established through shelterwood approaches may require more light or earlier release than other (e.g. white pine, white spruce) shelterwoodable conifers.
- Avoid competitive nutrient rich sites

Recommended reading:

- Mortality in Southern Ontario Red Pine Plantations: Causes, Consequences, and Management Options. (McLaughlin et al 2010)
- Annotated Bibliography of Eastern White and Red Pine 1960–2007. (Burgess, 2011)

Target Species: Red Pine

Silviculture systems and harvest method

	Designation	Conditions	Comments and Assumptions
Clearcut with standards	High Probability	Objective is for low density of red pine or relying on supplemental planting.	Narrow strips/patches will limit growth/survival at edges - opening should be greater than 2 tree heights across.
Clearcut - seedtree	High Probability	Objective is for low density of red pine OR Able to time harvest with a good/bumper seed year OR Relying on supplemental planting	
Shelterwood - uniform	High Probability	Apply principles from the tree marking guide.	
Shelterwood - strip/group	High Probability	Apply principles from the tree marking guide.	
Shelterwood - irregular	High Probability	1) Objective is for low density of red pine regeneration. 2) Apply principles from the tree marking guide.	Application normally limited to sites where multi-aged structure is preferred and return harvest is unlikely. Regeneration will be limited to openings.
Selection - individual	Not Recommended		Inadequate light for development beyond sapling/pole stage.
Selection - group	Low Probability		Inadequate light for development beyond sapling/pole stage.

Target Species: *Red Pine*

Pre-harvest treatments

	Designation	Conditions	Comments and Assumptions
Chemical	High Probability		Not a common practice.
Prescribed Burn	High Probability	Burn indices must be consistent with harvest and regeneration objectives.	Presence of ladder fuels (e.g. balsam fir) may lead to loss of mature trees and future seed source.
Site Preparation	High Probability		Harvest likely required shortly (1-2 yrs) after germination to provide adequate light levels for seedling development.
Planting	Low Probability		Pre-harvest stand unlikely to have adequate light for seedling development

Logging method

	Designation	Conditions	Comments and Assumptions
Cut-to-length	High Probability		
Tree length	High Probability		Long log lengths increase the risk of damage while skidding.
Full tree	High Probability	Not acceptable for shelterwood removal harvests or uneven-aged management.	Long log lengths and intact crowns increase the risk of damage - large limbs may need removal.

Target Species: *Red Pine*

Site Preparation

	Designation	Conditions	Comments and Assumptions
Mechanical	High Probability		
Chemical	High Probability		
Prescribed Burn	High Probability	Timing of application and burn indices must be consistent with regeneration objectives.	Burned seedbeds that eliminate most of the duff/litter layer are ideal for germination. Advanced regeneration will be eliminated.

Regeneration

	Designation	Conditions	Comments and Assumptions
Advance	High Probability	Objective is for low density of red pine or supplemental regeneration will be used.	
Natural seed	High Probability		Lack of seed outside good and bumper seed years may restrict this option. Seedbed preparation will increase success. May require supplemental planting to achieve
Vegetative (coppice)	Not Recommended		Red pine does not regenerate vegetatively
Planting	High Probability		
Seeding	High Probability		

Target Species: *Red Pine*

	Designation	Conditions	Comments and Assumptions
Cleaning			
Manual/mechanical	High Probability		
Chemical	High Probability		
Midstory/Improvement	High Probability		May be required to maintain desired light levels and eliminate undesirable seed sources. Assumes stem selection will be consistent with a future red pine stand.
Spacing			
PCT / crop tree	High Probability		Refer to density management diagrams.
Commercial thinning	High Probability		Refer to density management diagrams.

Suggested management approach – red pine

Option 1 – Uniform Shelterwood (two to three cuts): Objective is the renewal of an even-aged red and white pine-dominated forest

- Commonly applied to red pine when it is growing as an associate of white pine and other species adapted to even-aged management (He, Sr, Sw, Ow, Hi, Aw, Cb, By). Combined basal area is ideally ≥18 m^2 but may be successful as low as 12 m^2 if uniformly distributed. The amount of red pine present and species retention preferences will influence the density of red pine in the regenerating stand.
- Also used in red pine-dominated forests where rugged or rocky conditions make follow-up silviculture treatments difficult.
- When red pine is growing in these conditions refer to the suggested management approach for white pine uniform shelterwood as the basis of an approach. More light during the regeneration phase (40 to 50% canopy closure of dominant-codominant crop tree species) and a more rapid removal cut (typically 10 years after the regeneration cut, when red pine regeneration is sufficiently stocked and ≥ 1 meter in height), than a typical white pine shelterwood may be required to avoid losing the less tolerant red pine regeneration.
- Best success of natural regeneration can be expected under the following optimal conditions:
    - nearly pure red pine and white pine pre-harvest stand composition
    - dry, coarse textured soils or shallow soil with low competition
    - scarification is used to enhance mineral soil exposure
- Where optimal conditions are not present, planting is normally required as the primary or supplemental source of red pine renewal.

Option 2 – Clearcut Plant: Objective is the renewal of an even-aged red pine-dominated forest

- Normally applied to upland stands on sites with deep, dry to fresh, coarse textured soils where the potential for post-harvest competition from hardwoods (Po, Bw), shrubs (raspberry, beaked hazel, mountain maple, alder, pin cherry), and herbs (grass) is low.
- Mechanical SIP is usually required to increase the number and distribution of suitable planting spots. Site preparation can also help to set the stand up for future density regulation.
- Areas to be planted ideally have all-season access to facilitate cost-effective planting operations.
- Planting densities can be as high as 2000-2400 stems/ha on very clean sites (i.e. few residual trees, low slash, deep soils, etc) to a more typical 1200-1800.

- Planted seedlings require early competition control for full sunlight and open growing conditions. Survey for tending the year of planting and if necessary, schedule release (i.e. herbicide) as early as one year post-planting for overwinter crop (spring plant) seedlings and two years for current crop (summer plant) seedlings.

Option 3 – Clearcut with seedtree: Objective is regeneration of red pine ranging from dominant condition to a moderate component in a matrix of other species.

- Typically applied to red pine dominant stands, or stands with lower component of red pine (4 to 12 m^2 BA) but insufficient associates (Pw, He, Sr, Sw, Ow, Hi, Aw, Cb, By) to support a shelterwood approach.
- More successfully on dry to fresh, coarse textured soils where the potential for post-harvest competition is low. Retain 10 to 35 (tree length bole spacing) well distribute seed trees per hectare.
- Site preparation can improve success but open mineral soil in exposed environments is prone to surface drying.
- Moderate to high density can be achieved when timing harvest with good or bumper seed years. Supplemental planting very likely required where natural seed is limited (amount or viability).
- Open growing conditions will require early and regular competition control.

5.1.23 Eastern White Pine

White pine (*Pinus strobus*) is mid-tolerant of shade, regenerates exclusively from seed, is adapted to frequent ground fires, and can be very long-lived. White pine can tolerate a wide variety of soils, grows best on fresh to moist loams, and does poorly on heavy clays and saturated soils. Although growth is best on deep loams, more often white pine is found on drier coarse or shallow soils where competition is lower. Good seed years are generally 3-5 years apart with bumper crops every 10-12 years. Concentrations of white pine are typically managed through the shelterwood silviculture system with lower densities managed through clearcut with seedtrees. White pine blister rust and white pine weevil can significantly influence survival and quality.

Keys to success:

- Prepared seedbed (mineral or humus/mineral mix) timed with a good seed year when targeting natural regeneration.
- Early, aggressive, and frequent vegetation management
- 40% to 60% light maintained through successive overstory removals.
- Ensure harvest schedule (e.g. 2 vs 3 cut) is realistic based on current growing stock and influence of operational realities (clumpiness, harvest schedule of surrounding forest, etc) on ability to finish subsequent cuts

Cautions:

- Open grown white pine is highly susceptible to damage from white pine weevil.
- In high-hazard blister rust areas, consider diversifying the regeneration by mixing in red pine, white spruce or other desirable species
- Mid-story stems (e.g. maple, ironwood, beech, birch, balsam fir) must be removed to meet overstory canopy closure objectives and provide adequate light
- High density natural regeneration can be difficult to achieve and requires optimal conditions (nearly pure PWR pre-harvest, 60% canopy closure after regeneration cut, dry coarse textured soils – see suggested management approach for details).

Recommended reading:

- White pine blister rust and white pine weevil Management: Guidelines for white pine in Ontario. (Hodge et al 1989)
- Annotated Bibliography of Eastern White and Red Pine 1960–2007. (Burgess, 2011)

Target Species: *Eastern White Pine*

Silviculture systems and harvest method

	Designation	Conditions	Comments and Assumptions
Clearcut with standards	High Probability	Objective is for low density of white pine or relying on supplemental planting to achieve moderate density.	Application normally limited to stands with low pre-harvest white pine composition. Damage from weevil and blister rust may be significant. Planting very likely required.
Clearcut - seedtree	High Probability	Objective is for low density of white pine or relying on supplemental planting to achieve moderate density.	Application normally limited to stands with low pre-harvest white pine composition. Damage from weevil and blister rust may be significant. Planting very likely required.
Shelterwood - uniform	High Probability	Apply principles from the tree marking guide.	Planting likely required. Natural regeneration more likely when nearly pure PWR pre-harvest, 60% canopy closure after regeneration cut, and dry coarse textured soils with
Shelterwood - strip/group	High Probability	Apply principles from the tree marking guide.	Strip width should be less than 2 tree heights. Damage from weevil may be significant. Planting very likely required.
Shelterwood - irregular	High Probability	1) Objective is for low to moderate density of white pine regeneration. 2) Apply principles from the tree marking guide.	Application normally limited to sites where multi-aged structure is preferred and return harvest is unlikely. Development beyond sapling/pole stage will be limited to
Selection - individual	Not Recommended		Inadequate light for development beyond sapling/pole stage will be limited to openings.
Selection - group	High Probability	1) Objective is for low density of white pine regeneration. 2) Apply principles from the tree marking guide.	Application normally limited to hardwood stands with white pine regeneration and where follow up treatments can be applied.

Target Species: *Eastern White Pine*

Pre-harvest treatments

	Designation	Conditions	Comments and Assumptions
Chemical	High Probability		Not a common practice.
Prescribed Burn	High Probability	Burn indices must be consistent with harvest and regeneration objectives.	Presence of ladder fuels (e.g. balsam fir) may lead to loss of mature trees and future seed source.
Site Preparation	High Probability		White pine seedlings can tolerate heavy shade but growth is poor and release required within a few years to ensure survival.
Planting	High Probability		White pine seedlings can tolerate heavy shade but growth is poor and release required within a few years to ensure survival.

Logging method

	Designation	Conditions	Comments and Assumptions
Cut-to-length	High Probability		
Tree length	High Probability		Long log lengths increase the risk of damage while skidding.
Full tree	High Probability	Not acceptable for shelterwood removal harvests or uneven-aged management.	Long log lengths and intact crowns increase the risk of damage - large limbs may need removal.

Target Species: *Eastern White Pine*

Site Preparation

	Designation	Conditions	Comments and Assumptions
Mechanical	High Probability		
Chemical	High Probability		
Prescribed Burn	High Probability	Timing of application and burn indices must be consistent with regeneration objectives.	Advanced regeneration will be eliminated.

Regeneration

	Designation	Conditions	Comments and Assumptions
Advance	High Probability		
Natural seed	High Probability		Seedbed preparation will increase success. May require supplemental planting to achieve higher densities.
Vegetative (coppice)	Not Recommended		White pine does not regenerate vegetatively.
Planting	High Probability		
Seeding	High Probability		Limited experience but some documented successes.

Target Species: ***Eastern White Pine***

	Designation	Conditions	Comments and Assumptions
Cleaning			
Manual/mechanical	High Probability		
Chemical	High Probability		
Midstory/Improvement	High Probability		May be required to maintain desired light levels and eliminate undesirable seed sources. Assumes stem selection will be consistent with a future white pine stand.
Spacing			
PCT / crop tree	High Probability		Responds well to release if sufficient live crown.
Commercial thinning	High Probability		

Suggested management approach – white pine
(Note: all canopy closure references refer to measurements taken with a densiometer)

Option 1 – Uniform Shelterwood (two to four cuts): Objective is the renewal of an even-aged white pine-dominated forest

Overall comments

- Normally applied to uncut stands (no harvest or major disturbance in last 40 years) with a uniformly-distributed minimum component (basal area >=12 m^2/ha) of dominant/co-dominant white pine and other common associates adapted to even-aged management. These include red pine, red oak, white oak, hemlock, red spruce, white spruce, and hickory. (Re-entry into stands that have had a previous shelterwood harvest is addressed under option five).
- Best results are when ≥12m^2/ha of uniformly-distributed white pine with a combined basal of white pine and common associates totaling ≥18 $m^{2/}$ha can be retained after the regeneration cut.
- Depending upon overstory quality, initial stand stocking, presence and height of advanced regeneration and size and accessibility of the treatment unit, two to four harvest cuts will be scheduled over a period of 20 to 40 years.
- Stands designated for white pine management require regular observations of regeneration establishment and timely tending treatments and removal cuts.
- Conditions within a stand (species composition, crown size, BA, presence of regeneration, competition, etc.) can be quite variable and may require stratification into separate treatment units. Treatment units should be of a manageable/ trackable size to facilitate efficient renewal, tending, and future allocation for harvest. This may require sub-optimal treatment of some areas based on a pragmatic approach to the whole.
- Logistical considerations may influence the size of a treatment unit and the choice of one or two removal cuts (e.g. distance from major road, access, characteristics and stage of management of stands surrounding the treatment unit).
- For white pine regeneration cuts, tree marking within treatment units should maintain stand uniformity to help ensure predictable volumes from future harvests and to ensure uniform growth of regeneration. However, non-uniform strategies may be prescribed to manage for other associate species (e.g. low stocked portions can be managed to regenerate less shade tolerant red pine in more open areas), however, this should be consistent with the overall objective for the stand.
- Trees to favor for retention in shelterwood harvests are dominant-codominant crop trees with vigorous seed-producing crowns (recognizing that stands may have pockets of vigorous polewood and small sawlog sized trees of target species that are younger than codominants and that may be retained for future growth).
- Priority crop tree species to retain are white/red pine, red/white oak, hemlock, red/white spruce, hickory.
- Thinning from below, timely competition control, and timely return cuts are paramount to achieving success (Pitt et al, 2011).

Preparatory cut

- Normally applied in younger stands (60-80 years) with high BA (ideally ≥ 30m^2/ha), reasonably even distribution of compatible species, little to no advance regeneration, and small narrow crowns.
- Goal is to develop large seed producing crowns and prepare the stand (quality, spacing, composition, etc.) for future shelterwood harvest entries.
- Target 50% to 60% canopy closure post-harvest.
- Not suitable for older or open grown stands, where crown response potential is limited or unnecessary, or on high competition sites.
- In practice, preparatory cuts are not common.

Regeneration Cut

- Normally applied in stands 80+ years old with little or very patchy distribution of advanced regeneration and a sufficient basal area of dominant-codominant crop species to meet post-harvest residual targets.
- Goal is to establish regeneration in partial shade to optimize establishment and height growth of white pine regeneration while reducing potential growth losses to weevil, competing vegetation and mortality from blister rust (OMNR, 1998).
- Depending upon initial stand stocking and merchantable volume, the uniformity of dominant-codominant white pine distribution, the regeneration method, and logistical considerations (e.g. size of treatment unit, distance from major road, access, characteristics and stage of management of stands surrounding the treatment unit), one or two removal cuts will be scheduled.
- For example in some areas of the province two removal cuts are only scheduled when the following stand level conditions are encountered (2011-2021 Forest Management Plan, Ottawa Valley Forest):
    - Merchantable volume (all species) greater than or equal to 150 m3/ha
    - Pre-regeneration cut Pw, Or, Pr, He, Sw in a dominant or co-dominant crown position uniformly distributed greater than or equal to 16 m2/ha of basal area or
    - Pre-regeneration cut Pw, Or, Pr, He, Sw in a dominant or co-dominant crown position non-uniformly distributed greater than or equal to 20 m2/ha of basal area
- One removal cut is often scheduled in stands that have lower overall stocking and merchantable volume. This might include stands that received a regeneration cut within the last 30 years and require retreatment, rocky sites with natural low stocking, or mixedwood sites with a lower white/red pine component. Site preparation, artificial regeneration, and/or tending will be likely be needed to ensure regeneration establishment.
- For stands scheduled for 2 removal cuts (see decision key), the regeneration cut should target 50% to 60% canopy closure of dominant-codominant crop tree species which will provide light levels at ground level of 45 to 53% of full sunlight (Parker, in prep). Depending upon the forest age and composition, this will correspond to a

basal area from 14 to 18 m^2/ha and from 100 to 120 stems per hectare. This can generally be achieved by retaining crop trees at ½ to ⅓ crown spacing.
- For stands scheduled for 1 removal cut (see decision key), the regeneration cut should target 40% to 50% canopy closure of dominant-codominant crop trees species which will provide light levels at ground level of 53 to 61% of full sunlight (Parker, in prep.) Depending upon the forest age and composition, this will correspond to an average basal area of 10 to 12 m^2/ha and from 55 to 80 stems per hectare. This can generally be achieved by retaining crop trees at 1/2 to 2/3 crown spacing.
- Best results occur when a uniform basal area is maintained within the stand, although minor variations from overall stand targets can occur in pockets.
- Depending on the species of competing vegetation, lower retention levels may generate the need for more intensive tending requirements.
- Mid-story stems (e.g. maple, ironwood, beech, birch, balsam fir) must be removed (thin from below) to meet overstory canopy closure objectives and provide adequate light for the growth of white pine regeneration (Pitt et al, 2011).
- Seed germination is best on moist mineral soil or mineral soil humus mix (Smith 1951; Herr et al. 1999; Duchesne et al. 2000). Removal of thick duff through prescribed burning, mechanical site preparation, or skidding during harvest will improve establishment. Timing of harvest and/or site preparation with a good seed year will increase probability of success (Burgess et al 2000, Pitt et al 2011). If chemical site preparation is required in conjunction with mechanical site preparation, mechanical site preparation should be planned one year before a forecasted seed year to allow effective chemical treatment prior to germinant establishment.
- On high competition sites, the benefits of mechanical site preparation can be enhanced by following up with chemical site preparation (Burgess et al, 2000). Best results are achieved when there is a one year delay between the application of mechanical and chemical site preparation. Conversely, a chemical site preparation (ABS) in mid-summer followed by mechanical site preparation in September has shown good results (Heckman, 1992) except on moist, fertile sites with a large number of seed banking species (e.g. raspberry, blackberry, pin cherry, field bindweed). Best results occur when herbicide application and scarification treatments are done prior to majority of seed fall (timing may be difficult).
- Best success of natural regeneration can be expected under the following optimal conditions:
    - nearly pure white pine and red pine pre-harvest stand composition
    - approximately 60 % crown closure remains following harvest
    - dry, coarse textured soils or very shallow soil with low competition (understory dominated by bracken fern and moss with low abundance of broadleaf herbs and shrubs)
- Where optimal conditions are not present, planting is normally required as the primary or supplemental source of white pine renewal.
- Timely control of competition around established seedlings is often required more than once.

First Removal (Release Cut)

- Normally applied when regeneration is well-stocked, 30 cm to 1 m in height, and/or light levels at ground level are less than 40% sunlight. This may include stands with adequate advanced regeneration and no previous shelterwood entry.
- Goal is optimize height growth of white pine regeneration while reducing potential growth losses to weevil, competing vegetation and mortality from blister rust (OMNR, 1998).
- Target 40% to 50% canopy closure of dominant-codominant crop trees species which will provide light levels at ground level of 53% to 61% of full sunlight (Parker, in prep.) Depending upon the forest age and composition, this will correspond to an average basal area of 10 to 12 m^2/ha and from 55 to 80 stems per hectare. This can generally be achieved by retaining crop trees at 1/2 to 2/3 crown spacing.
- Delayed first removal may increase damage during harvest, and may lead to a decline in the vigour and amount of white pine regeneration over time as the environment becomes more shaded, making them less responsive upon the later release. Generally, release response is poor when the live crown is less than 30% of total height (Horton 1962, Wendel and Smith 1990) or when height growth before release is lower than 3 cm per year (Berry 1982). A rule of thumb used by some foresters in central Ontario is that release response is poor when average annual height growth is less than 10 cm.
- There is a high probability of obtaining a well-stocked (80%), pine dominated (60% white pine + red pine) stand on a medium productivity site if there are more than 600, >30 cm tall or more than 500, >1 m tall white pine seedlings per hectare of productive ground after harvest. Seedlings must be healthy, well-distributed, vigorous, and relatively free of competition, i.e. in a dominant-codominant position relative to other understory vegetation (Pinto et al, in prep).
- Forecast stocking levels must account for seedling/sapling losses during harvest.
- Careful logging practices (including advance trail layout, directional felling, and maximizing distance between extraction trails) will be required to reduce damage to regeneration during harvest.
- Apply timely control of competition around established seedlings.

Final Removal Cut

- Normally applied when a significant amount of regeneration reaches 5-6m and exceeds minimum stocking levels. This may include stands with adequate advanced regeneration and no previous shelterwood entry and stands with multiple-sized regeneration that need a release.
- Retain residual trees for wildlife habitat (e.g trees with cavities) and ecological reasons (e.g veteran trees) as prescribed in Stand and Site Guide.
- There is a high probability of obtaining a well-stocked (80%), pine dominated (60% white pine + red pine) stand on a medium productivity site if you have more than 330, 5+ m tall white pine saplings per hectare of productive ground after harvest. Saplings must be healthy, well-distributed, vigorous, and relatively free of competition, i.e. in a dominant-codominant position relative to other understory vegetation (Pinto et al, in prep).

- Careful logging practices (including advance trail layout, directional felling, and maximizing distance between skid trails) will be required to reduce damage to regeneration during harvest.
- Forecast stocking levels must account for seedling/sapling losses during harvest.
- If regeneration is not stocked to FMP standards before harvest, supplemental treatments such as scarification, planting or tending must occur after the harvest operation.

Option 2 – Clearcut with seed trees: Objective is maintain or increase the white pine component in a matrix of other species.

- Normally applied to stands with a lower pre-harvest component (4 to 12 $m^{2/}$ha BA) of dominant-codominant white pine and other crop species.
- The management objective may be a white pine dominated forest, white pine mixed-wood, or another species forest type with a minor white pine component, depending upon the site potential including ecosite, stand composition, and likelihood of white pine weevil/ blister rust.
- Retain an average of 15 to 35 seed trees per hectare.
- Best results for establishing a component of natural white pine regeneration are when associated conifer species are planted. Mechanical site preparation and effective competition control treatments used to successfully establish jack pine or red pine, for example, will also promote favorable conditions (mineral seedbed, competition control) for the natural establishment of white pine from seed trees.
- If a white pine component of >10% is desired, planting of white pine will certainly be required.
- Will likely have a higher incidence of white pine weevil and white pine blister rust.
- Blister rust may be mitigated in part through effective competition control and careful site selection (avoid areas of poor air flow, richer sites tend to have more *Ribes* and blister rust) (Hodge et al, 1989).
- Mixed plantings of white pine with red/jack pine, white/red/black spruce, and/or red oak can compensate for blister rust-related mortality. In areas with a very high blister rust hazard rating, plant other species.

Option 3 – Clearcut, restoration: Objective is to create an even-aged white pine-dominated forest on a suitable site

- Normally applied to stands with a very low pre-harvest component (<4 $m^{2/}$ha BA) of dominant-codominant white pine and other crop tree species (red pine, red/white oak, hemlock, red/white spruce, hickory).
- Typical sites where this has applied are sites that are believed to be have been occupied by white pine in the past, based on local knowledge, on-site evidence (charred white pine stumps/snags, large white pine stumps, large residual pine scattered on the site) historical white pine distribution, or where the quality of the site

appears to be better-suited to white pine than to the species that is currently on the site (e.g. off-site poplar).

- Retain residual trees for wildlife habitat (e.g trees with cavities) and ecological reasons (e.g veteran trees) as prescribed in Stand and Site Guide.
- Will likely have a higher incidence of white pine weevil and white pine blister rust.
- Planting of white pine will be required to ensure objective is met.
- Weevil may be mitigated in part by maintaining high stocking (2,000 + crop trees/ha) and/or using a nurse crop. An example of a nurse crop might be to encourage a target number (e.g. 400-500/ha) of faster growing tree species (e.g. trembling aspen, pin cherry, planted red pine) to allow 40% to 60% full sunlight to the white pine terminal bud, keeping it thin, yet not reducing height growth or causing mechanical damage to the leader. Remove when white pine has reached 6 m in height (Szuba and Pinto 1991)
- Blister rust may be mitigated in part through effective competition control and careful site selection (avoid areas of poor air flow, richer sites tend to have more *Ribes* and blister rust) (Hodge et al, 1989).
- Mixed plantings of white pine with red/jack pine, white/red/black spruce, and/or red oak can compensate for blister rust-related mortality. In areas with a very high blister rust hazard rating, plant other species.
- This objective may not be achievable in areas with a very high blister rust hazard rating.
- Mechanical site preparation and effective competition control will encourage a small component of white pine to establish naturally from seed trees.

Option 4 – Commercial thinning

- Normally applied to higher density younger stands (~35 to 80 years), including plantation origin or stands where juvenile spacing (density regulation) occurred. Can be applied in older stands (90-120 years old) on productive sites that support high MAI’s into the older age classes.
- Commercial thinning at later stages enhances crown development like a preparatory cut for subsequent shelterwood harvests.
- On productive sites a residual crown closure of 60% to 70% is required to moderate competition from shade tolerant species.
- Follow direction in Appendix 4: Best practices for commercial thinning.

Option 5 – Rehabilitation of failed shelterwood cuts.

- Some stands that were managed under the shelterwood system received a regeneration cut, but for a variety of reasons (not timing site preparation during a bumper seed crop, lack of tending, poor thinning from below, excessive windthrow, poor regeneration establishment, poor access, other values limiting treatments, etc.) regeneration efforts did not succeed. These stands are often poorly stocked and may have residual dominant/codominant overstory of white pine and associated species and a well-established understory of non-crop species (red maple, poplar, balsam fir, white birch, beaked hazel, etc.). These stands may also have a well-developed mid-story of non-crop species if not thinned from below during the regeneration cut.

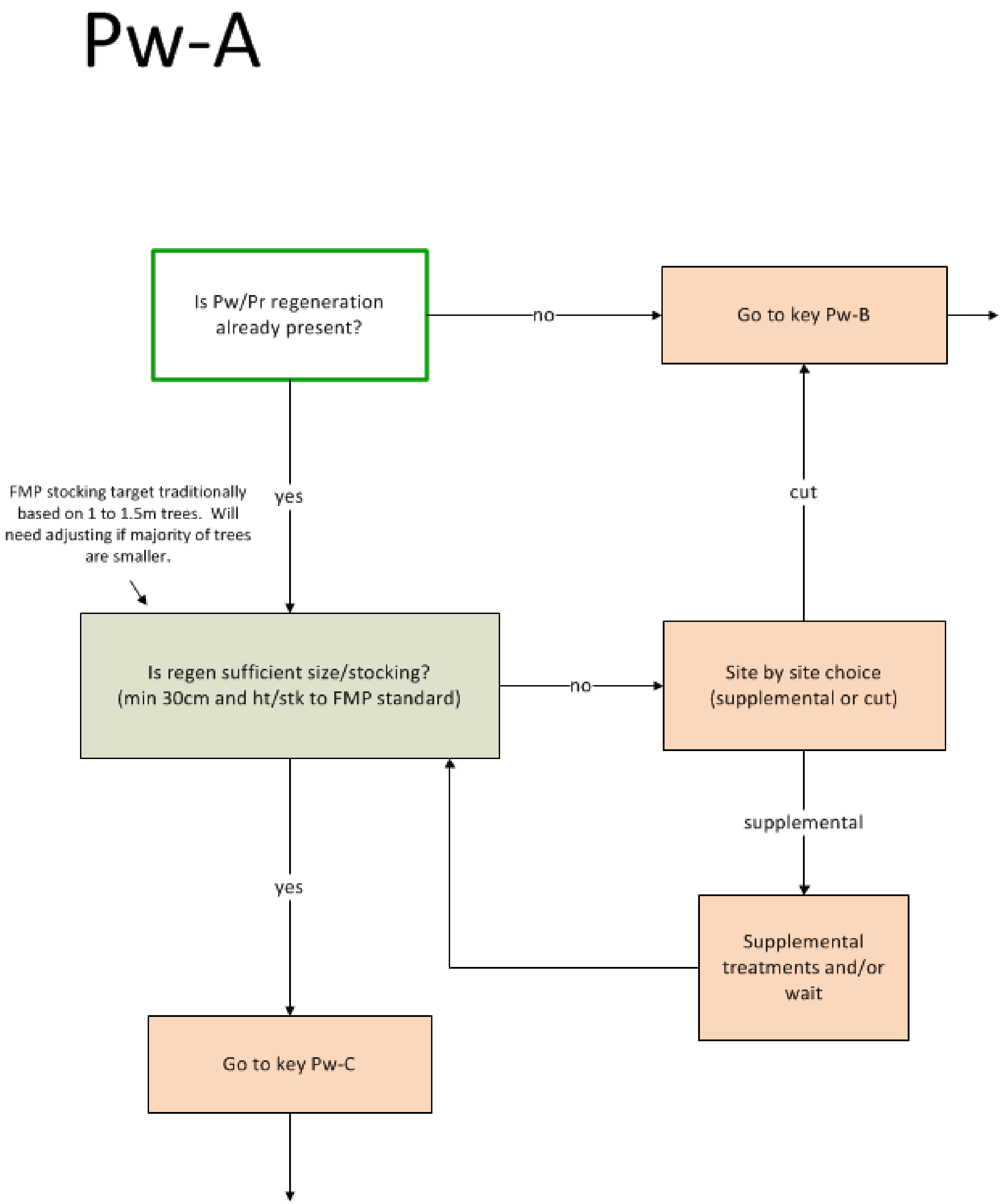
- A number of approaches have been used to rehabilitate these stands, depending on overstory conditions, available resources, and permitted treatment options.
    - Overstory dominant/co-dominant white pine and associated species are well distributed and well-stocked (average of ≥ 18 m^2/ha): the stand is a candidate for continued shelterwood management. It can be treated as described previously under option one, regeneration cut with one removal cut. Mechanical and/or chemical site preparation, natural regeneration (if appropriate conditions are met - see option 1) or artificial regeneration (white pine with or without one or more associated species), and/or tending will be needed to ensure regeneration establishment.
    - Overstory dominant/co-dominant white pine and associated species are poorly stocked (average < 18 m^2/ha):
        - if initial stocking levels are 14 – 16 m^2/ha and well-distributed, a residual target of 30% to 40% canopy closure may be achieved with 2/3 to full crown spacing.
        - if initial stocking levels are 14 – 16 m^2/ha but the patchy distribution of the overstory will not allow a residual target of 30% to 40% canopy closure, or if initial stocking <= 12 m^2/ ha, the clearcut with seed trees option described previously may be applied.
        - For all scenarios mechanical and/or chemical site preparation, planting of white pine (with or without one or more associated species), and tending will be required.
    - If the forest manager determines that the overstory canopy closure is currently suitable for regeneration and growth of white pine and resources are available, they may consider the removal of mid-story and understory vegetation using chemical/mechanical methods but no harvest of merchantable stems. Mechanical and/or chemical site preparation, natural regeneration (if appropriate conditions are met - see option 1) or artificial regeneration (white pine with or without one or more associated species), and tending will be needed to ensure regeneration establishment.

Commentary on white pine mixtures (red pine, red oak, hemlock, white spruce)

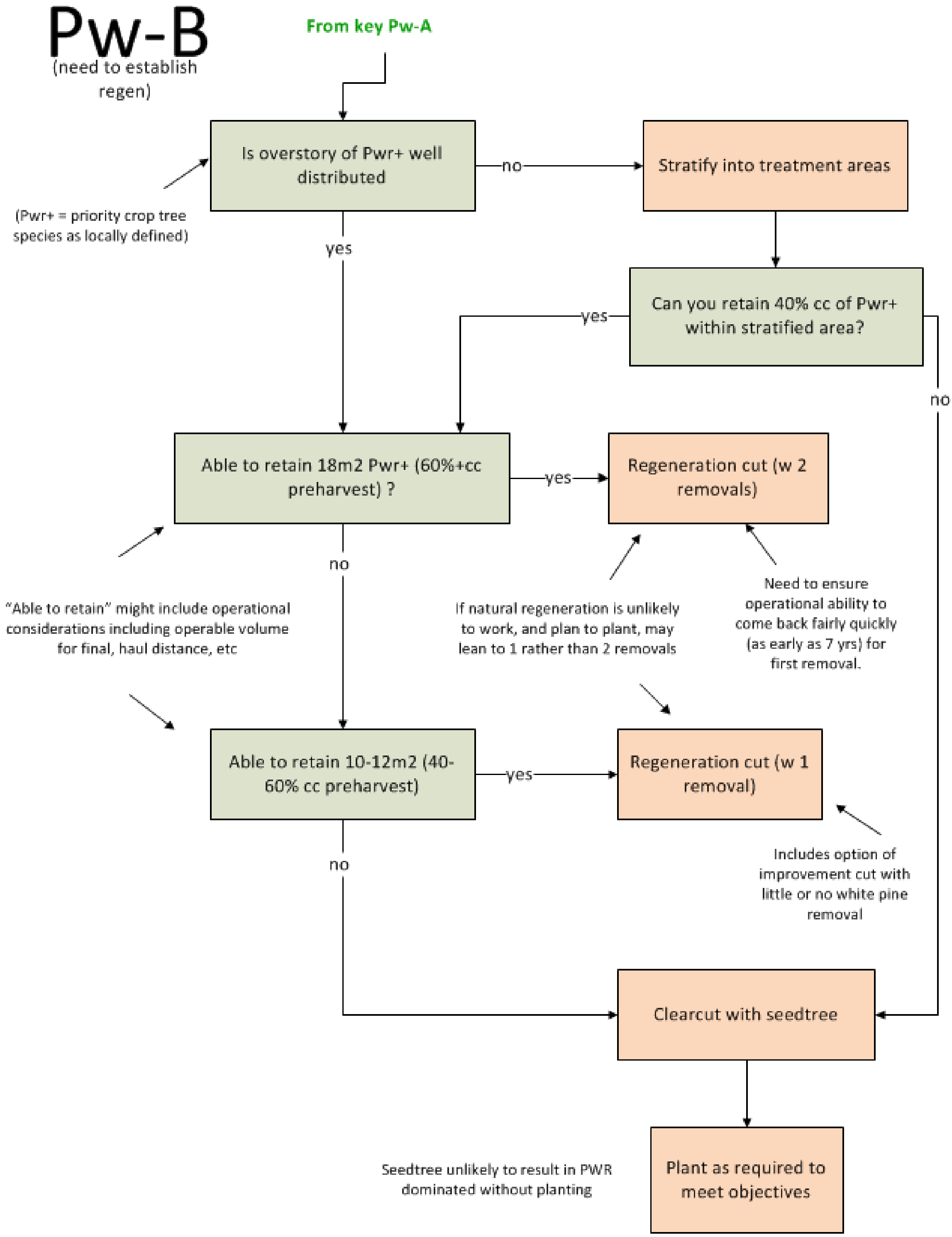
The direction for white pine management presented here is aimed largely at actively regenerating white pine as the target species. However, many "white pine" forests of Ontario are comprised of other desirable species which could and should be accommodated in silvicultural regeneration strategies of the forest as may be reflected in forest management plans. Red pine is often a close cohort of white pine and is linked with white pine in both thresholds for silvicultural decisions (e.g. the combined stocking of white and red pine) and provincial policy.

Red pine does show some shade tolerance when very young but is generally considered a shade intolerant species. As such, in non-uniform white pine stands, marking and supplemental treatments can favor red pine in parts of the stand where white pine stocking is very low while white pine remains the primary target species in areas where white pine provides a relatively well stocked and uniform overstory. The regeneration of species such as spruce, oak and hemlock might also be accommodated through silvicultural planning within white pine stands according to the specific needs of those species. Therefore, the direction on white pine management can and should be modified to accomplish forest management planning objectives of regenerating multiple species in appropriate white pine stands.

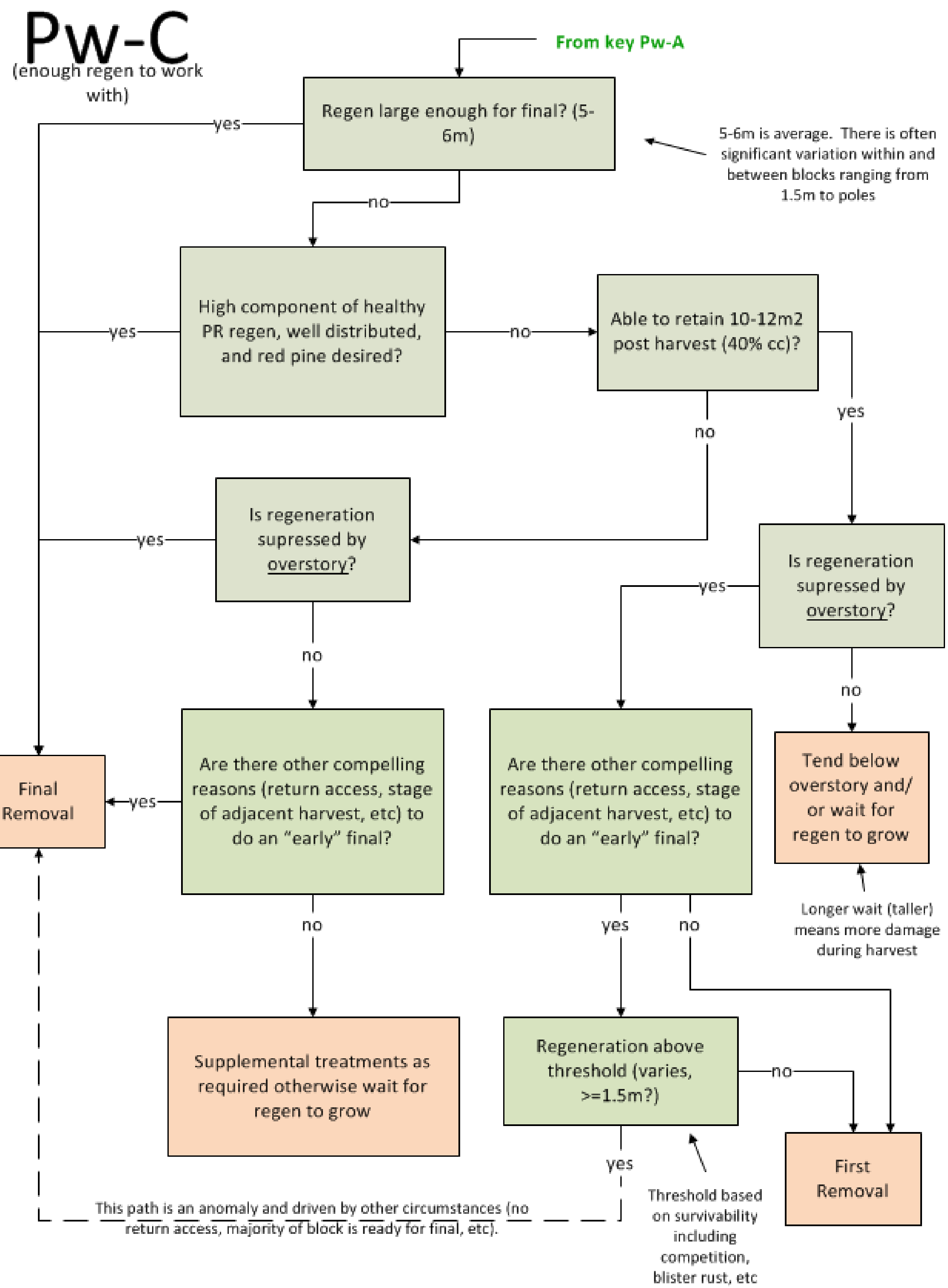
Suggested decision key when determining the appropriate management approach for eastern white pine (part A). Assumption is white pine regeneration objective and no recent (~20 years) harvest.



Suggested decision key when determining the appropriate management approach for eastern white pine (part B).



Suggested decision key when determining the appropriate management approach for eastern white pine (part C).



5.1.24 Eastern White Cedar

Eastern white cedar (*Thuja occidentalis*) is shade tolerant, more common in late successional forests, and can be even, multi or uneven aged. It can tolerate a wide range of sites from dry uplands to deep organics but grows best on moist calcareous soils with moving water and good aeration. Regeneration is from both seed and layering, with layering more common on low lying organics. Germination and establishment requires sustained moisture and is poor on drought prone or saturated substrates. Hummocky terrain can moderate moisture conditions when water table is high (e.g. lowlands) but prone to summer drying on upland sites. Once established, seedlings and layers can tolerate shade for prolonged periods and respond well to eventual release. Height growth is best in moderate light but shoot/root weights are maximized in full sunlight. Presence of deer or high incidence of hare can significantly reduce regeneration. Eastern white cedar is typically managed through shelterwood or strip clearcut silviculture systems.

Keys to success:

- Maintain shade (e.g. 30-50% full sunlight) during regeneration phase to limit establishment and growth of competitors and maintain moisture.
- Actively reduce competition from faster-growing competitors.
- Select sites with telluric drainage to ensure adequate aeration.
- Protect decayed logs and stumps during scarification and site prep.

Cautions:

- Presence of deer or high incidence of hare will significantly reduce regeneration.
- Apply careful logging practices to protect advance regeneration on all sites and avoid site damage on moist mineral and organic sites.
- Susceptible to blowdown, particularly in areas with a high water table and following partial harvest.
- Avoid sites expected to “water up” for prolonged periods following harvest.
- High amounts of slash can limit regeneration potential.
- Plan for a prolonged recruitment period on lowland sites.

Recommended reading:

- Silvicultural practices for eastern white cedar in boreal Ontario (Buda et al 2011)
- Silvicultural guide for northern white cedar (USDA 2012)

Target Species: ***Eastern white cedar***

Silviculture systems and harvest method

	Designation	Conditions	Comments and Assumptions
Clearcut with standards	High Probability	1) Objective is for low density of cedar, OR 2) Strip width less than 1 tree height, OR 3) Adequate advanced regeneration can be protected	Open conditions often lead to drying out of substrate and/or high levels of competition. Post-harvest watering up is common and can limit regeneration.
Clearcut - seedtree	High Probability	Objective is for low density of cedar OR able to protect adequate advanced regeneration to achieve higher density.	High risk of windthrow. Site prep may be required. See comments on clearcut with standards.
Shelterwood - uniform	High Probability	Apply principles from the tree marking guide.	Fulltree logging may cause excessive damage to regeneration.
Shelterwood - strip/group	High Probability	Apply principles from the tree marking guide.	Control of competing vegetation, particularly hardwoods, is critical to success.
Shelterwood - irregular	High Probability	Apply principles from the tree marking guide.	Application normally limited to sites where multi-aged structure is preferred and return harvest is unlikely.
Selection - individual	High Probability	Apply principles from the tree marking guide.	Caution required to avoid degrading the stand when choosing trees for harvest and retention.
Selection - group	High Probability	Apply principles from the tree marking guide.	Suggested group size of 1/2 tree height well distributed and covering <20% of stand.

Target Species: *Eastern white cedar*

Pre-harvest treatments

	Designation	Conditions	Comments and Assumptions
Chemical	High Probability	Chemical must be applied in a selective fashion or with an active ingredient and/or rate that is not damaging to cedar.	Not a common practice.
Prescribed Burn	Low Probability	Burn indices must be consistent with harvest and regeneration objectives.	Thin bark, shallow roots, and low crowns will very likely lead to loss of mature trees and future seed source.
Site Preparation	High Probability		Not a common practice
Planting	High Probability		Not a common practice.

Logging method

	Designation	Conditions	Comments and Assumptions
Cut-to-length	High Probability		
Tree length	High Probability		
Full tree	High Probability	Not acceptable for shelterwood removal harvests or uneven-aged management.	May cause excessive damage to regeneration.

Target Species: *Eastern white cedar*

Site Preparation

	Designation	Conditions	Comments and Assumptions
Mechanical	High Probability		
Chemical	High Probability		Assumes chemical will be applied in a selective fashion or with an active ingredient and/or rate that is not damaging to cedar.
Prescribed Burn	High Probability	Timing of application and burn indices must be consistent with regeneration objectives.	Advanced regeneration will be eliminated.

Regeneration

	Designation	Conditions	Comments and Assumptions
Advance	High Probability		
Natural seed	High Probability		Seedbed preparation will increase success. May require supplemental planting to achieve higher densities.
Vegetative (coppice)	Not Recommended		White cedar will layer to produce advanced regeneration, but does not regenerate from coppice.
Planting	High Probability		Not a common practice.
Seeding	High Probability		Not a common practice.

Target Species: *Eastern white cedar*

Cleaning

	Designation	Conditions	Comments and Assumptions
Manual/mechanical	High Probability		
Chemical	High Probability		Assumes chemical is applied in a selective fashion or with an active ingredient and/or rate that is not damaging.
Midstory/Improvement	High Probability		May be required to maintain desired light levels and eliminate undesirable seed sources. Assumes stem selection will be consistent with a future cedar stand.

Spacing

	Designation	Conditions	Comments and Assumptions
PCT / crop tree	High Probability		Better sites tend to have better response to thinning. Risk of windthrow.
Commercial thinning	High Probability		Better sites tend to have better response to thinning. Risk of windthrow.

Suggested management approaches – eastern white cedar

The following example management approaches are described when cedar is present in the pre-harvest stand and when targeting pure cedar or cedar dominated mixedwood regeneration. These approaches are largely based on the recommendations outlined in Buda *et al*. (2010).

Like all suggested management approaches included in this guide, the following suggestions should not constrain managers from exploring reasonable alternatives. While there is a reasonable comfort in the categorization (i.e. high, low, not recommended) of approaches (e.g. silviculture system and conditions) included in the management interpretation tables, the specific implementation parameters (e.g. crown closure) in the suggested management approaches below are less certain. Managers are encouraged to record as much detail as possible on site characteristics, pre-harvest condition, and the specific implementation parameters used on different sites to maximize learning potential.

Option 1 – Uniform Shelterwood: Objective is the renewal of an even-aged cedar-dominated forest

- Normally applied to upland mixedwood stands that have a cedar composition of greater than 50% and other common associates adapted to even-aged management. These include white pine, yellow birch, hemlock, and sugar maple.
- Provides moderated conditions where there is potential for surface drying and competition from shade intolerant species.
- A regeneration cut is conducted to remove poor quality and undesirable species with a post-harvest target crown closure of between 40% and 60%.
- Mechanical SIP may be required to increase receptive seedbed distribution and coverage. Especially critical on sites with heavier slash loads and thicker organic layers. SIP is ideally scheduled to occur as soon after harvest as possible or within one year of harvest to take advantage of natural ingress from cone-bearing slash and initial lower coverage of competing vegetation. Moderate site preparation that results in a uniform distribution of mixed humus and mineral soil exposure with roughly 12% - 25% coverage of ground area is suitable.
- Allow five growing seasons prior to surveying for seedling establishment. Supplemental treatments (e.g., fill planting) may be required to meet regeneration objectives.
- If necessary, schedule directed release treatments to control competing species prior to FTG age. The susceptibility of cedar to commonly used herbicides in Ontario (e.g., glyphosate) is uncertain.
- When regeneration has met FTG standards, conduct a removal cut that results in greater than 70% full sunlight conditions. Apply careful logging practices to minimize damage to regeneration.

Option 2 – Irregular Shelterwood: Objective is the renewal of a multi-aged cedar-dominated forest

- Normally applied to mixedwood stands that have a cedar composition of greater than 50% where maintenance or creation of mid- to late-successional stand characteristics is desired.
- Mark trees (by certified tree markers) for removal from all size classes with a focus on removal of undesirable seed sources and poor quality trees. Retain good quality, desirable cedar seed trees that represent the genetic diversity of the pre-harvest stand. Target less than 50% full sunlight conditions post-harvest to suppress any competing shade intolerant trees and shrubs.
- Mechanical SIP may be required to increase receptive seedbed distribution and coverage and is especially critical on sites with heavier slash loads and thicker organic layers. SIP is ideally scheduled to occur as soon after harvest as possible or within one year of harvest to take advantage of natural ingress from cone-bearing slash and initial lower coverage of competing vegetation. Moderate site preparation that results in a uniform distribution of mineral soil exposure with roughly 12 - 25% coverage of ground area is suitable.
- Allow five growing seasons prior to surveying for seedling establishment. Supplemental treatments (e.g., fill planting) may be required to meet regeneration objectives.
- If necessary, schedule directed release treatments to control competing species prior to FTG age. The susceptibility of cedar to commonly used herbicides in Ontario (e.g., glyphosate) is uncertain.
- An optional final removal cut is delayed with reserve trees retained for at least 20% of the rotation (operable age) or may be absent.

Option 3 – Group selection: Objective is the renewal of an uneven-aged cedar-dominated forest

- Normally applied to mixedwood stands that have a cedar composition of greater than 50% where maintenance or creation of mid- to late-successional stand characteristics and emulation of long fire cycles is desired.
- Preparatory treatments may be required on sites where balsam fir, hardwood, and shrub competition may inhibit cedar regeneration.
- Group openings should not exceed half of the average tree height in the stand.
- Openings should be distributed uniformly throughout the treatment area and should not exceed 20% of the stand area during each cycle.
- Supplemental treatments may be required to meet regeneration objectives. If necessary, schedule directed release treatments to control competing species. The susceptibility of cedar to commonly used herbicides in Ontario (e.g., glyphosate) is uncertain.
- Cutting cycle is likely to exceed 30 years and will depend on the rate of regeneration establishment and growth and desired future stand structure.

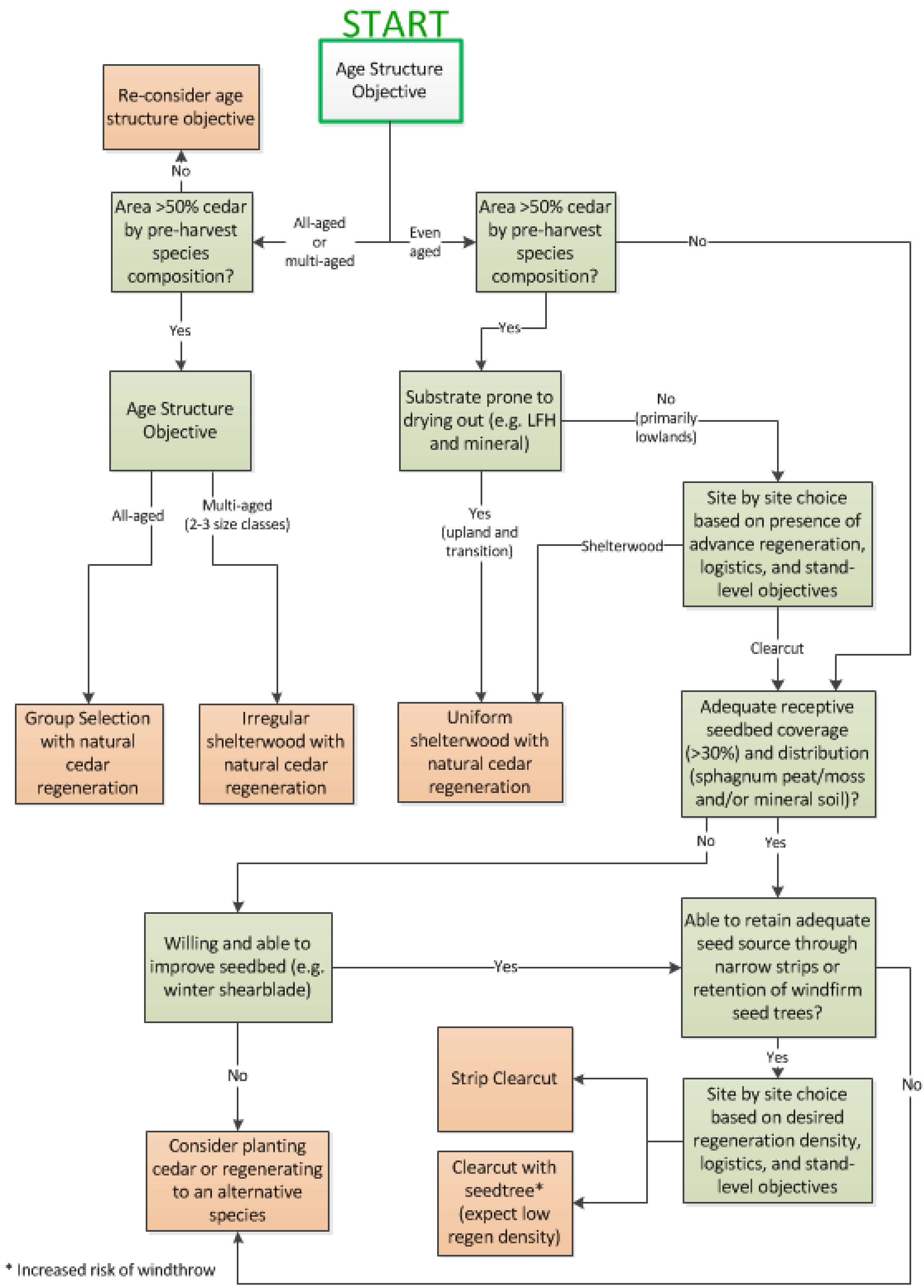
Option 4 – Clearcut Natural Seed: Objective is the maintenance of a minor cedar component in an even-aged mixedwood stand

- Normally applied to lowland stands that have a cedar composition of less than 50% where sphagnum moss and peat dominate the forest floor and where there is a low potential for post-harvest competition. The risk of windthrow of individual and small groups of residual cedar in clearcuts is high. This treatment is unlikely to be successful on upland sites where open conditions will cause surface drying.
- Windfirm individual cedar trees, groups of cedar trees or groups of cedar mixed with other species should be retained as seed bearing trees. Groups should be two tree lengths in diameter based on dominant tree height. Seed trees need to represent the genetic diversity of the pre-harvest stand.
- Winter harvest may increase amount of cone-bearing slash on the ground.
- The amount and distribution of advance growth should be assessed before harvest and where abundant, protected to supplement seeding regeneration.
- Mechanical SIP (i.e., winter shearblading) may be required to remove or reduce layers of living sphagnum and feather moss to improve seedbed receptivity. SIP is ideally scheduled to occur as soon after harvest as possible or within one year of harvest to take advantage of seeding potential from cone-bearing slash.
- Allow five growing seasons prior to surveying for seedling establishment. If necessary, schedule tending as early as two growing seasons after seeding. The susceptibility of cedar to commonly used herbicides in Ontario (e.g., glyphosate) is uncertain.
- Supplemental regeneration treatments (e.g., tree planting with black spruce) may be required to meet regeneration objectives.

Commentary on Cedar Management in Deer and Moose Winter Concentration Areas

The preceding best management practices reflect the current best knowledge for silvicultural systems for cedar. However in areas of high deer densities, recruitment of cedar past the seedling stage is very difficult due to its preference as winter browse. In these instances, forest managers may need to develop landscape level strategies to address regeneration and recruitment of cedar (e.g. focusing regeneration efforts in peripheral areas with lower wildlife populations), and silvicultural ground rules should reflect these conditions. See section 3.3.3. Ontario Stand and Site Guide (OMNR 2010b) for further guidance.

Suggested decision key when determining the appropriate management approach for eastern white cedar.



5.1.25 Eastern Hemlock

Eastern hemlock (*Tsuga canadensis*) is very tolerant of shade, more common in late successional forests, can be even, multi or uneven aged, and very long-lived. It can tolerate a wide range of sites from dry to very moist and sandy to fine loamy but grows best on cool moist to very moist sites with good drainage. Regeneration occurs almost exclusively from seed with good seed years occurring more than 50% of the time. Germination and establishment can occur on a range of substrates (mineral, mixed mineral, logs, humus, etc) when adequate moisture and moderate temperatures are maintained - drying for even short periods of time can cause failure. Once established hemlock can tolerate shade for prolonged periods and responds well to eventual release. Height growth is best in moderate light but it can survive as low as 5% full sunlight. Moderate concentrations of hemlock are typically managed through the shelterwood silviculture system with higher densities well suited to selection.

Keys to success:

- Select cool moist north facing slopes.
- Maintain adequate moisture during the regeneration phase through retention of partial overstory.
- Use careful logging practices to avoid damage to regeneration and residuals.
- Remove overstory gradually to avoid shock related dieback.

Cautions:

- Moose and deer browse can significantly reduce regeneration.
- Hardwood litter, particularly from maple, can inhibit regeneration.
- Rapid release of regeneration and poles may cause shock related dieback and mortality

Recommended reading:

- The Tolerant Conifers: Eastern Hemlock and Red Spruce, Their Ecology and Management. OMNR, Forest Research Information Paper No. 113. (Anderson and Gordon, 1990)

Target Species: *Eastern hemlock*

Silviculture systems and harvest method

	Designation	Conditions	Comments and Assumptions
Clearcut with standards	Not Recommended		Open growing conditions lead to excessive drying and/or severe competition.
Clearcut - seedtree	Not Recommended		Open growing conditions lead to excessive drying and/or severe competition.
Shelterwood - uniform	High Probability	Apply principles from the tree marking guide.	Fulltree logging may cause excessive damage to regeneration.
Shelterwood - strip/group	High Probability	Apply principles from the tree marking guide.	Control of competing vegetation, particularly hardwoods, is critical to success.
Shelterwood - irregular	High Probability	Apply principles from the tree marking guide.	Application normally limited to sites where multi-aged structure is preferred and return harvest is unlikely.
Selection - individual	High Probability	Apply principles from the tree marking guide.	
Selection - group	High Probability	Apply principles from the tree marking guide.	Suggested group size of 1/2 tree height well distributed and covering <20% of stand.

Target Species: *Eastern hemlock*

Pre-harvest treatments

	Designation	Conditions	Comments and Assumptions
Chemical	High Probability		Not a common practice.
Prescribed Burn	High Probability	Burn indices must be consistent with harvest and regeneration objectives.	Low crowns, shallow roots, and presence of ladder fuels (e.g. balsam fir) may lead to loss of mature trees and future seed source.
Site Preparation	High Probability		Not a common practice
Planting	High Probability		Not a common practice.

Logging method

	Designation	Conditions	Comments and Assumptions
Cut-to-length	High Probability		
Tree length	High Probability		Long log lengths increase the risk of damage while skidding.
Full tree	High Probability	Not acceptable for shelterwood removal harvests or uneven-aged management.	May cause excessive damage to regeneration.

Target Species: *Eastern hemlock*

Site Preparation

	Designation	Conditions	Comments and Assumptions
Mechanical	High Probability		
Chemical	High Probability		
Prescribed Burn	High Probability	Timing of application and burn indices must be consistent with regeneration objectives.	Low crowns, shallow roots, and presence of ladder fuels (e.g. balsam fir) may lead to loss of mature trees and future seed source.

Regeneration

	Designation	Conditions	Comments and Assumptions
Advance	High Probability		
Natural seed	High Probability		
Vegetative (coppice)	Not Recommended		Vegetative regeneration of hemlock is very rare.
Planting	High Probability		
Seeding	High Probability		Not a common practice.

Target Species: *Eastern hemlock*

	Designation	Conditions	Comments and Assumptions
Cleaning			
Manual/mechanical	High Probability		
Chemical	High Probability		
Midstory/Improvement	High Probability		May be required to eliminate undesirable seed sources. Assumes stem selection will be consistent with a future hemlock stand.
Spacing			
PCT / crop tree	High Probability		Response to release may be delayed.
Commercial thinning	High Probability		Response to release may be delayed.

Suggested management approaches when hemlock is present in the pre-harvest stand and targeting hemlock regeneration. (Note: all three options are regularly applied in Ontario).

Option 1 – Single Tree Selection: Objective is to manage for hemlock or a hemlock component in an uneven aged forest condition in areas that do not support high deer and moose populations.

- Management objective is the maintenance or development of a hemlock forest type with an uneven-aged structure. Includes uneven-aged hemlock-dominated stands growing on moderately well to imperfectly drained lower slopes with associates By, Ce, Ms, Ab, Sr/Sw and Pw and even-aged hemlock-dominated stands growing on upland sites with associates Pw, Or/Ow, Ms, Sr/Sw, Ce, Hi, Aw and By.
- Also applied to stands with a lower component (<40% of BA) of hemlock and common associates mixed with good quality tolerant hardwoods, or in settled landscapes with low forest cover.
- Recruitment of hemlock regeneration through single tree selection in areas of moderate to high ungulate browsing is unlikely to be successful.
- Hemlock regeneration is extremely slow to develop, sometimes taking 100 years to become sapling sized. Hemlock is adapted to germinate and survive in low light conditions (20% of full sunlight) but needs more light to grow well.
- Remove 25 - 33% of the stand basal area to release AGS crop trees while avoiding mortality from shock or windfall (USDA, 1983). Depending upon species composition and initial stand stocking, residual BA typically ranges from 24 m2/ ha to 34 m2/ ha.
- Residual stand structure should reflect a balance of size classes similar to tolerant hardwood management but reflective of the higher basal area stocking typical of hemlock forests.
- Careful logging to protect the advanced regeneration is critical.

Option 2 – Group Selection: Objective is to manage for hemlock, or a hemlock component, in an uneven aged forest condition in areas that do not support high deer and moose populations.

- Used for similar objective, site and forest conditions as described in single tree selection above.
- Group selection can be an effective means to release advanced hemlock regeneration in areas or during cycles of low to moderate ungulate browsing, while maintaining areas of mature conifer cover.
- Remove 25% to 33% of the stand basal area to release AGS crop trees while avoiding mortality from shock or windfall (USDA, 1983). Depending upon species composition and initial stand stocking, residual BA typically ranges from 24 m^2/ ha to 34 m^2/ ha.
- Groups are typically (but not always) applied in conjunction with a single tree selection harvest throughout the rest of the stand.
- Group diameter should be from ½ to full tree height from bole edge to bole edge.

- Number and arrangement of openings should be located to capture the best hemlock regeneration opportunities. The top priority is where hemlock advanced regeneration is already established, while second priority is where adjacent hemlock seed trees are present. Openings may range from 5% to 20% of total area, depending upon cutting cycle, regeneration objectives and stand quality. The total volume cut should not exceed stand growth over a cutting cycle.
- Group openings are most suited to north facing slopes which helps to limit competition.
- In group openings and the immediately surrounding forest (within 10 to 20 m, particularly on the north side of the opening), all trees 2.5 cm dbh and larger (except AGS polewood hemlock, pine and spruce) should be cut or removed by planned skidding disturbance or scarification . If trees of these species are retained the group opening size should be expanded to compensate for the impact of the crown(s) of the retained trees. Selective removal of non-crop tree species under 2.5 cm will also be of benefit to hemlock regeneration.
- Removal of leaf litter through prescribed burning, mechanical site preparation, harvesters or skidders during harvest will greatly improve success of establishment of new germinants – target 60 - 70% coverage of suitable seedbed (i.e. mineral soil, humus, well decayed logs/stumps)
- Scattered tops resulting from harvest will act as a form of natural fencing creating a physical barrier and will help discourage browsing of established hemlock seedlings in stands containing low to moderate ungulate populations. Tops will also decompose with time and serve as a potential seedbed for hemlock regeneration.
- Careful logging to protect the advanced regeneration is critical. Where feasible, schedule group expansion to maintain similar light levels to those suggested for uniform shelterwood (i.e. 70% canopy closure or about 30% to 40% of full sunlight).

Option 3 – Uniform Shelterwood (two or three cuts): Objective is the renewal of an even-aged hemlock dominated forest

- Typically used on well-drained mid to upper slopes, stands often of fire origin.
- Normally applied to stands with a minimum component of hemlock (≥ 40% of BA) and composition of hemlock plus other common associates adapted to the site and stand conditions (Pw, Sr, Sw, Ce, Or, Ow, Hi, Aw, By) of ≥ 60% of BA.
- Tolerant hardwoods (e.g. Mh, Be) may make up a significant component of the stand but regeneration of these species can be a barrier to successful hemlock regeneration as they are more likely to germinate and once established grow faster than hemlock.
- Hemlock regeneration is extremely slow to develop, sometimes taking 100 years to become sapling sized. Hemlock is adapted to germinate and survive in low light conditions (20% of full sunlight) but needs more light to grow well.
- Depending upon initial stand stocking and presence of advanced regeneration up to three harvests may be scheduled over an extended period of up to 60 years.
- Conditions within a stand (BA, presence of regeneration, competition, etc) can be quite variable and may require stratification into separate treatment units. Treatment units should be of a minimum size to facilitate efficient renewal, tending, and future

harvests. This may require sub-optimal treatment of some areas based on a pragmatic approach to the whole.

- Trees to favor for retention in shelterwood harvests are typically dominant-codominant crop trees with vigorous seed-producing crowns. However in some hemlock forest types where associates are faster-growing species (e.g. hemlock/white pine or hemlock/red oak) hemlock is commonly found in the intermediate crown position. In this instance because of hemlock's high tolerance to shade, retention in the residual canopy of a mixture of the dominant-codominant tree species and intermediate hemlock is acceptable.
- Priority crop tree species to retain are hemlock, white pine, red/white spruce, white cedar, red/white oak, hickory, yellow birch and white ash.
- A preparatory cut is not normally needed as hemlock is a regular seed producer.

Regeneration Cut

- Normally applied in stands 100+ years old, with little or very patchy distribution of advanced regeneration, and sufficient stocking of hemlock and associated species to meet post-harvest residual targets.
- Goal is to establish regeneration in partial shade where microclimatic conditions are moderated by tree cover and to limit the development of competing species.
- Target 70%-80% crown closure postharvest, thinned from below (remove approximately 25% to 33% of stand basal area) (Anderson (1994), OMNR, (1983), USDA (1983)). Depending upon species composition and initial stand stocking, residual BA typically ranges from 24 m^2/ ha to 34 m^2/ ha.
- Heavy mid-story (e.g. maple, ironwood) must be removed to meet overstory canopy closure objectives and provide adequate light for the growth of regeneration.
- Seeds germinate on a wide variety of substrates capable of retaining moisture, but the best seedbeds are mixed mineral soils and humus. Removal of thick duff through prescribed burning, light mechanical site preparation (to avoid root damage), or skidding during harvest will improve establishment.
- Unless mammal populations are very low, hemlock planting is unlikely to be successful.
- Tops will also decompose with time and serve as a potential seedbed for hemlock regeneration.
- Apply timely control of competition around established seedlings.

First Removal (Release Cut)

- The goal of the release cut is to provide increased light conditions to enhance development of hemlock regeneration while providing control over the development of competing regeneration. Hemlocks under 3 meters in height may have difficulty maintaining crown position after a full overstory removal (Kelty, 1986). Hemlock trees may be adversely affected by very high light levels arising from sudden release (Anderson, 1990).
- The release cut also reduces canopy closure and snow interception, making the stand less favorable for deer winter use and resultant browsing of hemlock regeneration.

- Normally applied when regeneration is between 30 cm to 2 m in height, stocked to FMP standards, and canopy closure exceeds 70%. This may include stands with adequate advanced regeneration and no previous shelterwood entry, and includes stands with overstory of different tree species (e.g. red oak or white pine).
- The release cut will leave approximately 60% crown closure, the optimum for hemlock height growth (Vasiliauskas and Aarssen (2000)). Depending upon species composition and initial stand stocking, residual basal area typically ranges from 16 to 24 m2/Ha.
- Forecast stocking of regeneration should anticipate some loss during harvest.
- Careful logging practices will be required to avoid damaging regeneration during harvest. Minimize the number and width of extraction trails.
- Hemlock saplings and poles are brittle in cold weather, which can result in significant damage to regeneration during winter harvest. Where feasible, schedule removal harvests for summer/fall seasons to minimize damage to regeneration.
- Apply timely control of competition around established seedlings.

Final Removal Cut

- Normally applied when regeneration reaches a minimum of 3 m+ in height and exceeds minimum stocking levels. This may include stands with adequate advanced regeneration and no previous shelterwood entry. Forecast stocking of regeneration should anticipate some loss during harvest.
- Due to the shade tolerance of hemlock and potential for negative response to over-release, the final removal should leave a minimum of 6 m^2/ha +.
- Heavy snow load soon after a final removal cut can cause significant damage to saplings and poles.
- Retain residual trees for wildlife habitat (e.g. trees with cavities) and ecological reasons (e.g. veteran trees) as prescribed in Stand and Site Guide.
- Careful logging to protect the hemlock regeneration during harvest is critical. Minimize the number and width of extraction trails.

Irregular Shelterwood

- Irregular Shelterwood may be an acceptable modification where the stand structure is not sufficient for uniform shelterwood or where the objective is to manage towards a multi-aged stand.

Commercial Thinning

- Younger stands (< 100 years old) may respond positively to light intensity thinning.
- Hemlock stands are normally thinned from below to about 70% to 80% crown closure.
- Thinning should focus on selection of AGS dominant and codominant crop trees (high vigour, well developed crowns) and releasing them on at least two sides or 50% circumference.
- For stands destined for hemlock renewal, thinning should focus on the removal of UGS shade tolerant hardwood species such as ironwood, sugar maple and

American beech which can present a future barrier to successful hemlock establishment.

- Fully stocked hemlock stands can have basal areas of over 50M2/ Ha before harvest. Remove 25 to 33% of the stand basal area to release AGS crop trees while avoiding mortality from shock or windfall (USDA, 1983).

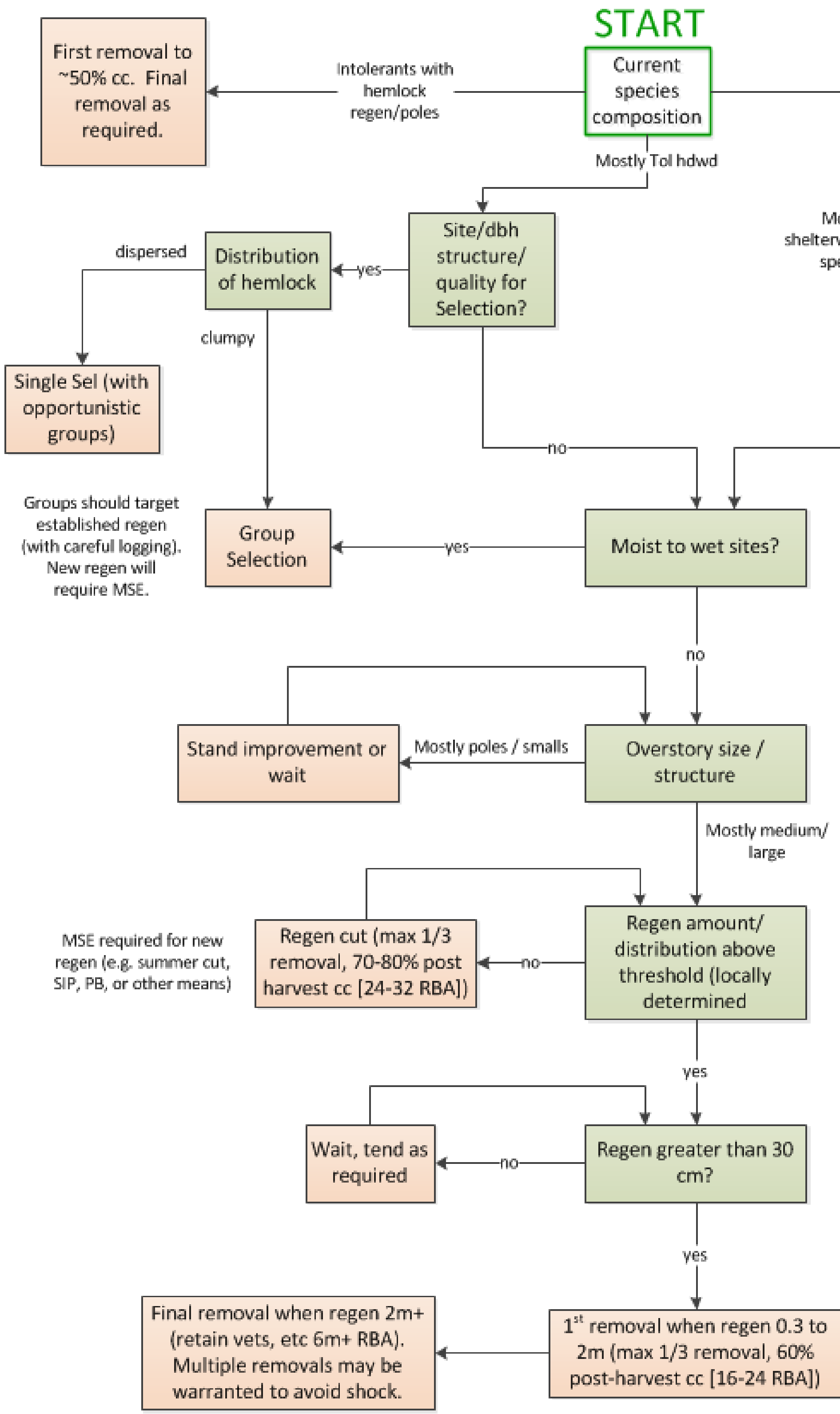
Commentary on Hemlock Management in Deer and Moose Winter Concentration Areas

The preceding best management practices reflect the current best knowledge for silvicultural systems for hemlock. However in areas with a high density of deer and moose during winter (i.e. most deer and some moose winter concentration areas), recruitment of hemlock past the seedling stage is very difficult due to its preference as winter browse.

Regeneration of hemlock cover in the presence of high numbers of deer and moose in winter may not be possible regardless of silvicultural system used (***see*** papers in OMNR, 1992). To maintain high quality cover in hemlock stands in these situations, managers may have to underplant a species such as red spruce. Red spruce is similar to hemlock in terms of shade tolerance, site requirements and snow interception capability but has low palatability to deer (Gordon, 1992). Planting of red spruce may also help re-establish this species, thus meeting broader biodiversity objectives.

Forest managers may need to develop landscape level strategies to address regeneration and recruitment of hemlock (e.g. focusing regeneration efforts in the peripheral parts (i.e. Stratum II) of deer winter concentration areas) and silvicultural ground rules should reflect these conditions.

Suggested decision key when determining the appropriate management approach for eastern hemlock.



5.2 Managing for Multiple Species

Mixed species stands tend to be more common as you move from north to south and more common in the GLSL than the boreal. It is not uncommon for stands in the GLSL to have 6 or more species, with none occupying more than 20% of the canopy space. Managing for multiple species on the same site can introduce both challenges and opportunities. This section is presented in two sections; the first being a discussion of mixedwood management, the second presenting the mechanics of using the management interpretation tables when intentionally targeting more than one species.

5.2.1 Mixedwood Management

Mixedwood management is a somewhat nebulous term that can mean different things to different people. A very broad definition is the presence of more than one tree species in the same general area. More common definitions narrow this based on a variables such as relative abundance (e.g. <70%), canopy position (e.g. co-dominant), taxanomic differences (e.g. conifer vs hardwood), and ecological traits (e.g. shade tolerance). Some definitions (e.g. OMNR, 2003) consider not only the current forest composition but also the potential of the site, current successional stage, and future vegetation dynamics.

Forest management plans typically include one or more mixedwood forest units with a definition that includes a minimum (e.g. greater than 30%) amount of both hardwood and conifer. The landscape guide (e.g. OMNR, 2010a) includes simulated ranges of natural variation and milestones for mixedwood forest types over long time periods. Forest management activities, including mixedwood management approaches, are then planned to maintain or move towards the desired level. Mixedwood targets may be achieved through maintenance of existing mixedwoods, intentional creation of mixedwoods through silviculture, accidental creation of mixedwoods when targeting other conditions, and mixedwood development through natural succession in unmanaged areas.

To achieve forest level objectives the silviculturalist needs an appropriate set of tools (e.g. SGRs) to maintain, create, or convert mixedwood forest conditions. Management effort is normally aimed at maintaining or enhancing the conifer component. With some notable exceptions (e.g. red oak, black cherry, etc), hardwoods tend to regenerate with relatively low effort and the focus is on getting desirable species.

5.2.2 Using the Management Interpretation Tables When Managing for More Than One Species.

It is quite common to have an objective for more than one species on the same site. However, the management interpretations in this guide are presented by individual species. To manage for multiple species on the same site the practitioner will combine the individual direction for the species of interest, with the site characteristics where management will occur, to develop silviculture ground rules and prescriptions. This approach allows for customization to forest management plan specific forest unit or sub-forest unit mixed species conditions of interest.

Table 5b provides an example of using the designations in the management interpretation tables when two species are targeted on the same site. In this example two combinations (clearcut seed tree and strip shelterwood) have been identified as compatible (i.e. both have a high probability designation), one combination (uniform shelterwood) as potentially compatible (if a low to moderate density of species A is consistent with objectives), and four combinations as not compatible as one or more of the two species are low probability or not recommended.

Table 5b. Example use of management interpretation table designations when two species are targeted on the same site.

Silviculture System	Designation for species A	Designation for species B	Interpretation[11]
Clearcut – with standards	High probability	Not recommended	Not compatible
Clearcut – seed tree	High probability	High probability	Compatible
Shelterwood – uniform	High probability for low to moderate density	High probability	Potentially compatible
Shelterwood – strip/group	High probability	High probability	Compatible
Selection – individual	Not recommended	Low Probability	Not compatible
Selection – group	Low Probability	High probability	Not compatible

5.2.3 Resources

A number of resources exist to help the silviculturalist plan both an overall strategy and determine specific implementation parameters for mixed species management. In conjunction with the revision of this guide, two mixedwood management resource documents have been prepared - one each for Boreal (in prep) and Great Lakes-St. Lawrence (in prep) regions have been prepared. Other documents including the Boreal Mixedwood Notes series (e.g. OMNR, 2000), and the results of the Vegetation Management Alternatives Project (e.g. Bell et al 2012) include a great deal of relevant information. Many operational research reports (e.g. Man et al 2013) are available to further inspire and customize local approaches.

[11] Not compatible means one or more of the target species is unlikely to do well. Potentially compatible means both species could do well if conditions are met. Compatible means both species are likely to do well with only minor modifications, if any.

As you move further south in the province mixed species stands and mixed species management approaches become much more common. The Tree Marking Guide (OMNR, 2004) includes a number of approaches designed to maintain or enhance desirable components of Great Lakes-St Lawrence mixed species stands.

Across the province there are practitioners with various levels of experience in mixed species management approaches. Perhaps the most valuable resource is a field visit with a knowledgeable colleague to explain what has been tried and what is working at a local level.

5.2.4 Suggested Management Approaches – Mixedwoods

A number of the suggested management approaches for individual species (section 5.2) include mixed species management approaches. These include approaches where a low to moderate density of a single target species is intended and the remaining component of the stand is not explicitly identified, as well as other approaches where more than one species is explicitly targeted.

The following text provides suggested management approaches when targeting a mixture of hardwood and coniferous tree species as a future regeneration objective. A pre-harvest assessment to determine pre-harvest stand (composition and structure) and site conditions will greatly increase the probability of success when matching silviculture system and renewal treatments to site conditions and future forest objectives.

Option 1 – Clearcut with cluster planting: Objective is the renewal of the conifer component of a mixedwood stand through the creation of an even-aged mosaic of strips or patches of conifers between hardwood regeneration.

- May be applied to upland mixedwood stands where the future percentage of area occupied by hardwoods and conifers can be varied to produce a desired mixture.
- Strip widths, patch sizes, inter-strip and inter-patch spacing, and planting densities will vary depending on future stand composition objectives (e.g., planting densities would be greater to achieve a conifer leading future stand condition than to achieve an aspen leading stand condition). Location of transects and clusters should be flagged. Linear arrangements make it easy to locate crop trees during any future treatments.
- Site preparation (mechanical and/or chemical) may be required to ensure planted spruce will grow at an acceptable rate in comparison to adjacent hardwoods.
- Clusters have been established using white spruce seedlings spaced 1 to 1.4 m apart in groupings of 6-10 trees. Other species may be considered if conditions are suitable for survival and growth.
- Planted seedlings may require early control of overtopping and lateral competition. Survey for tending the year of planting and if necessary, schedule release as early as one year post-planting. Aerial herbicide applications will treat entire transect, whereas ground applications (manual, mechanical, and /or chemical) can specifically target cluster planted areas.

Option 2 – Pre-harvest underplanting of white spruce: Objective is a two-tiered mixedwood stand (hardwood overstory with a conifer understory) as an alternative to clearcutting and even-aged management.

- May be applied to upland, hardwood dominated mixedwood stands that are 30 to 60 years in age with a BA >35 m^2/ha. Adequate light (>25% full sunlight) in the understory is required (and must be maintained) at seedling and sapling height. This system may be desired to protect spruce regeneration from exposure and competition from shade intolerant species.
- Chemical SIP (ground application) may be required where there is a well-established understory shrub layer.
- Schedule early spring planting of large stock white spruce between 15 to 20 years prior to the planned harvest of the overstory. A planting density of 1,400 – 1,800 sph is recommended.
- Avoid planting seedlings within 1 m of hardwood overstory tree stems.
- Planted seedlings may require competition control. Ground application of herbicide or mechanical brushing are effective treatments for controlling understory vegetation.
- Overstory aspen should not be removed until the spruce seedlings are able to withstand potentially aggressive post-harvest competition. Seedlings should achieve a minimum height of 2.5 m is before the overstory harvested.
- Underplanting may be carried out in conjunction with a shelterwood harvest (partial canopy removal) where overstory trees are left.
- Conduct a harvest to remove hardwood overstory. Spruce regeneration can be protected during harvest through predetermined layout of access trails and operational roads.

Option 3 – Pre-harvest herbicide with clearcutting: Objective is the renewal of an even-aged mixedwood forest

- May be applied to upland mixedwood stands composed of shade intolerant hardwoods and jack pine and shade tolerant spruce and balsam fir. This system may be desired to produce an intimate mixture (species mixed at the scale of a few metres or less) of conifers and hardwoods.
- Schedule a pre-harvest aerial herbicide spray of the overstory hardwoods with the intention of reducing but not eliminating post-harvest aspen suckering. Schedule treatment in late summer or early fall with clearcut harvesting to follow shortly after.
- Mechanical SIP may be required to increase the number and distribution of suitable planting spots.
- Schedule a planting treatment to occur in the spring directly following the pre-harvest spray treatment. Planting spruce seedlings at a density of around 1,500 sph is suggested.
- Short term results from recent research indicate pre-harvest application of herbicides as a potentially viable approach for mixedwood management. Readers are referred to the following publications for further information:
    1) Man, R., J.A. Rice, L. Freeman, and S. Stuart. (2011). Effects of pre- and post-harvest spray with glyphosate and partial cutting on growth and

quality of aspen regeneration in a boreal mixedwood forest. For. Ecol. and Manage. 262: 1298-1304.
2) Man, R., J.A. Rice, and G.B. MacDonald. (2011). Early effect of pre- and post-harvest herbicide application and partial cutting in regenerating aspen - jack pine mixtures in northeastern Ontario. CJFR 41: 1082-1090.
3) Man, R., J. A. Rice, and G. B. MacDonald. (2013). Performance of planted spruce and natural regeneration after pre- and post-harvest spraying with glyphosate and partial cutting on an Ontario (Canada) boreal mixedwood site. Forestry. 86, 475–480, doi:10.1093/forestry/cpt018

Option 4 – Corridor harvest with shearblading: Objective is the renewal of a two-tiered mixedwood stand with corridors regenerated to conifer in between unharvested or partially harvest hardwood dominated strips.

- May be applied to upland mixedwood stands with heavy amounts of unmerchantable stems and slash. The retained hardwood strips provide partial canopy closure that protects spruce regeneration from exposure and competition from shade intolerant species.
- Stand is harvested in strips. Leave strip widths should be wide enough to protect, but not limit the growth of the adjacent corridor regeneration. Strips should be oriented perpendicular to prevailing wind direction to minimize risk of windthrow.
- Shearblading is applied as a mechanical SIP treatment to remove competing vegetation and upper organic layers.
- Schedule spring planting of large stock white spruce in harvested corridors. A moderate planting density of 800 to 1,200 sph is suggested. Planting density will vary depending on future stand composition objectives (e.g., planting densities would be greater to achieve a conifer leading future stand condition than to achieve an aspen leading stand condition).
- Planted seedlings may require early competition control. Survey for tending the year of planting and if necessary, schedule release as early as one year post-planting. Ground application of herbicide or mechanical brushing are effective treatments for controlling competing vegetation in the corridors.

5.2.5 Suggested Management Approaches – GLSL Mid-tolerants

The following text outlines typical parameters for regenerating mid-tolerant and intolerant hardwoods as a minor component in tolerant hardwood forest types.

There are a number of mid-tolerant and intolerant hardwood tree species which occur regularly as a component of the tolerant/ mid-tolerant hardwood forest but rarely, if ever, occur as the dominant species in the stand. When regeneration of these species in the tolerant hardwood forest is an objective, group selection is usually the recommended treatment. A component of these species can also be regenerated through a uniform shelterwood prescription on suitable sites and seedbeds, if sufficient residual seed trees and/ or advanced regeneration are maintained. Table 5c provides the recommendations for incorporating regeneration of these species into group selection and uniform shelterwood prescriptions for management for tolerant/ mid-tolerant hardwood forest types. Further details on the implementation of both systems are provided in the sugar maple, red oak, yellow birch and lowland hardwoods sections.

Table 5c. Recommendations for regeneration establishment and/or initial release of advanced regeneration of selected mid-tolerant species through group selection.

SPECIES	GROUP SELECTION		COMPATIBLE SPECIES WITH UNIFORM SHELTERWOOD FOR:
	Group Opening Size (crown edge to edge)	Preferred Site Location	
Basswood	20 meters	Mid to Lower Slope	Sugar Maple, Yellow Birch
Bitternut hickory	20 -30 meters	Mid to Upper Slope	Sugar Maple, Red Oak
Black cherry	30-40 meters	Mid Slope	Sugar Maple, Yellow Birch
Bur oak	20 meters	Lower to Upper Slope	Sugar Maple, Yellow Birch, Red Oak, Lowland Hardwoods
Butternut	30-40 meters	Mid to Lower Slope	Sugar Maple, Yellow Birch, Red Oak, Lowland Hardwoods
White ash	20 meters	Mid Slope	Sugar Maple, Yellow Birch, Red Oak
White elm	20-30 meters	Mid to Lower Slope	Sugar Maple, Yellow Birch, Lowland Hardwoods
White oak	20-30 meters	Mid to Upper Slope	Sugar Maple, Red Oak

Black ash and white birch are of cultural importance to aboriginal people for basket and canoe making. Although they often occur as the dominant species in Ontario's forests, they are also common as a minor species component in tolerant/mid-tolerant hardwood forest types. Table 5d provides the recommendations for incorporating regeneration of these species into group selection prescriptions.

Table 5d. Recommendations for regeneration establishment and/or initial release of advanced regeneration of black ash and white birch through group selection.

SPECIES	GROUP SELECTION		COMPATIBLE SPECIES WITH UNIFORM SHELTERWOOD FOR:
	Group Opening Size (crown edge to edge)	Preferred Site Location	
Black ash	20-30 meters	Mid to Lower Slope	Lowland Hardwoods, Yellow Birch
White birch	20-30 meters*	Mid to Upper Slope	Red Oak, Sugar Maple, Yellow Birch

*The lower range of opening size is preferred for developing canoe-quality birch

Recommendations for Regeneration Monitoring and Maintenance

- During the establishment stage stands should be assessed for advanced regeneration and existing competition. These stands may require planting, manual tending or chemical spot tending to favor establishment of desirable hardwood regeneration.
- After successful establishment overhead shade should be closely monitored. When shade conditions slow the growth of the target species or favor competing species canopy manipulations to increase ground level light conditions will be required.
- In the group opening this will mean expanding the group opening size, while in stands treated with uniform shelterwood, this will mean conducting an over story release or removal harvest treatment.
- The canopy manipulation may be done as one treatment or a series of treatments aimed at gradually removing the over story.

6.0 Adaptive Management

6.1 Introduction

Silviculture is the art and science of growing trees. It is a science in that there is a wealth of information from long-term plot networks, research trials, operational monitoring, physiological studies, theoretical ecology, experiential knowledge, and more that can be used to form a hypothesis (choose appropriate treatments based on predicted outcomes) and test it. But it is also an art in that the large multi-dimensional matrix of desired knowledge used to form a hypothesis has many gaps, many variables are difficult to predict (e.g. weather), and some variables may be difficult to measure or even unknown.

This duality was well described as early as 200 years ago by German forester Heinrich Cotta, in the preface to his book *Anweisung zum Waldbau* ("Advice on Silviculture" 1816; as cited by Baker (1950)) and is worth repeating here;

Thirty years ago, I prided myself on knowing forestry science well. Had I not grown up with it and in addition had learned it in the universities! Since then I have not lacked the opportunity for increasing my knowledge in many directions, but during this long period I have come to see very clearly how little I know of the depths of the science, and to learn that this science has by no means reached that point which many believe to have been passed.

Many perhaps may be in the condition in which I was thirty years ago; may they in the same manner be cured of their conceit! Forestry is based on the knowledge of nature; the deeper we penetrate its secrets, the deeper the depths before us. What the light of an oil lamp makes visible is easily overlooked; many more things we can see by torchlight, but infinitely more in the sunlight. The lighter it grows around us, the more unknown things become apparent, and it is a sure sign of shallow-ness, if anybody believes he knows it all.

Our foresters can still be divided into empiricists and scientists; rarely are both united.

That the former considers sufficient in a forest management is easily learned, and the systematic teachings of the other are soon memorized. But in practice the art of the first stands to a thorough forestry science in the relation as the quack medicine to the true pharmacopoeia; and the other often does not know the forest for the many trees. Things look very differently in the forest from what they do in the books; the learned man stands therefore, frequently, left by his learning and at the same time without the bold decision of the empiricist.

Three principle causes exist why forestry is still so backward:

1. *The long time which wood needs for its development,*
2. *The great variety of sites on which it grows,*

3. *The fact that the forester who practices much writes but little, and he who writes much practices but little.*

The long time period causes that something is considered good and prescribed as such which is only good for a time, and later becomes detrimental to the forest management. The second fact causes that what many declare good or bad proves good or bad only in certain places. The third fact brings it about the best experiences die with the man who made them, and that many entirely one-sided experiences are copied by the merely literary forester so often that they finally stand as articles of faith which nobody dares gainsay, no matter how one-sided or in error they may be.

In the intervening centuries since Cotta captured these thoughts, and particularly in the last few decades, the goal of silviculture has shifted from one of timber production to ecosystem management with timber as one of many desired benefits. Much has been studied, quantified, learned, and indeed in some cases re-learned. The tools and information at our disposal have greatly increased. However, despite these advances, cause and effect is not always obvious, nature is still messy, and things do not always go as planned. This does not mean we throw our hands up in frustration with the occasional failure, but that we embrace the uncertainty with which we are working, and commit to learning through practice. This is the essence of the silviculture effectiveness monitoring (SEM) program outlined in section 6.2.1.

To fully embrace uncertainty and learning through practice we need the courage to be wrong. It is often by trying things that have an uncertain outcome where the most learning occurs. Of course, with uncertainty comes risk, and the potential for learning needs to be balanced with the probability and impact of a negative result. Within this guide, practices believed to have a lower probability of success are categorized as such and those that are unlikely to be successful are categorized as *not recommended* (see section 5.1). However, this does not automatically prohibit them from occurring. Low probability treatments can still occur as part of a trial area (as described in section 6.2.2) and *not recommended* treatments can still be carried out as part of an exceptions monitoring program (as described in section 6.2.3).

Learning through practice is greatly enhanced when operating above the level of an individual or small group. It is important to foster an environment where we learn from each other by recording and communicating our successes, failures, and discoveries in a way that is easily translatable across time, sites, and administrative formalities. The framework (i.e. Bayesian belief networks [BBN]) used to synthesize and document the knowledge that supports the direction in this guide is hoped to serve this purpose and be a solid foundation for adaptive management (i.e. learning through practice) moving forward. The BBN framework is used to provide a representation of how we believe the system works, what level of knowledge we have to support that belief, and critical assumptions that can be tested and either supported or disproven as we learn through practice.

6.2 Monitoring and Evaluation

Continued learning and innovation can increase the productivity, value, and resiliency of Ontario's regenerating forests. Our understanding of silviculture treatment effects and effectiveness has evolved through time as a result of past silviculture experimentation, evaluation, and monitoring by scientists and practitioners in formal and informal settings. This guide encourages continued learning to improve silviculture treatments under common use and explore the potential of new and evolving treatments for future operational implementation. This can be achieved through monitoring and evaluating all treatments through a Silviculture Effectiveness Monitoring (SEM) program as well as focused monitoring of specific treatments of interest, particularly those associated with a higher uncertainty (trial areas and exceptions).

6.2.1 Silviculture Effectiveness Monitoring

Learning through practice is a very intuitive process that is part of human nature. People are inherently very good at observing the world around them and developing conclusions about how it works. Casual learning through observation can be a very efficient way to gain knowledge about a system. Continued observation over long time periods and/or in multiple locations, can allow people to move from observational knowledge to synthesis level understanding of processes and fundamental principles – moving from what to why. However, human nature can also lead to confirmation bias, where we internally emphasize results that fit our belief, and downplay those that do not. To guard against confirmation bias and other human failings requires a more formal articulation of assumptions and a dedicated monitoring and evaluation process using relevant metrics. Ideally we should be able to describe in advance what signals from our monitoring would cause us to change our management approach.

The effort expended to monitor the effectiveness of treatments should be proportional to the risk involved and the value of the stand. Time tested treatments on simple sites with trusted operators may not warrant intensive monitoring freeing up resources for monitoring of other higher risk sites. A risk and value based approach to monitoring should include a basic level of effort, that will occur on all sites, and is consistent with data quality standards (photo: Mike Brienesse).

Silviculture effectiveness monitoring (SEM) is a formalized program used to determine if management activities are producing the desired results and why. SEM entails describing the objective, monitoring results, analyzing and understanding trends, and feedback to strategic planning.

SEM may be viewed from various perspectives: at the stand level for particular prescriptions or treatments, at the forest or management unit level for trends within particular forest units, and at the regional and provincial levels to measure program success. Analysis at each level provides answers to the basic questions:

"What did we intend to accomplish?"
"What did we actually accomplish?"
"How well did we do it?" (Robbins (1992))

Some of the components of a SEM program are referenced in the Forest Operations and Silviculture Manual (FOSM) and the Forest Information Manual (FIM), but are presented in a more useable manner in the Silviculture Effectiveness Monitoring Manual for Ontario (SEMMO).

Monitoring associated with the SEM program includes both formal and informal monitoring. All treatment areas are monitored informally to ensure the stand is developing as expected and any necessary follow-up treatments are scheduled appropriately. Informal monitoring varies from ocular assessments to plot-based surveys depending on the complexity of the site and the experience of the practitioner. Formal monitoring occurs at specific milestones (e.g. free-to-grow) that vary based on the silviculture system being employed. These milestones are selected as significant points in the development of the future stand and timed with the development of regeneration in clearcut and shelterwood systems, or shortly after harvest in selection silviculture systems. The results of monitoring are compared with a pre-set performance standard (e.g. renewal standards – see section 4) specific to the treatment package employed on a site by site basis. The results from similar sites are then compared to understand trends.

Figure 6a presents an idealized timeline of activities, including monitoring, for clearcut, shelterwood, single, and group selection.

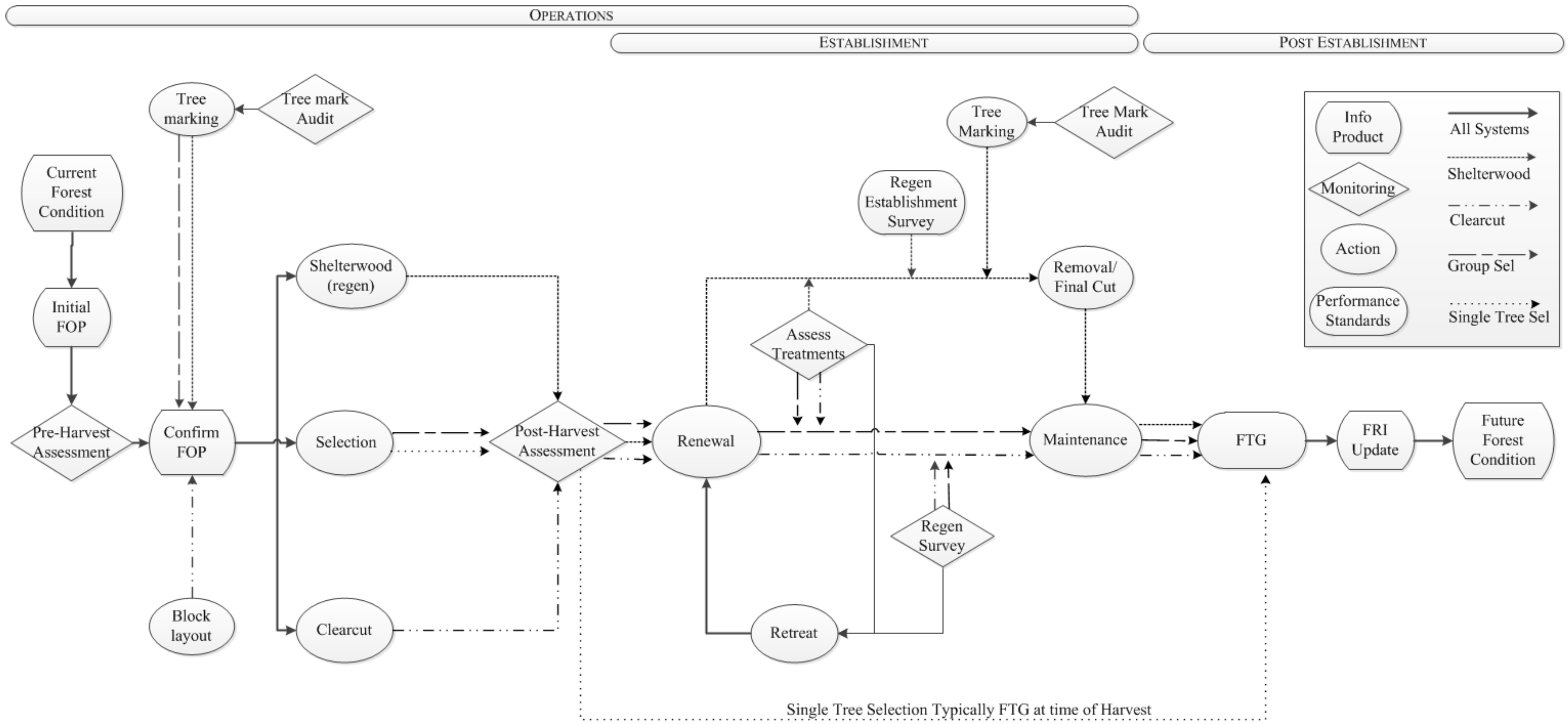


Figure 6a. Idealized silviculture effectiveness monitoring pathway and timeline of activities and assessments. (FOP=forest operations prescription, FTG=free-to-grow).

There are of course limitations to what an SEM program can accomplish and what conclusions can be drawn from the data. The most important limitation being the realization that milestones themselves (e.g. FTG) are a hypothesis. The free-to-grow standard is an estimate of a condition that will eventually evolve into the desired future forest condition. Assumptions are made about natural stand dynamics, application of future treatments (e.g. pre-commercial thinning), and growth and yield relationships. Each of these assumptions has a degree of uncertainty, that generally increases in more complex (e.g. mixed) stands.

6.2.2 Trial Areas

All low probability treatments are conditionally recommended with the condition being that they occur as part of a trial area. This section describes the minimum requirements and limitations of a trial area.

6.2.2.1 Description and Limitations

The intent of a trial area is to allow for the initial exploration of an idea, on a limited basis, with minimal administrative encumbrances. Individual trial areas may be undertaken to increase operational efficiency, improve achievement of objectives (i.e. forest condition), improve cost effectiveness, minimize adverse effects, demonstrate an expected failure, or any other number of reasons.

The forest management plan will include enabling text to allow for the implementation of trial areas. This will include information on treatment and forest type eligibility, limitations (e.g. size and number), and any applicable renewal standards **(guideline)**.

The planning team should carefully consider what forest types are eligible for trial area implementation. Forest types that have high diversity value, represent critical species at risk habitat, or are locally uncommon should be paid particular attention. When determining if any forest types should be eligible for trial area implementation, the effect of a failed trial area on achievement of forest management plan targets should be forecast (**best management practice**).

Details of individual trial areas may not be known at the time of FMP development and opportunities for trial areas may arise at any time. Trial areas can potentially occur on any harvest, renewal or tending operations included in this guide[12] by following the FMPM process regarding a stand level change to silviculture treatments.

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[12] As such, amelioration treatments including drainage and fertilization are not eligible for implementation through a trial area approach.

Prior to trial commencement, a project plan for the trial area will be prepared **(standard)**. The project plan is intended to provide a basic and informal outline of the fundamental trial area details. The project plan will briefly summarize the following (**guideline**):

- Project objectives and brief rationale,
- Description or map of the site location,
- Description of the project design, and the treatments involved
- Timelines including expected duration of project,
- Renewal standard (if applicable). The minimum renewal standard for a trial area is FRI definition of productive forest.
- Description of project monitoring, evaluation, and reporting of results.
- A description of anticipated re-treatment activities (if any), and associated timelines, should the trial fail to develop as expected or meet the minimum renewal standard.

The project plan will be provided to the MNRF office responsible for compliance prior to commencement of the trial and serve as written notification to the MNRF that the trial area is planned to occur (**standard**).

Individual trial areas will not normally exceed 100 hectares (**guideline**). Trial areas exceeding 100 hectares in size will be considered on a case by case basis by the regional director or designate through review and approval of the project plan (**guideline**).

In some instances, a limited window of opportunity may exist to establish a trial area. Project plans requiring approval (i.e. over 100 ha) should be submitted as far in advance of the desired start date as possible and approval authorities are encouraged to undertake a timely review. Project plans for trial areas less than 100 hectares in size do not require review and approval when the process (e.g. enabling words in FMP) and limitations in this section (section 6.2.2.1) are adhered to.

A maximum of three trial areas can be initiated in any 5 year period (**standard**). Individual trial areas (new, ongoing, or previous) will be substantially different in scope, objectives, or design to warrant a new investigation (**guideline**).

6.2.2.2 From Trial Areas to Practice

If the short term findings of a trial area prove to be positive the application of those results to regular practice may be difficult if trial area design or inherent limitations of the trial area approach do not allow for the size, replication, or monitoring effort required to give confidence in the results. It is likely that to change the status of a low probability treatment, or condition on a high probability treatment, in future revisions of this guide, additional investigations beyond the initial trial area will be required. It is hoped that a trial area will serve as an initial proof of concept to encourage interest and investment in a more rigorous investigation.

Collaboration and development of partnerships between forest resource managers, MNRF science and silviculture staff, Canadian Forest Service staff, academic institutions, silviculture contractors, and other partners are encouraged but not required for trial areas to occur. Combining practical expertise together with science and information products, as a result of such partnerships, would optimize investment and uptake of knowledge gained from trial areas for incorporation into future guide revisions and improved silviculture practices.

6.2.3 Exceptions

Forest management guides, including this silviculture guide, are used during the preparation of a forest management plan. Using the silviculture guide includes selection of treatments that are consistent with the objectives described in the forest management plan. When *not recommended* treatments are selected they are considered an exception. If *low probability* treatments (see section 5.2) are selected, and not undertaken as part of a trial area, those treatments are also deemed *not recommended* in this guide and considered an exception.

Inclusion of an exception in a forest management plan requires the development of an exceptions monitoring program. The details of the monitoring program are normally customized to the nature of the exception, the degree of departure from any conditions, and the specific reason and/or circumstances that lead to the exception being included.

The forest management planning manual provides details on the process and documentation requirements of an exceptions monitoring program. When developing an exceptions monitoring program it may be helpful to consider the following questions.

- What is the basis for the not recommended designation?
- What question are you asking?
- Will this monitoring program answer that question?
- Will the answer be in a format that can help update guide direction?
- Can you narrow the scope to minimize the degree of deviation from recommended?
- What role can standard monitoring (e.g. SEM) play?
- Is anyone else investigating a similar question?
- For long-term questions, what short term milestones would be informative?

6.3 Approach to Effectiveness Monitoring

Direction in this guide is based on the best scientific information and expert advice available at the time of writing (see Background and Rationale for Direction Document – in prep). Direction for some species and treatments is based on a large body of scientific literature supported by years of experience. However, direction for some species, and some practices, is based on a more limited body of scientific knowledge relying more heavily on expert opinion. For all direction, there is uncertainty associated with the outcome of its application. Uncertainty arises for numerous reasons. For example, there may have been few studies upon which to base direction, studies may have been conducted in a different ecological context, results of studies may have been inconclusive or even contradictory, and practitioners may have had success in some locations but failures in others without a clear understanding of the difference. Direction that is uncertain can be viewed as a hypothesis that requires testing within the context of the suite of forest management operations practised across Ontario's ecologically diverse landscape.

The declaration order regarding MNRF's *Class Environmental Assessment Approval for Forest Management on Crown Lands* (MNR-71 as amended by MNR-71/2) implicitly recognizes uncertainty and stipulates the following conditions associated with testing the effectiveness of forest management guides:

38(f). Each revised, amalgamated, or new Guide shall contain a description of an approach that shall be undertaken to monitor the effectiveness of the Guide.

and

31. MNR shall maintain a program of scientific studies to assess the effectiveness of Guides. Updates on the progress of these studies shall be provided to the Provincial Forest Technical Committee to assist in the review and revision of Guides.

The following two sections address each of these declaration order requirements.

6.3.1 Guide Effectiveness

Testing the effectiveness of guide direction forms one part of the guide development cycle. The stated purpose of this guide as described in section 1.1 is:

> …to provide practitioners and forest management planning teams with information and direction to determine which silviculture activities are effective in meeting local forest management objectives.

Testing the effectiveness of this guide then involves testing if the sum of silviculture planning and implementation leads to achievement of forest management objectives. To isolate cause and effect, the achievement of forest management planning objectives can be broken down into 2 separate but related questions;

1. Did the treatments create the expected future forest condition?
2. Does that forest condition contribute to objective achievement?

The first component will be tested using the silviculture effectiveness monitoring program described in section 6.1. This may include drawing on the conclusions of individual forest management unit analysis or a roll-up and analysis at broader scales.

If it is found that the guide is effective in helping achieve the first component, it may still be possible that forest management plan objectives will not be achieved. This is partly a test of the planning teams ability to translate forest management objectives into forest condition parameters, but also a test of underlying assumptions that the silviculture approaches described in this guide will create the expected function. Function may be for wildlife habitat (e.g. structural diversity), timber products (e.g. piece size), or any number of purposes. The approach to testing the effectiveness of the Landscape (OMNR 2010b, OMNR 2010c) and Stand and Site (OMNR 2010a) guides will be relied upon to test the assumption that silviculture activities will create a forest condition that conserves biodiversity at site, stand, and landscape scale. Other forest management plan objectives (timber, viewsheds, etc) are difficult to test above a management unit scale as they are specific to each plan. Feedback from the regular forest management planning reporting, monitoring, and auditing program will be relied upon for this purpose.

6.3.2 Evolution of Knowledge

Many individual pieces of direction in this guide do not require rigorous testing because they are based on an extensive body of scientific evidence, have been used successfully for decades, or may already have been tested within the context of Ontario's forest management practices (see Background and Rationale for Direction – in prep). The outcome of these practices will continue to be checked through regular monitoring (e.g. section 6.2.1) to ensure these assumptions hold true.

Conversely, there are other pieces of direction in this guide for which there is greater uncertainty associated with the outcome of their application and where new or expanded knowledge would be very useful.

The MNRF will use a number of different approaches to facilitate the acquisition and dissemination of new knowledge that will aid in addressing these uncertainties:

- The MNRF will continue to monitor the broad scientific literature, attend conferences, and maintain connections with federal and academic researchers to identify new research that may challenge assumptions about the effectiveness of direction or otherwise provide new knowledge to revise direction.

- The MNRF will remain aware of ongoing monitoring and research studies and will attempt to provide support, advice, or otherwise collaborate to the extent feasible. This may include re-measurement of ongoing research, establishment of new research, or analysis of existing monitoring data.
- The MNRF will maintain a record of the occurrence and conclusion of exceptions monitoring, and to the extent possible, trial areas associated with this guide.
- The MNRF will encourage regular dialogue among silviculture practitioners through discussion forums, sponsored field tours, and the development of practice notes and practice based resource documents.

The Bayesian Belief Networks (BBN) created to support the development of this guide provide a foundation to build from. They provide a description of how we think the system works (i.e. what variables matter and how they relate), what information we have to support that view, and which variables are the most influential on a successful result. By its very definition a BBN is not intended to be a static document, but rather provides a structured framework by which new information can be incorporated. As new information becomes available the BBNs will be periodically updated. The new information will either increase the certainty of the existing network (i.e. strengthen the belief), decrease the certainty but not change the structure, or require a structural change to add, remove, or modify a relationship. When the BBN changes, the influence of that change on the conclusion (i.e. management interpretations) will be examined. If the change to the BBN suggests a different management interpretation is required, that information will be communicated to forest managers and considered during the regular schedule of guide review.

Literature Cited

Abrams, M. 1998. The Red Maple Paradox – What explains the widespread expansion of red maple in Eastern forests. BioScience. Vol 48. No 5.

Adams, M.J. A. Groot, G.W. Crook, R.L. Fleming and F.F. Foreman. 2005. Direct seeding black spruce and jack pine: a field guide for northern Ontario. Nat. Resour. Can., Can. For. Serv., Sault Ste. Marie, Ontario. 254 pp.

Algonquin Forestry Authority. 2010. 2010-2020 *Forest Management Plan for the Algonquin Park Forest*.

Anderson, Harvey. 1994. *Hemlock, its ecology and management*. In: The Tolerant Conifers: Eastern Hemlock and Red Spruce, Their Ecology and Management. pp 62-86. Ontario Ministry of Natural Resources. Forest Research Information Paper No. 113. Queen's Printer for Ontario. Toronto.

Baker, F.S. 1950. Principles of Silviculture. McGraw Hill.

BCMOF 1997. Paper Birch Managers' Handbook for British Columbia. B.C. Ministry of Forests. Forest Science Program. FRDA Report 271.

Bell, F.W., J. Parton, N. Stocker, D. Joyce, D. Reid, M. Wester, A. Stinson, G. Kayahara, and B. Towill. 2008. Developing a silvicultural framework and definitions for use in forest management planning and practice. Forestry Chronicle. Vol. 84, No 5.

Bell F.W., N. Thiffault, K. Szuba, N. Luckai, and A. Stinson. 2011. Synthesis of silviculture options, costs, and consequences of alternative vegetation management practices relevant to boreal and temperate conifer forests: Introduction. Forestry Chronicle. Vol 87. No 2.

Boisvenue, C. and S.W. Running. 2006. Impacts of climate change on natural forest productivity – evidence since the middle of the 20th century. Glob. Change Biol. 12: 862-882

Box EO. 1981. Predicting physiognomic vegetation types with climate variables. Vegetatio 45: 127-139.

British Columbia Ministry of Forests. 2000. Mixedwood management in the boreal forest using cluster planting of white spruce. Forest Practices Branch, BCMoF, 14 pp.

Buda, N.J., G.J. Kayahara, R.G. White, S.F. Duckett and B.E. Fox. 2011. Silvicultural Practices for Eastern White Cedar in Boreal Ontario. Technical Report CNFER TR-005. Ontario Ministry of Natural Resources, Centre for Northern Forest Ecosystem Research, Thunder Bay, Ontario. 51 pp.

Burgess, D., S. Wetzel and J. Baldock. 2000. White/red pine stand response to partial cutting and site preparation. J. Sustainable Forestry. 10: 221-227.

Chen, H.Y.H., A. Luke, and W. Bidwell (Editors). 2000. Workshop Proceedings for the Ecology and Management of White Birch, September 21-22, 1999, Wawa, NEST Workshop Proceedings WP-003, Queen's Printer for Ontario. pp. 67.

CFSA 1994. Crown Forest Sustainability Act, RSO 1994.

Colombo, S.J., D.W. McKenney, K.M. Lawrence and P.A. Gray. 2007. Climate change projections for Ontario: practical information for policymakers and planners. Climate Change Research Report no 5. Ontario Ministry of Natural Resources.

Crow, T.R. 1992. Population dynamics and growth patterns for a cohort of northern red oak (*Quercus rubra*) seedlings. Oecologia 91: 192-200.

Delong, S.C. 1997. Operational considerations for underplanting hardwood stands with white spruce. British Columbia Ministry of Forests, Prince George, B.C. Research Note PG-11.

Dey, D.C and W.C. Parker. 1996. *Regeneration of red oak (Quercusrubra L.) using shelterwood systems: Ecophysiology, silviculture and management guidelines*. Ont. Min. Nat. Resources, Ont. For. Res. Inst., Sault Ste. Marie, ON. For. Res. Inf. Pap. No. 126

Dey, D.C. ES. Gardiner, CJ Schweitzer, JM Kabrick and DF Jacobs. 2012. Underplanting to sustain future stocking of oak (Quercus) in temperate deciduous forests. New Forests.

Dey, D.C. 2013. Personal communication.

Duchesne, L.C., D.G. Herr, S. Wetzel, I.D. Thompson and R. Reader. 2000. Effect of seed predation, shade and soil organic matter on the early establishment of eastern white pine and balsam fir seedlings. For. Chron. 76: 759-763.

Gordon, Alan. 1994. *The Red Spruce Option: Red Spruce and the Hemlock Connection*. In: The Tolerant Conifers: Eastern Hemlock and Red Spruce, Their Ecology and Management. pp 98 - 114. Ontario Ministry of Natural Resources. Forest Research Information Paper No. 113. Queen’s Printer for Ontario. Toronto.

Greene, D.F., D.D. Kneeshaw, C. Messier, V. Lieffers, D.Cormier, R.Doucet, K.D. Coates, A.Groot, G.Grover, and C. Calogeropoulos. 2002. Modelling Silvicultural alternatives for conifer regeneration in boreal mixedwood stands (aspen/white spruce/balsam fir). For. Chron. 78:281-295.

Groot, A. 2001. In: Regenerating the Canadian Forest: Principles and Practice for Ontario. Wagner, Robert G. and Colombo, Stephen J. (Eds.). Fitzhenry & Whiteside, Ltd.

Groot, A. 2014. Fifteen-year results of black spruce uneven-aged silviculture in Ontario, Canada. 2014. Forestry 87:99-107.

Heckman, S.T. 1992. White pine management on the Menominee and its evolutionary process. Pages 157–167in R.A. Stine and M.J. Baughman, eds. White pine symposium proceedings: history, ecology, policy and management, Duluth, MN, 16–18 September 1992.University of Minnesota, Extension Service Distribution Center, St. Paul, MN.

Herr, D.G., L.C. Duchesne and R.J. Reader. 1999. Effects of soil organic matter, moisture, shading and ash on white pine (Pinus strobus L.) seedling emergence. New For. 18: 219-230.

Hodge, J. C.; Juzwik, J.; Gross, H. L.; Retnakaran, A., 1989: White pine blister rust and white pine weevil management: Guidelines for white pine in Ontario. Report PM-36. Ontario: Ministry of Natural Resources, Pest Management Section. 21 p.

Horton, K.W. 1962. Low cost regeneration of white pine. Timber of Canada 23: 60-75.

IPCC 2007. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Eds. S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (eds.). Cambridge University Press, Cambridge, United Kingdom.

Jacobs, R.D. 1974. *Damage to northern hardwood reproduction during removal of shelterwood overstory.* Journal of Forestry. 72:654-656.

Johnston, W.F. and R.E. Brittain. 1983. Tamarack. In Silviculture systems for the major forest types of the United States. Compiled by R.M. Burns. USDA For. Serv. Agric. Handb. No. 445. pp 99-101.

Jones, T. A. and S. McPherson. 2012. Comparative effects of full-tree and tree-length shelterwood harvesting on residual tree damage and coarse woody debris volume in the Great Lakes – St. Lawrence forest. Forestry Chronicle. Vol 88. No 6.

Joyce et al 2001 in: Regenerating the Canadian Forest: Principles and Practice for Ontario. Wagner, Robert G. and Colombo, Stephen J. (Eds.). Fitzhenry & Whiteside, Ltd.

Kayahara, G.J., McKinnon, L.M. and R.G. White. 2006. Commercial Thinning Specifications and Exceptions Monitoring Protocol for Jack Pine, White Spruce and Black Spruce in Ontario’s Boreal Forest. Ontario Ministry of Natural Resources, Northeast Science and Information, Timmins, ON. NESI Technical Note TN-022. 8pp.

Kelty, M.J. 1986. *Development patterns in two hemlock-hardwood stands in southern New England.* Canadian Journal of Forest Research. 16: 885-891.

Leak W.B., D.S. Solomon, and S.M. Filip. 1969. *A silvicultural guide for northern hardwoods in the northeast*. USDA Forest Service. Research paper NE-143

Leak, W.B. and C.H. Tubbs. 1983. *Percent crown cover tables for applying the shelterwood system in New England.* USDA Forest Service. Northeastern Forest Experiment Station. Research Note NE-313. 4pp.

Leak W.B., D.S. Solomon, and P.S. Debald. 1987. *Silvicultural guide for northern hardwood types in the northeast.* USDA Forest Service. Research paper NE-603. 36 p.

Loehle, C. 2014. Climate change is unlikely to cause a biodiversity crisis: evidence from northern latitude tree responses to warming. Energy & Environment. Vol. 25 No. 1

Loftis, D.L. 1990. *Predicting post-harvest performance of advanced red oak reproduction in the Southern Appalachians*. Forest Science.36 (4).908-916.

Man, R., G. Kayahara, Q. Dang, and J. Rice. 2009. A case of severe frost damage prior to budbreak in young conifers in Northeastern Ontario: Consequence of climate change? The Forestry Chronicle, Vol 85, No3.

Man, R., J.A. Rice, L. Freeman, and S. Stuart. 2011a. Effects of pre- and post-harvest spray with glyphosate and partial cutting on growth and quality of aspen regeneration in a boreal mixedwood forest. For. Ecol. and Manage. 262: 1298-1304.

Man, R., J.A. Rice, and G.B. MacDonald. 2011b. Early effect of pre- and post-harvest herbicide application and partial cutting in regenerating aspen - jack pine mixtures in northeastern Ontario. CJFR 41: 1082-1090.

Man, R., J. A. Rice, and G. B. MacDonald. 2013. Performance of planted spruce and natural regeneration after pre- and post-harvest spraying with glyphosate and partial cutting on an Ontario (Canada) boreal mixedwood site. Forestry. 86, 475–480, doi:10.1093/forestry/cpt018

Marquis, D.A., R.L. Ernst, and S.L. Stout 1992. *Prescribing silvicultural treatments in hardwood stands of the Alleghenies (revised).* USDA Forest Service. General Technical Report NE-96.

McDonald, David. 2003. *Silver maple (Acer saccharinum) A bottomland hardwood in Ontario.* (Thesis-unpublished). 31pp.

McCann, R. B. Marcot, R. Elis. 2006. Bayesian belief networks: applications in ecology and natural resource management. Canadian Journal of Forest Research, 2006, 36(12).

McCullough, D.G., R.L. Heyd and J.G. O' Brien. 2005. *Biology and Management of Beech Bark Disease.* Michigan State University. Extension Bulletin E-2746. 12pp. http://www.baycounty-mi.gov/Docs/Health/GypsyMoth/BeechBark.pdf.

McLaughlin, J and S Greifenhagen. 2012. *Beech bark disease in Ontario. A primer and management recommendations.* Ontario Forest Research Institute, Ontario Ministry of Natural Resources. Forest Research Note Number 71.

McKenney DW, Pedlar JP, Iverson LR, Hutchinson MF, Lawrence K, Campbell K. 2007. Potential impacts of climate change on the distribution of North American trees. Bioscience, Vol. 57 No. 11:939-948.

McKinnon, L.M., Kayahara, G.J. and R.G. White. 2006, Biological framework for commercial thinning even-aged single species stands of jack pine, white spruce, and black spruce in Ontario. Ontario Ministry of Natural Resources, Northeast Science and Information, Timmins, ON. NESI Technical Report TR-046. 129 pp.

Michigan Department of Natural Resources. 2012. American Beech Management: Beech Bark Disease. Forest Resources Division. IC-4029-7. 9pp.

Miller, G.W., J.W. Stringer, and D.C. Mercker. 2007. *Technical guide to crop tree release in hardwood forests*. University of Tennessee Professional Forestry Note. PB 1774. 24pp.

MOEE 1994. Environmental Assessment Board Reasons for Decision and Decision. EA 87-02.

Naylor, B. and L. Thompson (eds.). 1992. Regenerating conifer cover in deer yards. OMNR, COFTDU Tech. Rpt. No. 28.

Nipissing Forest Resource Management (NFRM). 2009. 2009-2019. *Forest Management Plan for the Nipissing Forest.*

Nyland, R.D. 1987. *Selection system and its application to uneven-aged northern hardwoods*. In: Proceedings of Managing Northern Hardwoods Silvicultural Symposium at Syracuse. R.D. Nyland (ed). Publication No. 13 (ESF 87-002), pp. 49-80. State University of New York, College of Environmental Science and Forestry. Syracuse, NY.

O.M.N.R. 1983. *Management of tolerant hardwoods in Algonquin Provincial Park*. Ontario Ministry of Natural Resources. 72 pp.

OMNR 1992. *Regenerating conifer cover in deeryards.* Editors Brian Naylor and Lyn Thompson. Central Ontario Forest Technology Development Unit. Technical Report 28. North Bay, Ontario. 126pp.

NRCan 1995. Silviculture Terms in Canada. Canadian Forest Service, Ottawa. 112 pp.

OMNR, 1996. *Seed Manual for Ontario: Guidelines for tree seed crop forecasting and collecting.*

OMNR, 1996b. (P. K. Bidwell, B. Turner, D.J. Archibald & N. Maurer). An Approach to Pre-Harvest Silvicultural Prescriptions in Boreal Ontario. NESI TN-014

OMNR, 1998. *A silvicultural guide for the tolerant hardwood forest in Ontario.* Version 1.1. Ontario Ministry of Natural Resources. Queen's Printer for Ontario. Toronto. 500 pp.

OMNR. 1998. A silvicultural guide for the Great Lakes-St. Lawrence conifer forest in Ontario. Ont. Min. Nat. Resour. Queen's Printer for Ontario. Toronto. 424p.

OMNR, 2000. Boreal Mixedwood Notes. Ontario Ministry of Natural Resources. Queen's Printer for Ontario. Toronto.

OMNR, 2003. Silviculture Guide to Managing Spruce, Fir, Birch, and Aspen Mixedwoods in Ontario's Boreal Forest. Ontario Ministry of Natural Resources. Queen's Printer for Ontario. Toronto. 230 pp.

OMNR, 2004. *Ontario tree marking guide*, Version 1.1. Ontario Ministry of Natural Resources. Queen's Printer for Ontario. Toronto. 252 pp.

OMNR, 2009. Forest Management Planning Manual for Ontario's Crown Forests. Toronto: Queen's Printer for Ontario. 447 pp.

OMNR, 2009. Ecological Land Classification field manual – operational draft, April 20th, 2009. Ecological Land Classification Working Group. OMNR. Unpublished manual.

OMNR, 2000. *A silviculture guide to managing southern Ontario forests*. Editors, Silvia Strobl and David Bland. 654pp.

OMNR, 2010a. Forest Management Guide for the Conservation of Biodiversity at Stand & Site Scales (Stand and Site Guide). Ontario Ministry of Natural Resources. Queen's Printer for Ontario. Toronto. 211 pp.

OMNR, 2010b. Forest Management Guide for Great Lakes-St. Lawrence Landscapes (GLSL Landscape Guide). Ontario Ministry of Natural Resources. Queen's Printer for Ontario. Toronto. 57 pp.

OMNR, 2010c. Stand & Site Guide Background and Rationale. Ontario Ministry of Natural Resources. Queen's Printer for Ontario. Toronto. 582 pp.

OMNR, 2011. Ontarios Biodiversity Strategy: Renewing our Commitment to Protecting What Sustains Us. Ontario Ministry of Natural Resources. Queen's Printer for Ontario. Toronto. 80 pp.

OMNR, 2014. Forest Management Guide for Boreal Landscapes (tentative date). Ontario Ministry of Natural Resources. Queen's Printer for Ontario. Toronto.

Palmer, C.L. and W.D. Towill. 2004. Regeneration techniques for the management of boreal mixedwood stands. Ontario Ministry of Natural Resources, Science and Technology Series Volume 9. Boreal Mixedwood Note No. 37.

Parker, W.C. and D.C. Dey. 2008. Influence of overstory density on ecophysiology of red oak (Quercus rubra) and sugar maple (Acer saccharum) seedlings in central Ontario shelterwoods. Tree Physiology 28:797–804.

Parker, W., S. Columbo, and M. Sharma. 2012. An Assessment of the Vulnerability of Forest Vegetation of Ontario's Clay Belt (Ecodistrict 3E-1) to Climate Change. OMNR. CCRR32.

Parker, W.C. 2014.The relationship of stand structure with canopy transmittance: Simple models and practical methods for managing understorey light conditions in eastern white pine (Pinus strobus L.) - dominated forests. For.Chron (In review).

Pinto, F., A.E. Morneault, S. McPherson, S. Reid, M. Woods, A. Stinson, S. D'Eon. In prep. Developing regeneration standards for Ontario's publicly owned white pine forests.

Pitt, D.G., P.G. Comeau, W.C. Parker, D. MacIsaac, S. McPherson, M.K. Hoepting, A. Stinson, and M. Mihajlovich. 2010. Early vegetation control for the regeneration of a single-cohort, intimate mixture of white spruce and trembling aspen on boreal upland sites. CJFR 40:549-564.

Pitt, D.G., Morneault, A., Parker, W.C., Lanteigne, L., Hoepting, M.R., Stinson, A. 2011. The effects of herbaceous and woody competition on planted and natural white pine regeneration in a shelterwood. For. Chron. 87, 653-668.

Ponder, F. Jr., R. Fleming, S. Berch, M. D. Bussed, J. D. Elioffe, P. W. Hazlett, R. D. Kabzems, J. M. Kranabetter, D. M. Morris, D. Page-Dumroese, B. J. Palike, R. F. Powers, F. G. Sanchez, D. A. Scott, R. H. Stagg, D. M. Stone, 2, D. H. Young, J. Zhang, K. H. Ludovici, D. W. McKenney, D. S. Mossa, P. T. Sanborn, R. A. Voldseth. 2012. Effects of organic matter removal, soil compaction and vegetation control on 10th year biomass and foliar nutrition: LTSP continent-wide comparisons. Forest Ecology and Management. 278: 35-54.

Puettmann, K. J., Coates, K. D., & Messier, C. C. 2009. A critique of silviculture: managing for complexity. Island Press.

Rosenvald, R., and A. Lohmus. 2008. For what, when, and where is green-tree retention better than clear-cutting? A review of the biodiversity aspects. For. Ecol. Manage. 255: 1-15.

NRCAN. 2007. Jack pine ecosystem productivity project [online]. Available at http://cfs.nrcan.gc.ca/projects/61 [Accessed October 2013]

Smith, D.M. 1951. The influence of seedbed conditions on the regeneration of eastern white pine. Conn. Agric. Exp. Sta. Bull. 545, New Haven, CT, 61 pp. 230.

Smith, D. M., B. C. Larson, M. J. Kelty, and P. M. S. Ashton. 1997. The practice of silviculture: applied forest ecology. John Wiley, New York, New York, USA.

Streit M., T. Scarr and L. Farintosh. 2012. *Preparing for emerald ash borer: A landowner's guide to managing ash forests.* Leeds-Grenville Stewardship Council and Eastern Ontario Model Forest. 16pp.

Sturrock, R. N. , S. J. Frankel, A. V. Brown, P. E. Hennon, J. T. Kliejunas, K. J. Lewis, J. J. Worral, and A. J. Woods. 2011. Climate change and forest diseases. Plant Pathology 10: 133-149.

Sutherland, B.J., F.F. Foreman. 1995. Guide to the use of mechanical site preparation equipment in Northwestern Ontario. Canadian Forest Service – Sault Ste Marie, ON, Canada.

Swanston, C. and M. Janowiak. 2012. Forest Adaptation Resources: Climate Change Tools and Approaches for Land Managers. General Technical Report NRS-87. USDA Forest Service.

Szuba, K.; Pinto, F. 1991. Natural history of the white pine weevil and strategies to decrease its damage to conifers in Ontario. COFTDU Tech. Rep. No. 13.OMNR, Central Ontario Forest Technology Development Unit, North Bay, ON.60 p.

Thompson I, Mackey B, McNulty, and S. Mosseler, A. 2009. Forest Resilience, Biodiversity, and Climate Change. Secretariat of the Convention on Biological Diversity, Montreal. Technical Series no. 43.

Townshend, Elisha. 2012. Black Ash Stand Dynamics and Flooded Jellyskin Potential Habitat Quality in Rich Hardwood Swamps of the Great Lakes St. Lawrence Forest Region. Undergraduate Thesis, Nipissing University, North Bay.

Trees Ontario, 2013. Nursery Stock Size Class Parameters.

Tubbs, C.H. 1977a. *Natural regeneration of northern hardwoods in the northern Great Lakes region*. USDA Forest Service, Research Paper NC-150.

Tubbs, C.H. 1977. *Manager's handbook for northern hardwoods in the north-central states*, USDA Forest Service, Gen Tech Report NC-39. 29 p.

USDA, 1983. *Silvicultural systems for the major forest types of the United States*. Forest Service. Agricultural Handbook N0 445. 191pp.

Vasiliauskas, S.A. and L.W. Aarssen. 2000. *The effects of moose on hemlock seedling establishment in Algonquin Provincial Park, Ontario, Canada*. Proceedings: Symposium on Sustainable Management of Hemlock Ecosystems in Eastern North America. McManus, K.A., K.S. Shields and D.R. Souto. Editors. Newtown Square, PA. USDA Forest Service, Northeastern Research Station. Gen. Tech. Rep.-NE-267.
Pp 148 – 153.

Wagner, R.G., T.D. Petersen, D.W. Ross and S.R. Radosevich. 1989. Competition Thresholds for the survival and growth of ponderosa pine seedlings associated with woody and herbaceous vegetation. New Forests 3: 151-170.

Wagner, R.G., F.W. Bell and R.A. Campbell. 2001. Vegetation management. pp. 432-457 in: Regenerating the Canadian forest: Principles and Practice for Ontario. Wagner, Robert G. and Colombo, Stephen J. (Eds.). Fitzhenry & Whiteside, Ltd.

Wendel, G.W. and H.C. Smith. 1990. Pinus strobus L: Eastern White Pine. In: R.M. Burns and B.H. Honkala tech. coords., Silvics of North America. Vol. 1. Conifers, Pp. 476-488, USDA Agric. Handbk. No. 654, Washington DC.

Wester, M., P. Uhlig, E. Banton and R. Lalonde. 2011. A guide to translate central Ontario ecosites into “Ecosites of Ontario”. Ont. Min. Natur. Resour. SSI Tech. Note TN-11. 5 pp.

Worrall, J., G. Rehfeldt, A. Hamann, E. Hogg, S. Marchetti, M. Michaelian, and L. Gray. 2013. Recent declines of Populus tremuloides in North America linked to climate. Forest Ecology and Management. Vol 299; 35–51

Wotton, M., K. Logan, and R. McAlipine. 2005. Climate Change and the Future Fire Environment in Ontario: Fire Occurrence and Fire Management Impacts

Appendices

Appendix 1 – History of Silvicultural Guides in Ontario

Prepared by J. A. Rice, RPF
Aug, 2013.

Ontario's formal recognition of the forestry profession began in the early part of the 20th century with the establishment of the province's first forestry school in 1907 and the appointment of the province's first chief (provincial) forester in 1912.

Early efforts by the Ontario government in forestry focussed primarily on the afforestation of abandoned lands in southern Ontario. The Ontario Department of Lands and Forests (ODLF) oversaw the production of a number of forestry related documents primarily aimed at providing guidance for woodlot owners, typically farm woodlots, in the southern part of the province.

During that same period, while timber harvesting was occurring in central and northern Ontario, there were few documents produced that focussed on managing the vast tracks of Crown land in that region, as the province's focus there was on fire protection (e.g., the passing of the Forest Fires Protection Act in 1917).

It wasn't until the late 1940s and early 1950s, after World War II, that the province took the next step to managing Crown forests and produced a "Manual for Timber Management" (ODLF 1948). The manual was made up of 5 separate booklets covering legislation, timber estimating (field work), timber estimating (compilations), timber marking for partial cutting operations, and methods of stumpage appraisal. While this manual spoke of the need to consider silviculture, it provided little direction or advice on methods to grow healthy and productive forests. A revised edition of this manual was produced in 1951.

The next advances took place in the late 1960s and early 1970s. In this period land-use issues in the province, including how forests were managed, were being examined and debated by experts as well as the public. The resulting changes and transformations that came out of these discussions included the province reviewing its approach to managing Crown forests.

During that time, factors that drove the changes included:

- New and expanding mills were leading to an increased demand for wood fibre. The forest product industry was booming, and demand for fibre was putting stress on forests to continuously supply the needed raw materials (Newnham 1978).
- As demand grew, there was also a reduction of easily accessible fibre for existing mills across the province. Delivery distances to mills were increasing, and the forest resources inventory (FRI), originally established in 1963, was found to have overestimate timber volumes by as much as a third. The result was a need to better

manage forests to ensure that continual low-cost accessible fibre remained (Newnham 1978).

- Governments and the science community were starting to look at forests as something more than just a place to grow future 2x4s, as the focus expanded to include a range of broader ecological considerations (wildlife habitat, water, nutrient cycles, etc.) (Kimmins 1973).
- During this timeframe, the development of the Algonquin Provincial Park Master Plan was underway. With the development of the Master Plan came the discussion and debate of whether logging should be allowed to continue in the Park. The public looked to the government to see what rules and regulations were in place to enable logging while protecting our public lands. A management guide for tolerant hardwoods in Algonquin Park (OMNR, 1973a) was produced at this time to support the Park's Master Plan development.
- Finally, beyond the economic and social factors, there was also an important information availability issue. At that time, a combination of fewer research journals and technical reports being produced, along with difficulties in acquiring any available printed resource materials, and high phone charges on long-distance calls (to researchers or specialists) all meant that the ability to transfer knowledge to practitioners was limited. This was well before the electronic age began, and readily accessible means of securing information (that we currently have) were not in place.

These factors helped the province to decide to develop and distribute a series of silvicultural guides. These guides were designed to provide forest managers a set of stand-alone documents with all the information they needed to manage forest blocks of commercially important species in an efficient and effective manner. In theory they would also lead to more consistent and predictable approaches to management across the range of a species or working group (working group was a term used to describe the leading species in a stand, see previous FRI specifications for details).

The decision to produce silvicultural guides was not unique to Ontario. Similar factors and discussions were occurring in other provinces and throughout the United States. Each jurisdiction was searching for better methods to manage their forests, and most decided to produce guides to help address these concerns. Examples of guides from other jurisdictions included an aspen guide in the Prairie Provinces (Steneker 1976), and a spruce-fir guide in the US northeast (Frank and Bjorkbom 1973) to name but two.

The evolution of silvicultural guides in Ontario from the late 1960s until today closely follows the changing view that society has put on our forested landscape. The guides have evolved from having timber oriented goals based primarily on traditional textbook direction, to having timber oriented goals with an increasing emphasis on advances in science, and finally to having broader forest oriented goals (including timber) with science based management directions.

The other major change to the guides over the years has been the move from being purely silviculture-based (i.e., focussing on the art and science of growing trees), to a silviculture/management mix – where arguably the management side (i.e., what techniques are recommended to be used on specific sites) has taken the dominant role.

The first series of silvicultural guides in Ontario were published in the 1970s. They were intended to help forest managers appropriately renew and manage harvested stands on their forest units.

The first series of silvicultural guides covered the important tree species in the province including:

- the white pine working group (OMNR, 1973b),
- the spruce working group (Robinson, 1974),
- the hard maple, yellow birch and hemlock working group (Heeney and Bruce 1974), and
- the aspen working group (Heeney et al 1975).

The primary objective of these guides was to provide direction that would result in a continuous flow of raw materials for the saw and pulp mills across the province. Direction in each guide was built on established, traditional management approaches, with some limited local management experiences. The guides also identified aesthetics and site protection as 2 secondary objectives.

Each guide included a description of the silvics of the species, management alternatives (with some limited references to site and featured wildlife species), damaging agents, and minimum stocking standards. Each was written by head office staff – all based in Toronto, with limited input from field researchers or practitioners.

While these Guides brought together a range of information, a concern with these guides was that in many cases they described past operational practices that may or may not have had success in Ontario, rather than focus on the best currently available knowledge provided by recent scientific studies and management trials. It was also not mandatory to use any of these guides in the development of Timber Management Plans. They were available, and some plans used them, but incorporating their direction into management decision was left to local discretion.

The decision to include a guide for the aspen working group was a surprising choice. Up to that time aspen was generally seen as a weed species. But, expected increases in demand for wood fibre along with the vast volumes of aspen across the province, primarily in the north, made it an increasingly important species. At this time the province was also considering the use of hybrid poplar to address the increasing wood demands (Heeney 1972).

The original set of silvicultural guides were in place and used for approximately 15 years.

In the early 1980s a number of additional management guides were published in Ontario. While they weren't officially tied to the initial set of silvicultural guides, they did provide additional information on specific species/areas within the province. This group include: A silvicultural guide for hybrid poplar (Barkley 1983), which built on Heeney's earlier work (1972) and the work of the Brockville Fast Growing Hardwoods Group; an updated guide for managing tolerant hardwoods in Algonquin Park (OMNR, 1983), which built on the 1973 version with updated research results; and a guide to Managing Red Pine Plantations in southern Ontario (OMNR, 1986) based on the management approaches and trials done by many of the conservation authorities in southern Ontario. These additional guides brought together the best available science, including local research and field trial results, to provide management direction for the cover type in one document. But similar to the first set of silvicultural guides none were mandatory to use.

The "Class Environmental Assessment by the Ministry of Natural Resources for Timber Management on Crown Lands in Ontario" (Timber EA) (EAB 1994) became the key driver for the next set of silvicultural guides, and it remains the key driver that continues to influence guide development and use to the present day.

During the run up to Timber EA hearings, and during the actual hearings themselves (1988-1992), there was pressure on the OMNR, to demonstrate that their policies for forest planning and operations were current and relevant. When the hearings began the existing set of silvicultural guides were more than 10 years old, and there were concerns that direction in those guides may not reflect the current state of scientific knowledge and monitoring results.

Also during this time a key focus for the OMNR, was the management of old-growth white and red pine in the Temagami area. The old-growth white and red pine issue focused the public's attention on not only the need for appropriate silviculture in Crown forest, but also the inclusion of social concerns in the decision making process.

The second series of provincial silvicultural guides was produced in this environment, and included:

- Jack Pine working group, (Galloway, 1986)
- Silvicultural guide for the poplar working group in Ontario, (Davison, et al. 1988)
- Silvicultural guide for the spruce working group in Ontario, (Arnup et al. 1988)
- Silvicultural guide for the white pine and red pipe working group in Ontario, (Chapeskie et al. 1989)
- Silvicultural guide for the tolerant hardwoods working group in Ontario, (Anderson et al. 1990)

The volume on Jack Pine (a species not included in the first series of silvicultural guides) was built primarily on the work presented at the Federal-Provincial Jack Pine Symposium held in 1984 (Smith and Brown 1984). Jack Pine had been utilized for saw-timber for quite some time, but it was only with it's increased use in pulp mills that the need for more specific management direction evolved.

The initial draft of the Silvicultural Guide for the Tolerant Hardwoods working group was extremely long – more than 400 pages in length when other guides in this series were 100 pages or less. To deal with the "excessive" length, an agreement was made to include only the "strategic" portions in the silvicultural guide itself (making it similar to other volumes in this set), and to produce a companion tree marking guide (Anderson and Rice, 1993) which would describe the tactics of how to implement uneven-aged management direction in these forest types.

The irony to this decision was that tree marking was used in other forest types and silvicultural systems (e.g., pine shelterwoods), and managers of those forests wondered why a tree marking guide did not include all scenarios that required tree marking. This concern was addressed in a later revision.

By the time the Timber EA hearings ended in 1992, and the final report was tabled (EAB 1994), the new series of silvicultural guides were completed.

This second series of silvicultural guides, developed in the mid- to late-1980s went well beyond the guides that were created 15-years earlier. While they contained some of the same topics, including information on silvics, site conditions (including expanded references to ecosites and site conditions), management alternatives, damaging agents, and in some cases minimum stocking standards, they were developed and treated as new documents, and not as simply updates of the previous volumes. While the guides still maintained a timber focus, they also included a greater emphasis on other, broader forest considerations (e.g., wildlife and habitat).

Each guide was written by local experts for the specific working group (scientists, foresters, consultants), with a designated "lead author" (who wrote the majority of the material) and a supporting team. Head office staff provided oversight and some administrative support.

The second series of silvicultural guides were available for use for about a decade.

With the second series of silvicultural guides and a tree marking guide in place, there were still some concerns around ensuring that partial harvest silvicultural systems were being implemented in a sustainable manner. These concerns led to the decision that tree marking on Crown stands in the Great Lakes-St Lawrence forest region needed to be done by certified tree markers. Tree marking certification began in 1993 using the tree marking guide (Anderson and Rice 1993) as the foundation for the certification course. Use of certified tree markers was engrained into the forest management system in the Great Lakes-St. Lawrence forests with its inclusion in the Forest Operations and Silviculture Manual (FOSM) in 1995.

Use of this second set of silvicultural guides was again not mandatory in management planning. It wasn't until 1995, with the enactment of the Crown Forest Sustainability Act and the need to comply with the regulated Forest Operations and Silviculture Manual, that the use of provincial silvicultural guides became mandatory in forest management planning and operational activities.

In their decision report, the EA Board supported the use of guides (or what the Board called "implementation manuals") to ensure that forest management operations would be based on silvicultural prescriptions developed with the most current science and knowledge available.

The EA Board report (EAB 1994) also embedded the use and maintenance of silvicultural guides in the Terms and Conditions of the original Timber Class EA. Specifically:

- Term and Condition 61(c): "…the (Timber Management) Plan has been prepared in accordance with the appropriate implementation manuals." (Note that direction to use those "manuals" now embedded in FOSM.)
- Term and Condition 94(a): "In accordance with the foregoing procedure, all existing silvicultural guides shall be reviewed to ensure that they reflect current scientific knowledge as it applies to Ontario, and revised to provide descriptions of general standard site types for use in developing Silvicultural Ground Rules in Timber Management Plans. Those revisions shall be completed within three years of this approval."
- Term and Condition 93(a): "Within five years of this approval, and thereafter at least every five years, MNR shall review each implementation manual or preparation of any new manuals. The Provincial Technical committee shall have an integral role in the review of existing implementation manuals, and the setting of priorities for revisions or amalgamation of the existing manuals which may be required from time to time."

From these Term and Conditions, the time requirement to review (and potentially revise) each of the guides became legally binding.

In addition, to address the increasing amount of mixedwood conditions in the boreal forest, an additional term and condition required the development of an entirely new silvicultural guide:

- Term and Condition 94(d): "MNR shall undertake … the preparation and completion of a mixed wood silvicultural guide."

The first guides of the post-Timber EA period were developed in the second half of the 1990s after the Timber EA board's decision, with the new Boreal Mixedwood guide completed in 2003.

In recognition of the need for similar silvicultural information and guidance for tree species that grew south of the Area of the Undertaking, MNR also developed an additional silvicultural guide that addressed southern Ontario forests.

The third series of provincial silvicultural guides included:

- Silvicultural guide to managing black spruce, jack pine, and aspen on boreal forest ecosites in Ontario.
    - Book I: Silviculture in Ontario. (OMNR, 1997)
    - Book II: Ecological and management interpretations for northwest ecosites. (OMNR, 1997)
    - Book III: Ecological and management interpretations for northeast site types. (OMNR, 1997)
- Silvicultural guide for the tolerant hardwood forest in Ontario: version 1.0, (OMNR, 1998a)
- Silvicultural guide for the Great Lakes-St. Lawrence conifer forest in Ontario: version 1.0, (OMNR, 1998b)
- Silvicultural guide to managing southern Ontario forests, (OMNR, 2000)
- Silvicultural guide to managing spruce, fir, birch, and aspen mixedwoods in Ontario's boreal forest, (OMNR, 2003)

Similar to the work done during the development of the second set of silvicultural guides a decade earlier, an updated tree marking guide (OMNR, 2004) was also produced. It included tree marking direction for all stands receiving selection and shelterwood management approaches in the Great Lakes-St Lawrence forest region. This included both tolerant hardwood and conifer stand conditions where tree marking was necessary, and thus addressed the concern previously raised around tree marking in pine shelterwood stands.

Needing to follow the direction provided in the Timber EA Board's report and Term and Conditions, this series of silvicultural guides is distinctly different that the previous ones.

The key differences were:

- the focus on management recommendations being based on "general standard site types" (which was interpreted as ELC based "eco-sites" or "site types" depending on which OMNR, administrative region you were in),
- the increasing emphasis on direction being supported by proven scientific study, and
- the continuing increased focus on non-timber values (wildlife, habitat, sensitive areas, biodiversity, etc.).

The requirements put forth by the Timber EA decision changed the focus of this series of guides to ones that focused primarily on management options (i.e., what was recommended, conditionally recommended, or not recommended to do) as opposed to the more traditional silvicultural guides (i.e., detailing the art and science of growing trees).

The third series of guides was again written by a writing team of experts (scientists, foresters, consultants). While there was a writing team leader, each section was authored by a specialist of that area/discipline. As with previous series, there was oversight and administrative support from head office staff.

In 2000 the OMNR, hired a group of consultants (Arborvitae et al. 2000) to review the existing series of forest management guides (including not only the silviculture guides, but also guides dealing with wildlife, aquatics, disturbance patterns, physical environment, and roads). As part of their review, they addressed how well direction in the existing guides was integrated with other guides. This review met the Timber EA requirement for a 5-year review of silviculture guides. No changes to the silvicultural guides were recommended at that time.

In 2003, nine years after the Timber EA decision had been in place, a legally required review of the entire Timber EA decision (as outlined in Term and Condition 113 (a)) took place. This review included an assessment of how OMNR, had addressed all Terms and Conditions in the original Timber EA Board decision. This review was part of the process that led the EA Board to renew the approval to practice forest management on Crown lands in Ontario. That renewal request was approved in 2003.

With the approved renewal request, the Ministry of the Environment issued a Declaration Order ("Declaration Order Regarding MNR's Class Environmental Assessment Approval for Forest Management on Crown Lands in Ontario", 2003). The "Dec Order" renewed the approval to conduct forestry on Crown lands, and came with a set of Conditions – many similar to the original Timber EA's Terms and Conditions. The need for guide review and revision is found in Dec Order Condition 38.

To meet the legal requirements of the Dec Order conditions, the black spruce, jack pine, and aspen guide, the tolerant hardwood guide, and the Great Lakes-St. Lawrence conifer guide were reviewed in 2005 (5 years after being part of the review of all forest management guides). The boreal mixedwood guide was reviewed in 2008 (5 years after its original approval). Reviews were based on the criteria listed in Dec Order Condition 38(d).

Since the southern Ontario silviculture guide addresses Crown forests outside of the Area of the Undertaking, it is not addressed by the Dec Order. Nonetheless, as part of good policy development, it, too, was reviewed in 2005, five years after its publication. That review followed the same review criteria as used for the other guides.

The recommendation from the 2005 and 2008 guide reviews, and supported by the Provincial Forest Technical Committee (PFTC), was to not revise the silvicultural guides immediately, but to wait until after the Landscape Guide and Stand and Site Guide were completed. This recommendation reflected the limited staff available to work on the various guides. Once the Landscape and Stand and Site guides neared completion, revisions to the silvicultural guides for the area of the undertaking (AOU) would begin.

It was also decided by OMNR, that until work on a new silvicultural guide was to begin, silvicultural science and research efforts needed to focus on knowledge synthesis and field trials that would advance our understanding in three contentious issues. Those being: Full tree harvesting on shallow sites in northwestern Ontario, thinning and pre-commercial thinning of jack pine and spruce stands, and silvicultural approaches to manage eastern white cedar in the boreal forest region. Results of that work would feed into the silvicultural guide revision process once it began.

The Landscape Guide for Great Lakes-St. Lawrence Forests (OMNR, 2010a) and the Stand and Site Guide (OMNR, 2010b) received final approval in March 2010. Approval for the Landscape Guide for Boreal Forests (OMNR 2014) was received in February 2014.

With the Great Lakes St-Lawrence Landscape Guide and the Stand and Site Guide approved, formal work on the revision of the silvicultural guides for the AOU began in 2010. The results of that revision are in this document today.

Finally, to meet the requirements of the Dec Order, a second 5-year review of the southern Ontario silvicultural guide was undertaken in 2010. The primary recommendation from that review was for a revision of the southern Ontario guide to take place, and to begin once work on the AOU silvicultural guide is completed.

<Wish to acknowledge, and say thank you to the following individuals for their input and comments on this section: Harvey Anderson, Rob Arnup, David Chapeskie, and Joe Churcher. >

Literature Cited:

Anderson, H.W., B.D. Batchelor, C.M. Corbett, A.S. Corlett, D.T. Deugo, C.F. Husk and W.R. Wilson. 1990. A silvicultural guide for the tolerant hardwoods working group in Ontario. Science and Technology Series, Volume 7. Ontario Ministry of Natural Resources, Forest Resources Group. Queen's Printer for Ontario. Sault Ste. Marie, ON. 178 pp.

Anderson, H.W. and J.A. Rice. 1993. A tree marking guide for the tolerant hardwoods working group in Ontario, Science and Technology Series, Volume 8. Ontario Ministry of Natural Resources, Forest Resources Group. Queen's Printer for Ontario. Sault Ste. Marie, ON. 227 pp.

Arborvitae Environmental Services Ltd., Callaghan & Associates Inc., and CMC Ecological Consulting. 2000. Review of Forest Management Guides. Consultant's report to the Provincial Forest Technical Committee. 294 pp.

Arnup, R.W., Campbell, B.A., Raper, R.P., Squires, M.F., Virgo, K.D., Wearn, V.H. and White, R.G. 1988. A silvicultural guide for the spruce working group in Ontario. Science and Technology Series, Volume 4. Ont. Min. Nat. Resour., Queen's Printer for Ontario, Toronto, Ont. 100 pp.

Barkley, B. 1983. Silvicultural guide for hybrid poplar in Ontario. OMNR. Brockville. 35 pp.

Chapeskie, D.J., D.F. Galley, J.R. Mitchell, N.W. Quinn and H.H. Struik. 1989. A silvicultural guide for the white pine and red pine working groups in Ontario. Science and Technology Series, Volume 6. Ontario Ministry Natural Resources, Forest Resources Group. Queen's Printer for Ontario. Toronto. 102 pp.

Davidson, R.W., Atkins, R.C., Fry, R.D., Racey, G.D. and Weingartner, D.H. 1988. A silvicultural guide for the poplar working group in Ontario. Science and Technology Series, Volume 5. Ont. Min. Nat. Resour., For. Resour. Group. Queen's Printer for Ontario. Toronto, ON. 67 pp.

Environmental Assessment Board (EAB). 1994. Reasons for the decision and decision, Class Environmental Assessment for the Ministry of Natural Resources for Timber Management on Crown Lands in Ontario (EA-87-02). Queen's Printer for Ontario. Toronto. 576 p.

Frank, Robert M. and John C. Bjorkbom. 1973. A silvicultural guide for spruce-fir in the northeast. Gen. Tech. Rep. NE-6. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 29 pp.

Galloway, R. 1986. Jack pine working group. Ontario Ministry of Natural Resources. Silvicultural guide series. 40 pp.

Heeney, C.J. 1972. A silvicultural guide to hybrid poplar production. Ontario Department of Lands and Forests. Toronto. 16 pp., plus appendix.

Heeney, C.J. and D.S. Bruce. 1974. Silvicultural guide for the hard maple, yellow birch and hemlock working group. OMNR. Forest Resources Branch. Toronto. 65 pp.

Heeney, C., J. Kemperman, and G. Brown. 1975. Silvicultural guide to the aspen working group. OMNR, Forest Resources Branch, Toronto. 47 pp.

Kimmins, J.P. 1973. Forest ecology: the biological basis for the management of renewable forest resources. For. Chron. 49(1): 25-30.

Newnham, R.M. <FLC Reed and Associates Ltd>. 1978. Forest management in Canada: Summary. Canadian Forestry Service, Environment Canada. Forest Management Institute. Ottawa. Info Rep FMR-X-104. 55 pp.

Ontario Department of Lands and Forests (ODLF). 1948. Manual of Timber Management. Toronto. Baptist Johnson, Printer to the King's Most Excellent Majesty. 5 books. 303 pp.

OMNR. 1973a. Management of tolerant hardwoods in Algonquin Provincial Park. OMNR. For Management Branch. 84 pp.

OMNR. 1973b. Silvicultural guide to the white pine working group. OMNR, Forest Resources Branch, Toronto. 34 pp.

OMNR. 1983. Management of tolerant hardwoods in Algonquin Provincial Park. OMNR. Forest Resources Branch. 72 pp.

OMNR. 1986. Managing Red Pine Plantations. OMNR. Queen's Printer for Ontario. Toronto. 134 pp.

OMNR. 1997. Silvicultural guide to managing for black spruce, jack pine and aspen on boreal forest ecosites in Ontario. Version 1.1. Ont. Min. Nat. Resour., Queen's Printer for Ontario, Toronto. 3 books. 822 pp.

OMNR. 1998a. A silvicultural guide for the tolerant hardwood forest in Ontario. Ont. Min. Nat. Resour. Queen's Printer for Ontario. Toronto. 500p.

OMNR. 1998b. A silvicultural guide for the Great Lakes-St. Lawrence conifer forest in Ontario. Ont. Min. Nat. Resour. Queen's Printer for Ontario. Toronto. 424 pp.

OMNR. 2000. Silvicultural guide to managing southern Ontario forests, Ont. Min. Nat. Resour. Queen's Printer for Ontario. Toronto. 654 pp.

OMNR. 2003. Silvicultural guide to managing spruce, fir, birch, and aspen mixedwoods in Ontario's boreal forest. Version 1.0. Ont. Min. Nat. Resour., Queen's Printer for Ontario. 382 pp.

OMNR. 2004. Ontario tree marking guide, Version 1.1. Ont. Min. Nat. Resour. Queen's Printer for Ontario. Toronto. 252 pp.

OMNR. 2010a. Forest management guide for Great Lakes-St. Lawrence landscapes. Toronto. Queen's Printer for Ontario. 57 pp.

OMNR. 2010b. Forest management guide for conserving biodiversity at the stand and site scales. Toronto. Queen's Printer for Ontario. 211 pp.

Robinson, F.C. 1974. Silvicultural guide for the spruce working group. OMNR, Forest Resources Branch, Toronto. 43 pp.

Smith, C.R. and G. Brown <co-chairmen>. 1984. Jack Pine Symposium Proceedings, COJFRC Symposium Proceedings O-P-12, CFS Catalogue Number: Fo18-3/12-1984E, Sault Ste. Marie, ON. 195 pp.

Steneker, G.A. 1976. Guide to the silvicultural management of trembling aspen in the prairie provinces. Canadian Forestry Service, Northern Forest Research Centre, Edmonton, Alberta. Information Report NOR-X-164. 6pp.

Appendix 2 – Ecological Land Classification and Silviculture

Prepared by Peter Uhlig [with minor edits]

Sustainable resource management requires maintenance of ecosystem components, their functions and supporting processes. To be sustainable, silvicultural activities and technologies must be applied within the bounds of ecosystem capacity and resilience. Central to defining these bounds is an understanding of the range of ecosystem responses to management practices (Hills 1961, Bailey 1996; Uhlig and Jordan 1994). Ecosystem classification is a critical tool to this end.

An ecosystem classification delineates areas of similar ecology at different nested—or hierarchical—levels, providing an effective framework for organizing knowledge of important ecosystem features, spatial patterns and interactions (Figure 1). Classifying ecosystems allows for better description, greater understanding of controlling processes, efficient inventory, communication, and hence management.

Both abiotic and biotic factors are used to classify ecosystems into units that are ecologically-meaningful (Hills 1961, Rowe and Sheard 1981, Bailey 1996). Units within a class have similar composition and structure, and share similar ecological processes such as growth and succession. The hierarchical structure of an ecosystem classification facilitates planning and management at different scales, from coarse level suitable for strategic planning (ecoregions and districts), through to a fine levels (ecosite, substrate and vegetation types), ideal for site-level interpretation (Rowe 1980).

Ecosystem classification, together with inventory and management interpretations, provide the fundamental information framework essential to the planning, management, monitoring and evaluation for all of Ontario's forest resources. Ranging from ecoregional reporting on state of the resources, policy, resource planning, site-level management decision support, growth and yield evaluation, successional projections, effectiveness monitoring and accountability at national/provincial scales.

Figure 1 – Ecoregions and Ecodistricts (Crins et al 2009)

Ontario's ecosystem classification program (ELC)

While ecosystem classification spans many scales and provides numerous information products the level most pertinent to the majority of forest management concerns is the Ecosite level. Ecosites are landscape areas consisting of typical, recurring associations of Vegetation Types (v-type) and Substrate Types (s-type) combinations within a context of repeating toposequence, landform and catenary sequences.

Ecosites are, first and foremost, based on the stable features of the physical landscape (substrate depth, texture, landform and nutrient regimes). Ecosite polygons are identified and delineated using those features of the environment which most affects the distribution and character of the vegetation, including substrate formation or depositional types (e.g. rock, organic, frozen, active, flooded), along with the substrate depth, texture, slope, and moisture. These physical features make up the "ecological domains", or the ecological drivers, which direct the establishment and growth of vegetation, or community assembly. The delineation of the polygon is finally determined by the varying character of the vegetation, which is responding to not only the physical environment, but disturbance and succession as well. Since different vegetation communities can exist on similar environmental features, vegetation characteristics like treed, shrub, herbaceous, coniferous, deciduous (to name a few) are used as the basis to further distinguish and delineate polygons. Figure 2 provides a graphic depiction of the various scales influencing ecosite classification.

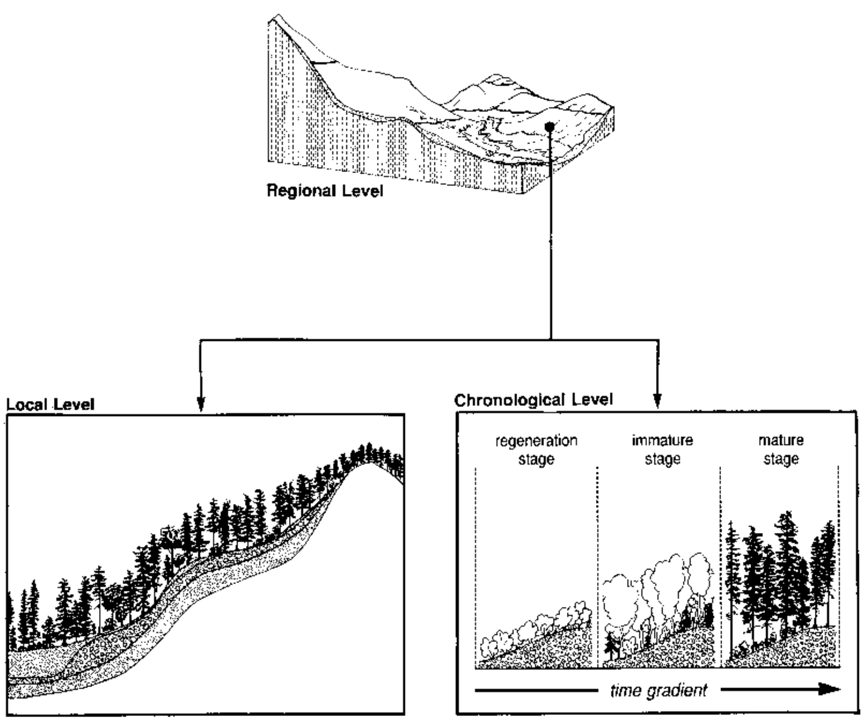


Figure 2 – Graphic depiction of regional, local, and chronological influences on ecosite determination.

With their fundamental characteristics of substrate and vegetation characteristics, and hence site-level biological legacies, they also form a suitable information framework to assist with the understanding of vegetation changes over time, succession, establishment and competition.

Ecosites are spatial units to facilitate major corporate and partner ecological inventory, monitoring and assessment programs in support of operational planning, natural heritage planning and various program deliveries. Ecosites will provide the framework for operational planning of forests, wetlands, wildlife habitat, and natural heritage applications. In addition, ecosites may become the corporate inventory classes that MNR will be delivering through automated mapping processes that are critical to mapping ecosystems for watershed and other jurisdictional and local planning. Figure 3 provides an example inventory product, ecosite classification, and photograph of ground conditions.

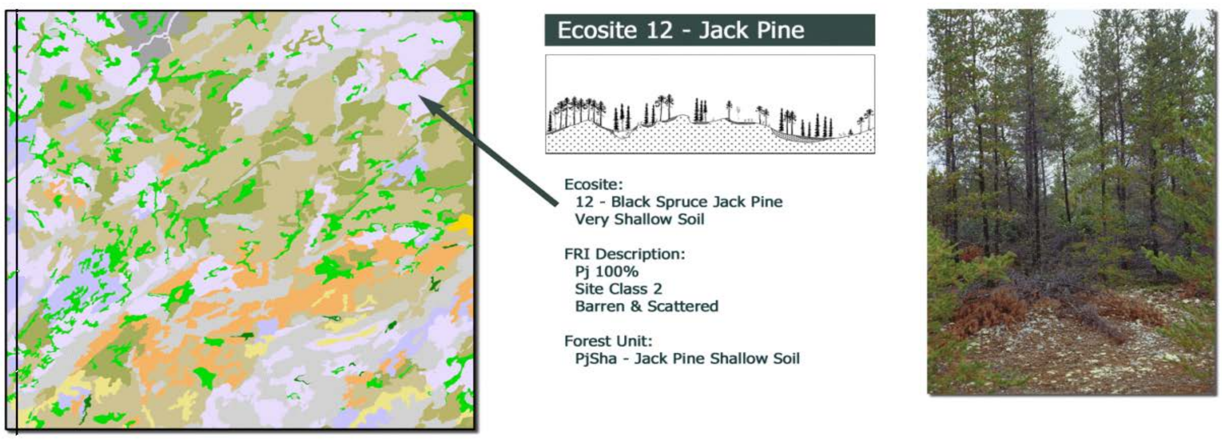


Figure 3 – ELC linkage to inventory.

An ecosystem classification can be re-interpreted through class aggregations for a variety of applications pertinent to silviculture. The results are most effective when coupled with an explicit, spatial inventory such as the first frame of figure 3. The re-interpretation and aggregation is typically customized to the specific question or application. For example if a forest manager was interested in forecasting the anticipated amount of competition following harvest, they would consider both direct site attributes (e.g. texture, moisture regime, depth, etc.) as well as current vegetation (e.g. indicator species, open vs closed canopy, etc), both of which can be interpreted from ecosite information.

Substrates provide a stable representation of key factors supporting forest growth and play a critical role in the definition and recognition of ecosites. There are many ways to describe and quantify the substrate. Ecosites are ordered primarily by depth, texture, chemistry and moisture regime. Gradients of moisture and nutrients are particularly useful summaries of the combined influence of many substrate characteristics (depth, texture, parent material, landform, slope position, etc). Combining these two conceptual scales into a single diagram provides a full edatopic grid which can be used to examine species and ecosite distribution in a broad and relevant environmental space. **The**

resulting diagrams (immediately below this text) portray, for general silvicultural interpretation, the growing domain for each species of interest to this guide.

The nutrient regime classification used in the edatope diagrams was drawn from well developed applications in B.C. and Alberta using specific soil morphological features quantified in terms of soil nutrient chemical characteristics (Figure 5).

	NUTRIENT RANGE/Indicators of Fertility				
	Very Poor	Poor	Moderate	Rich	Very Rich
Humus Form	<----increasing depth Mor				
			Moder		
				Mull	
	Fibric Peaty Mors				
			Mesic/Humic Peaty Mors		
				Anmoors and Marl	
A Horizon	Ae				
		A horizon may be absent			
			Ah present and thickness increases-->		
Substrate Texture	Sandy		Coarse Loamy		
			Silty		Fine Silty and Clayey
Coarse Fragments Abundance	High				
			Medium		Low
Substrate Depth	Very Shallow and shallow				
			Moderately Deep and Deep		
Bedrock Exposure	High				
			Low		
ph of parent material	Acidic				
		Acidic to Neutral			
				Neutral or Calcareous	
bedrock lithology					
Salinity	Saline				
			Non-Saline		
Slope Seepage			Seepage may be present		
Seasonal Pooling			Seasonal Pooling may be present		
Groundwater	Stagnant				
			Moving		

Figure 5 – nutrient regime classification used to develop the edatope diagrams

The moisture regime classification follows that originally defined by Hills in 1959. Moisture regime expresses the long-term growing season availability for plant growth with a scale ranging from Dry (theta) through to wet (9).

To define the nutrient/moisture domain of each species, province-wide plot data networks supporting the ELC (Figure 6) were interrogated in conjunction with the ecosite level of classification to examine the affinities and prevalence of species across moisture and nutrient gradients. In general, a threshold of 20% occupancy was used for common species, and individually adjusted for less common species. Where data was limited, species-site relationships from other published sources were used as an additional source of information. The resulting domain therefore is neither an inclusive domain of all edaphic conditions where that species would occur, nor an ideal domain where growth or management success would be optimized. Rather, it is a generalized domain where the bulk of observations of that species occur.

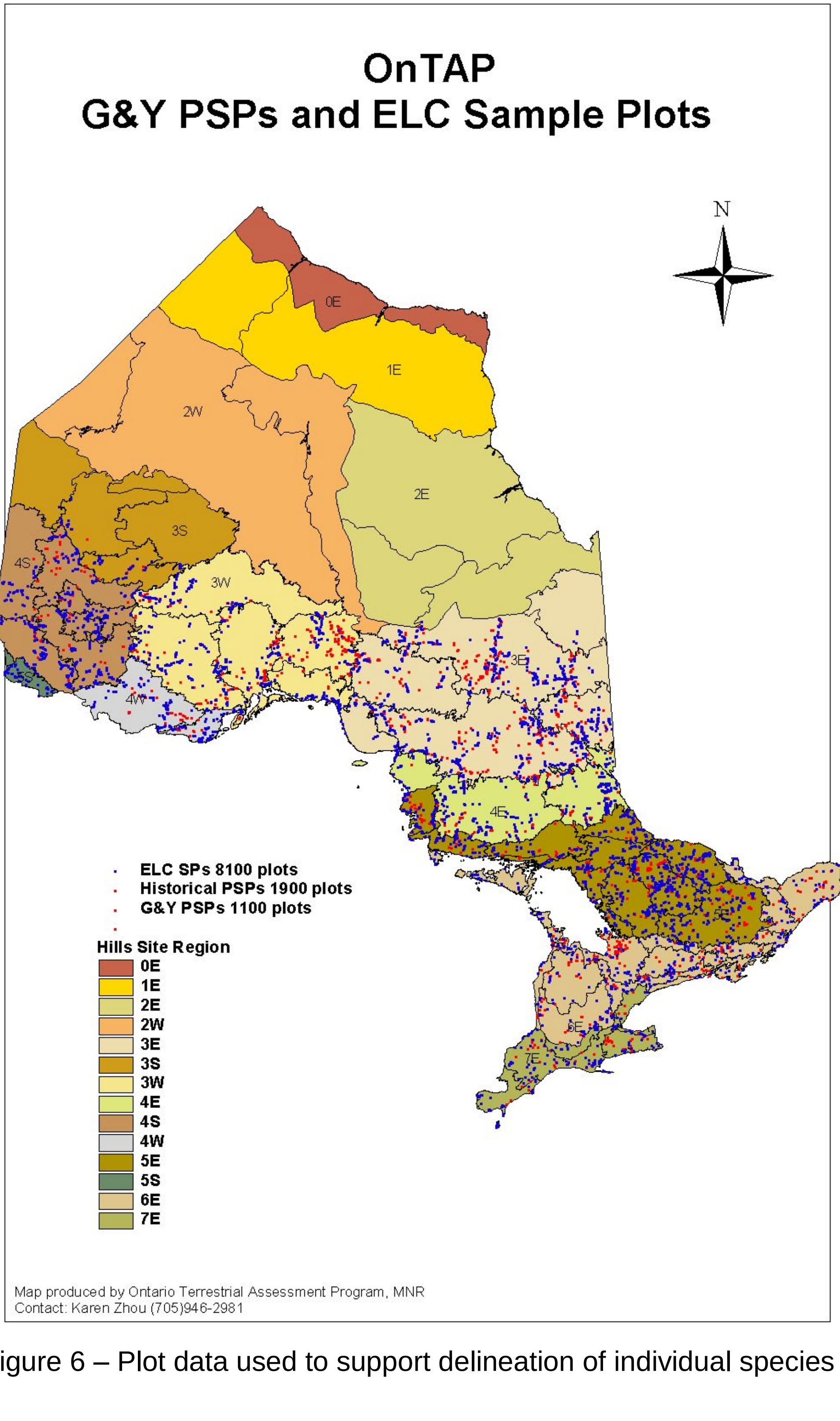
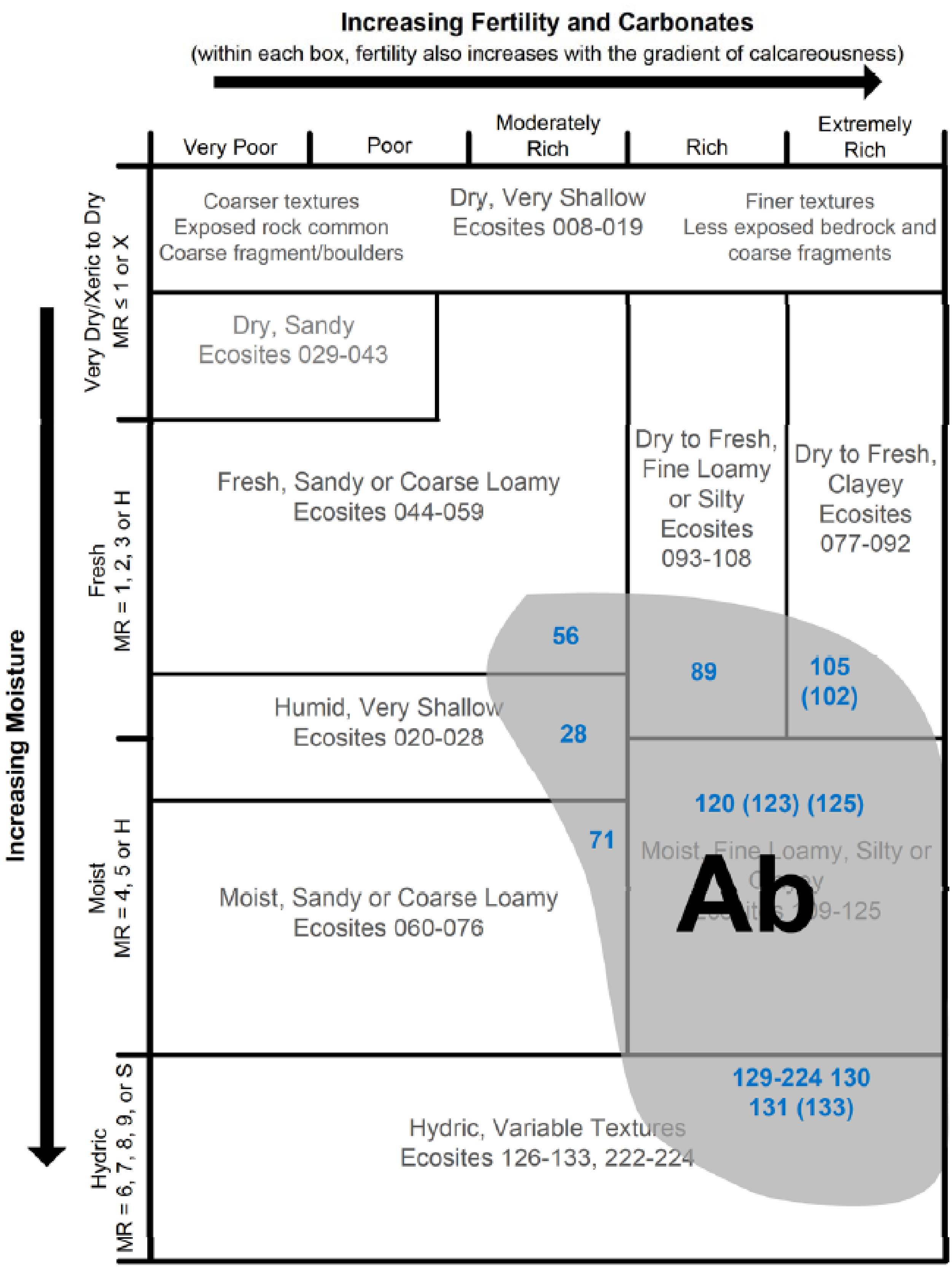


Figure 6 – Plot data used to support delineation of individual species domains.

The following pages present edatopes for individual species using common abbreviated species codes that can be translated as follows:

Code	Common name
Ab	black ash
Aw	white ash
Bd	basswood
Be	beech
Bf	balsam fir
Bw	white birch
By	yellow birch
Cb	black cherry
Ce	eastern white cedar
Ew	white elm
He	eastern hemlock
Id	ironwood
La	eastern larch
Mh	sugar maple
Mr	red maple
Ms	soft maple group
Or	red oak
Pb	balsam poplar
Pg	large-toothed aspen
Pj	jack pine
Pot	trembling aspen
Pr	red pine
Pw	white pine
Sb	black spruce


Increasing Fertility and Carbonates
(within each box, fertility also increases with the gradient of calcareousness)
Very Poor
Poor
Moderately Rich
Rich
Extremely Rich
Increasing Moisture
Very Dry/Xeric to Dry MR ≤ 1 or X
Fresh MR = 1, 2, 3 or H
Moist MR = 4, 5 or H
Hydric MR = 6, 7, 8, 9, or S
Coarser textures Exposed rock common Coarse fragment/boulders
Dry, Very Shallow Ecosites 008-019
Finer textures Less exposed bedrock and coarse fragments
Dry, Sandy Ecosites 029-043
Fresh, Sandy or Coarse Loamy Ecosites 044-059
Dry to Fresh, Fine Loamy or Silty Ecosites 093-108
Dry to Fresh, Clayey Ecosites 077-092
56
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Moist, Fine Loamy, Silty or Clayey Ecosites 109-125
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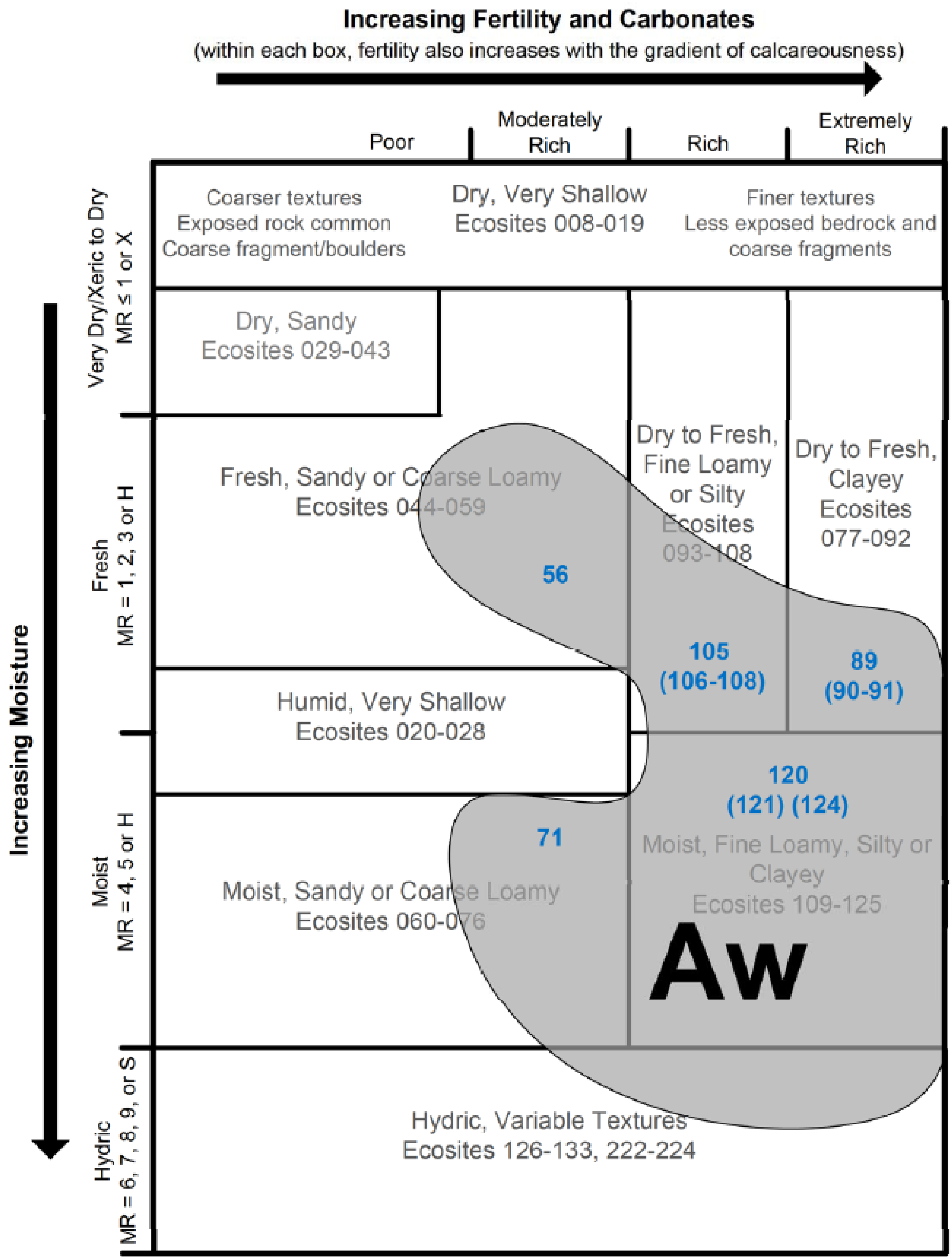
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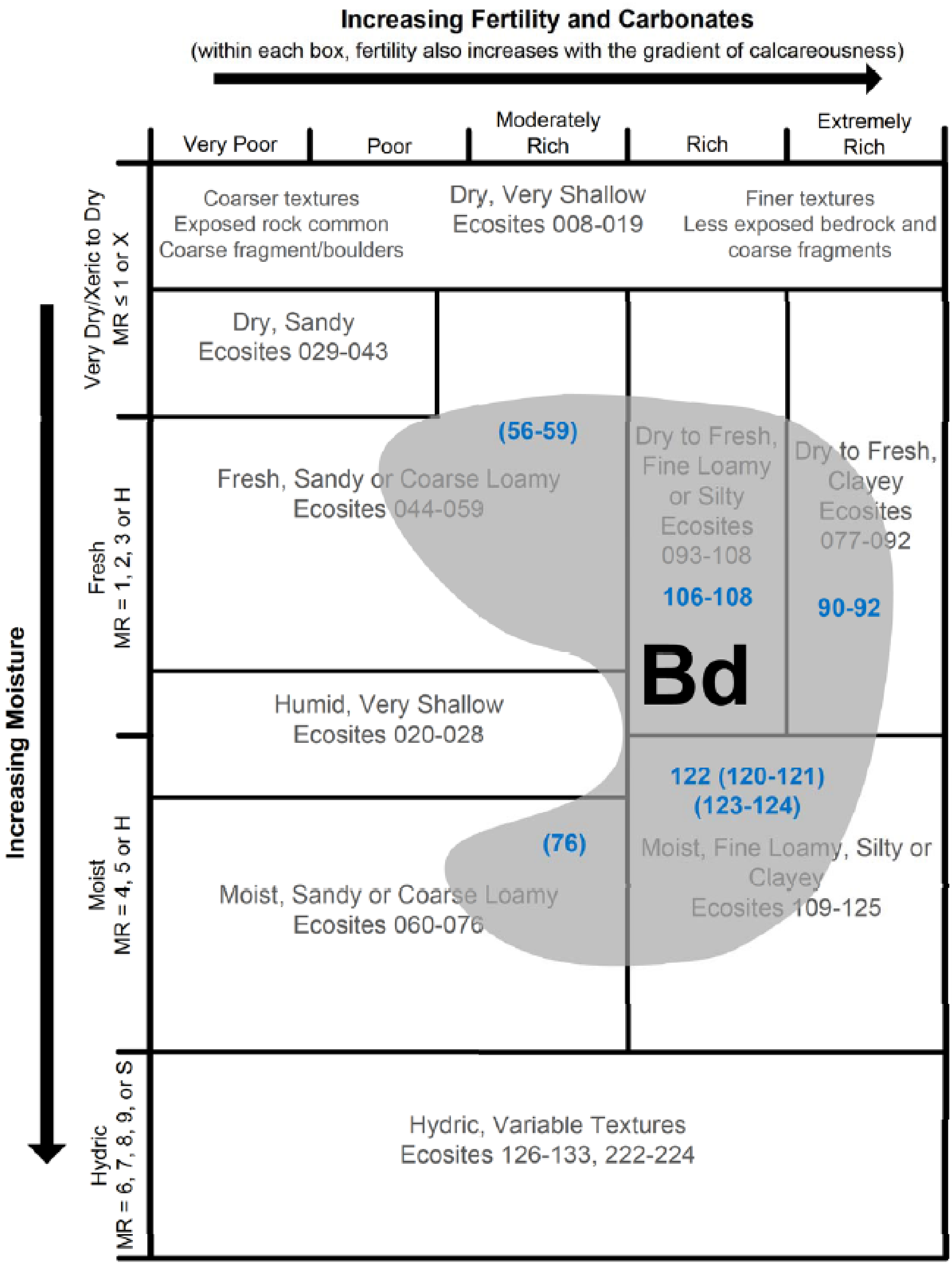
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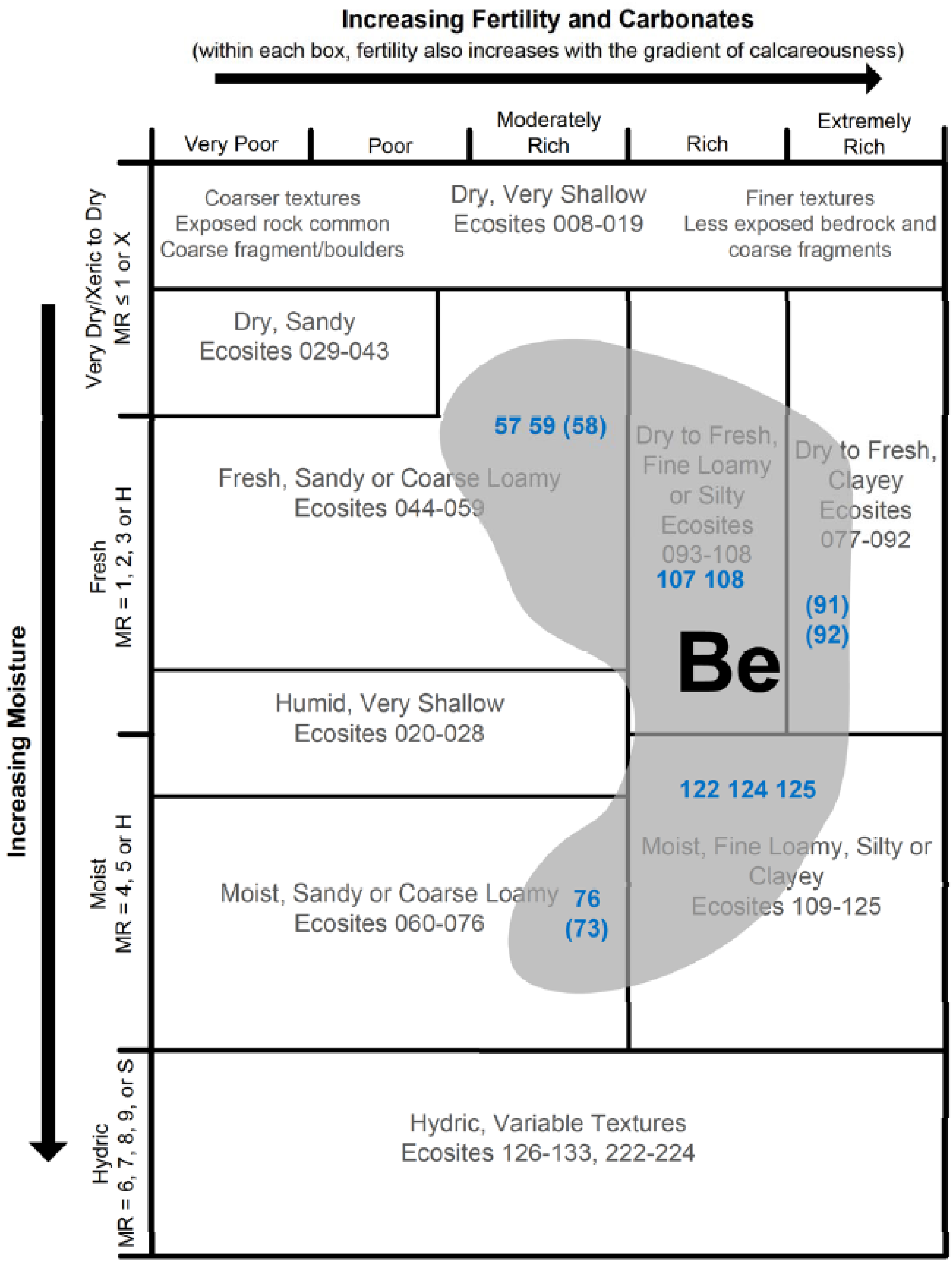
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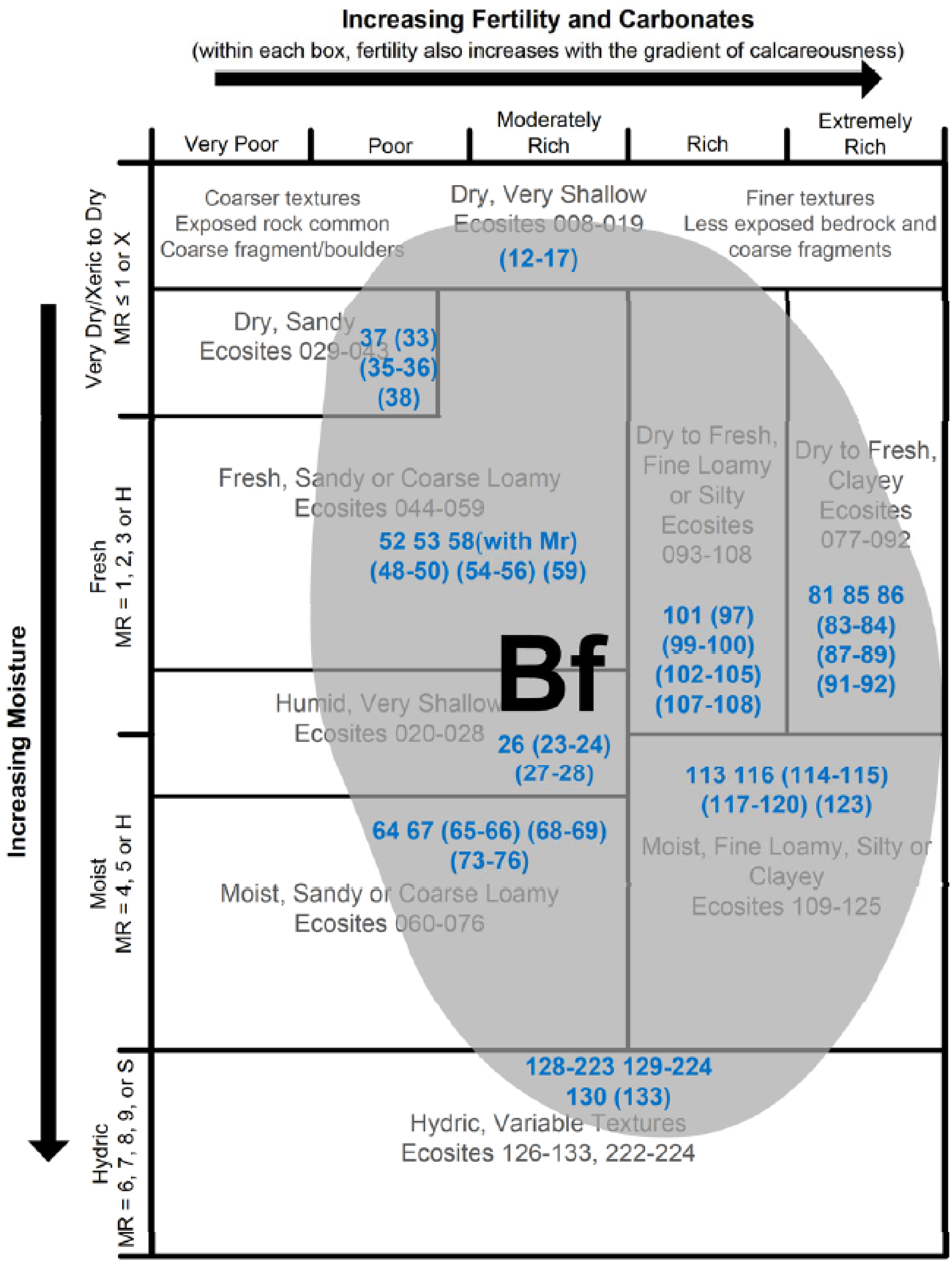
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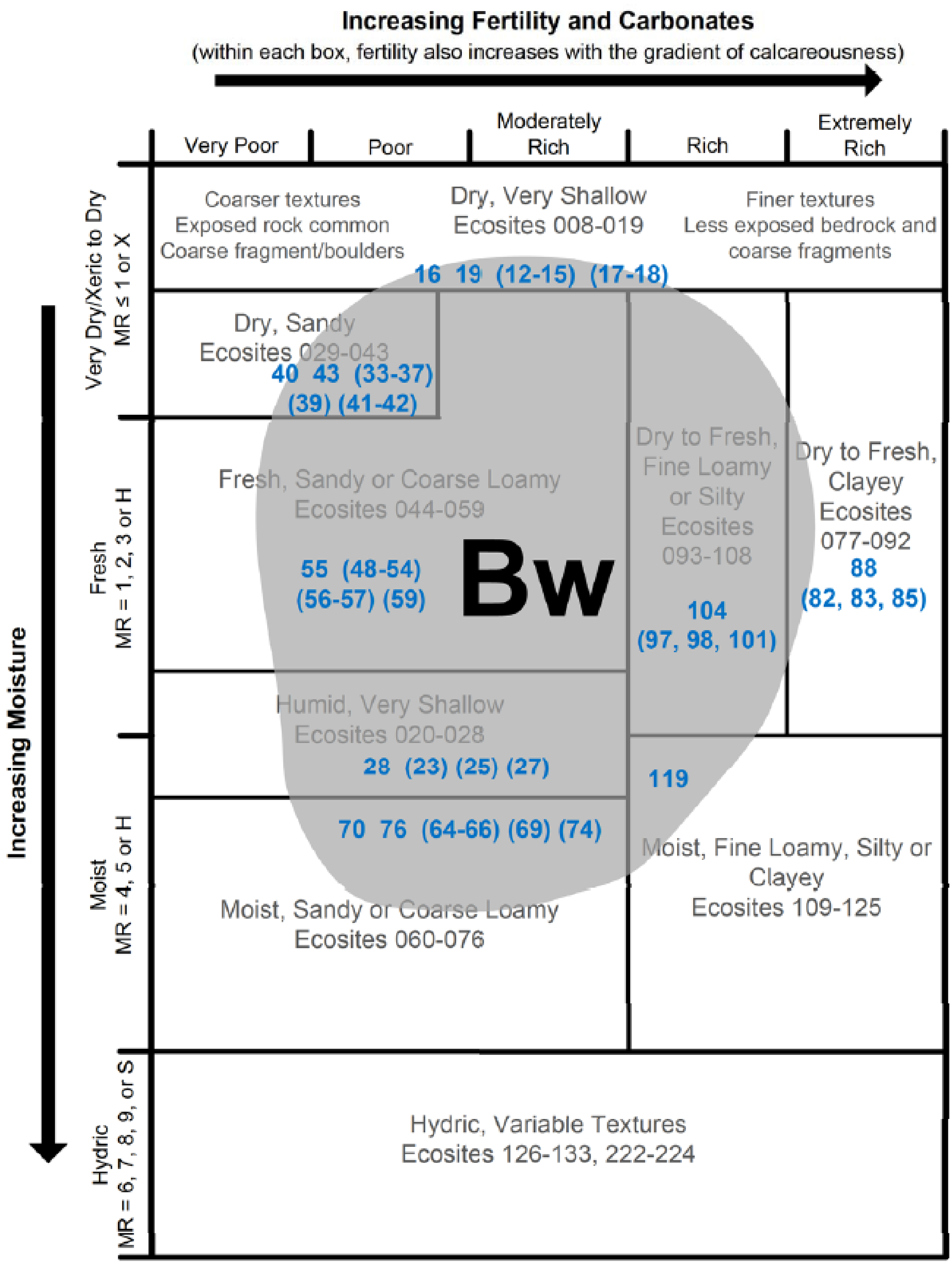
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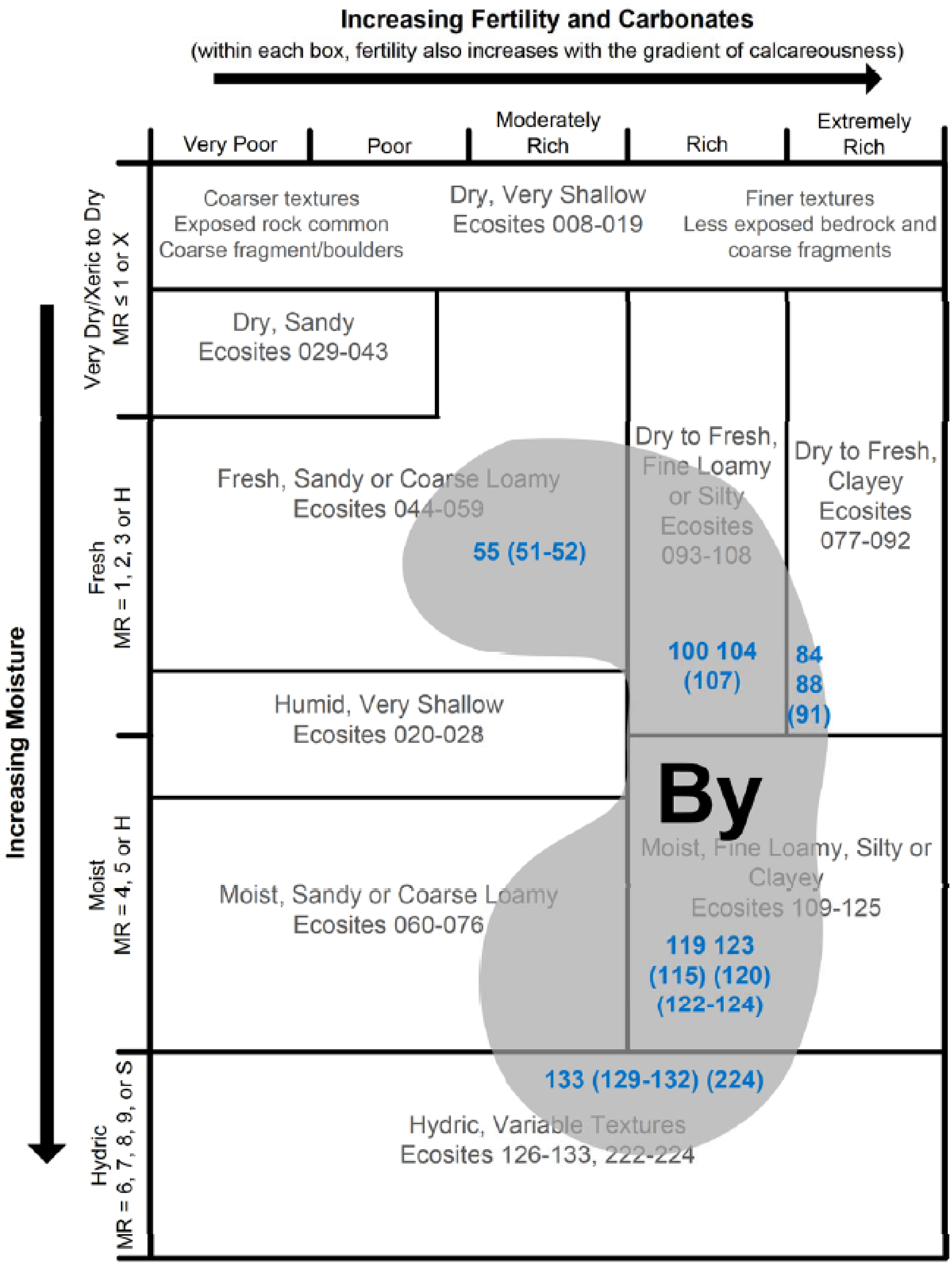
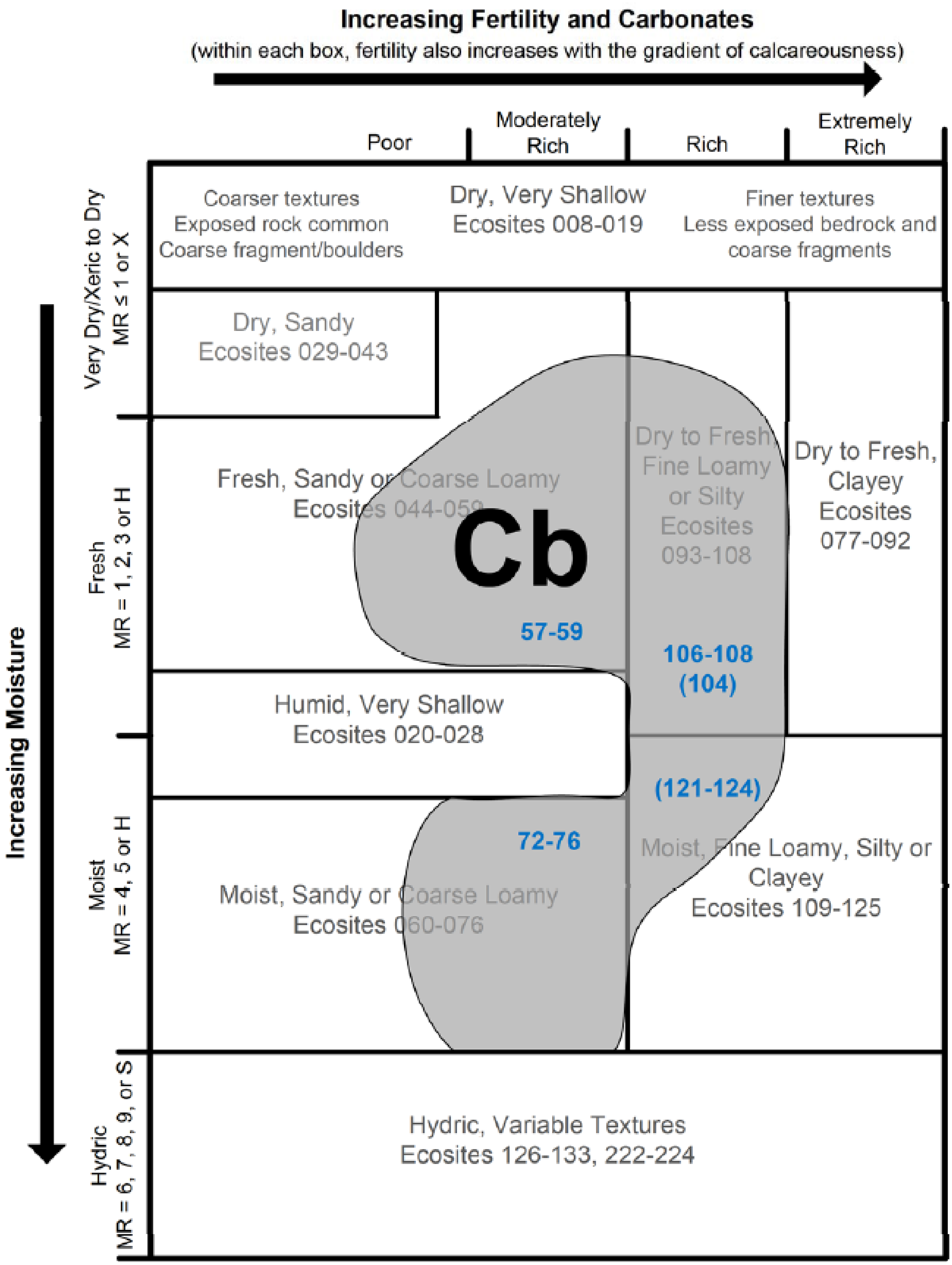
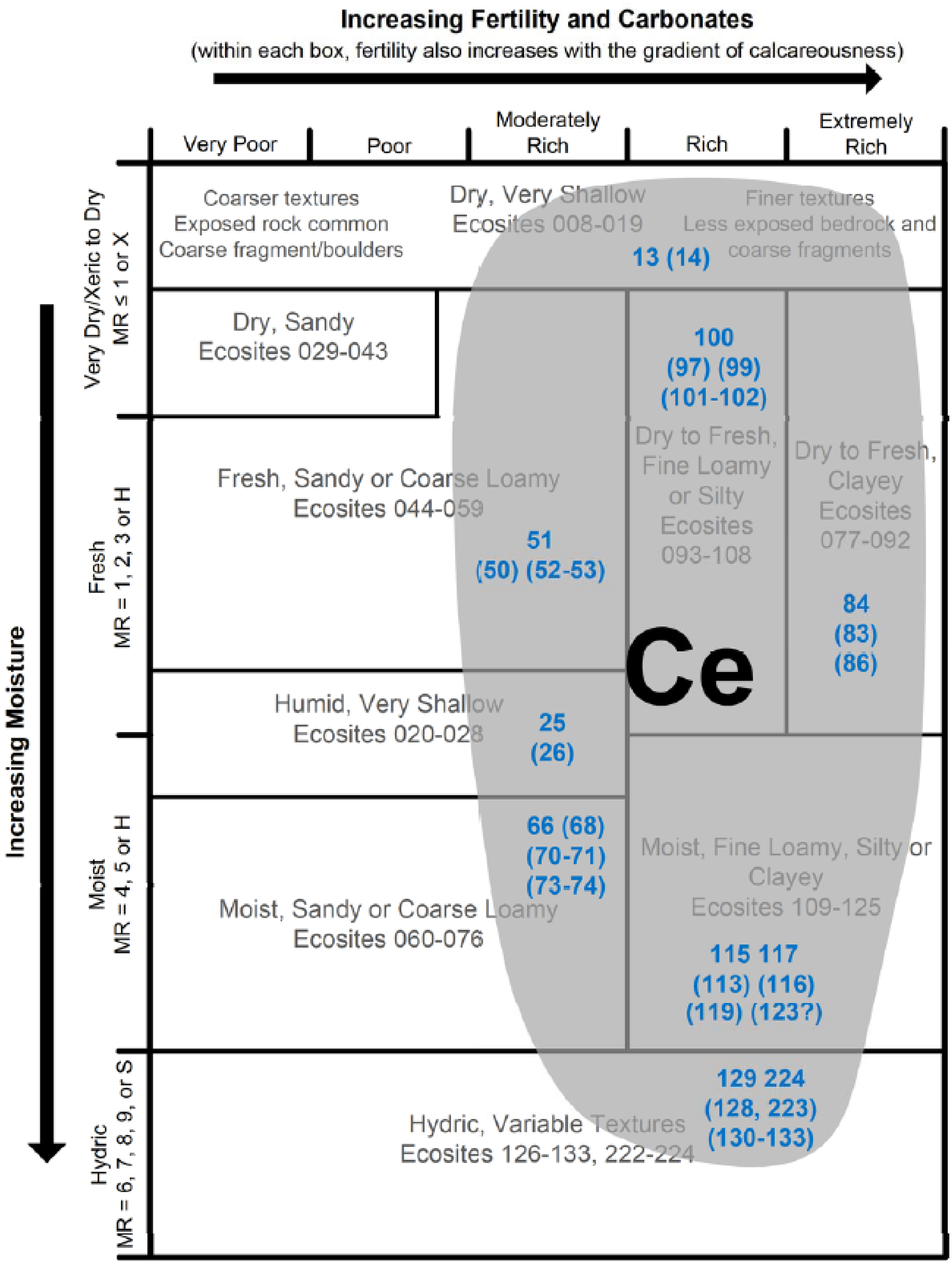
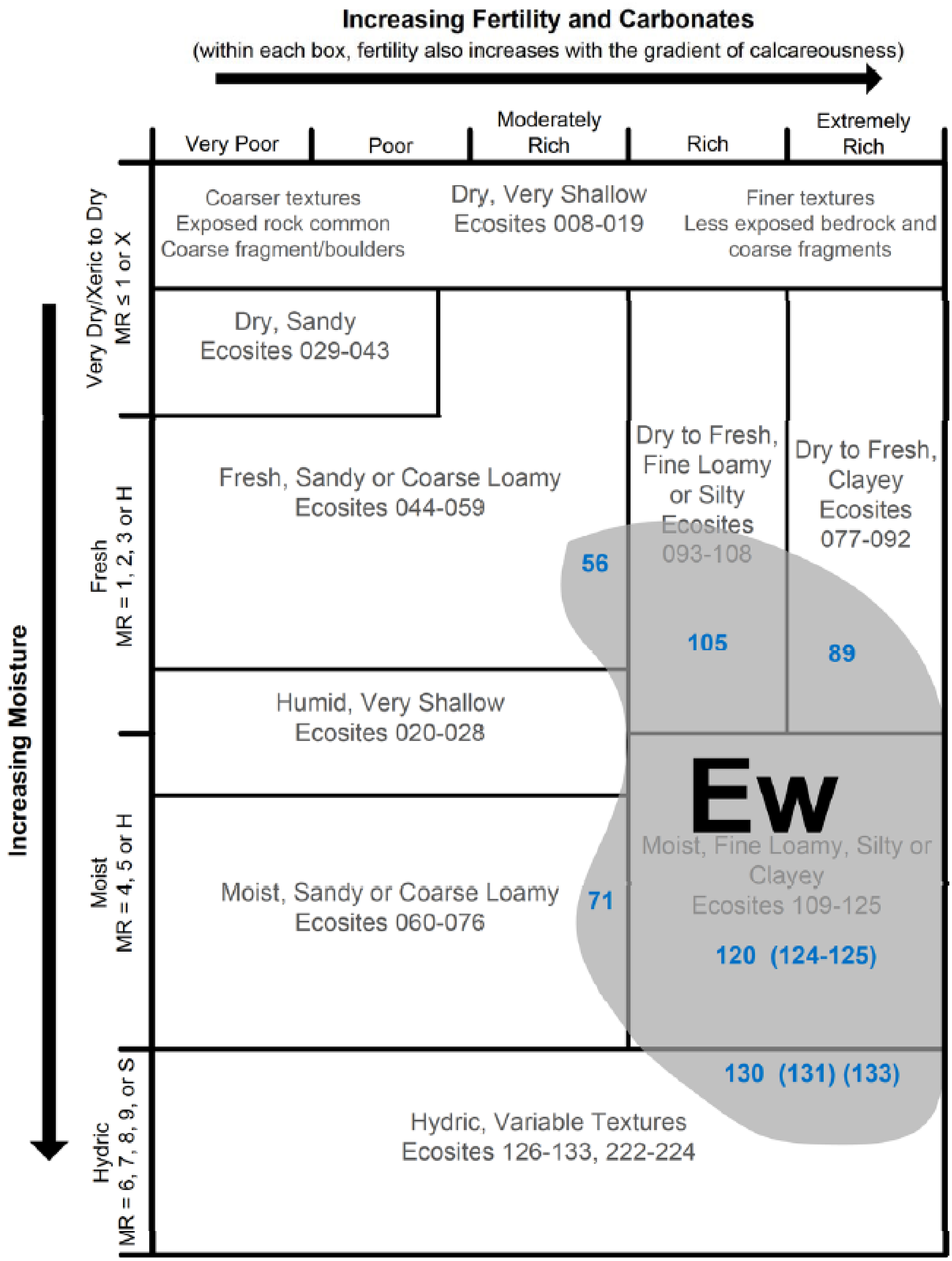
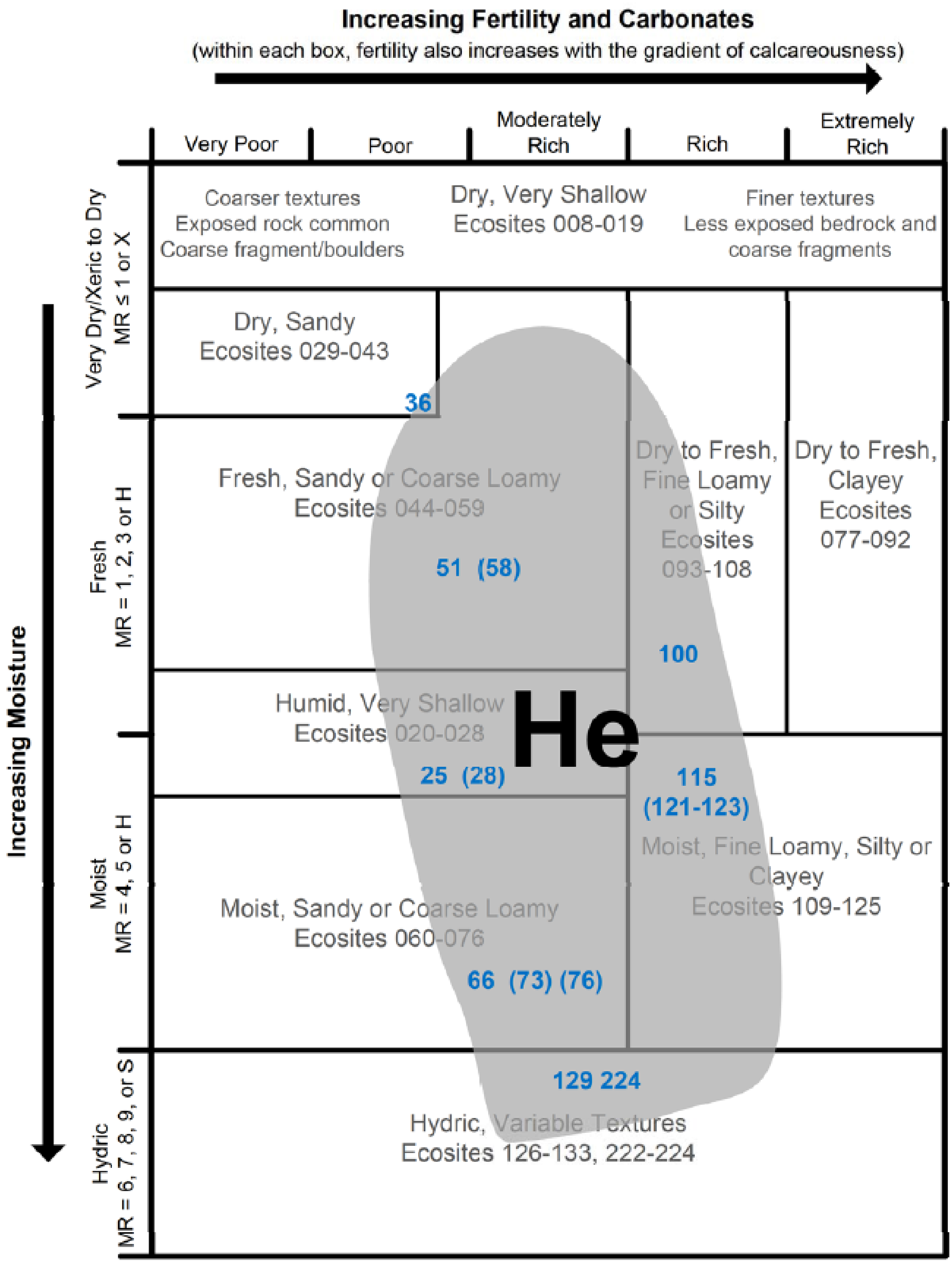
Coarser textures
Exposed rock common
Coarse fragment/boulders
Dry, Very Shallow
Ecosites 008-019
Finer textures
Less exposed bedrock and coarse fragments
16 19 (12-15) (17-18)
Dry, Sandy
Ecosites 029-043
40 43 (33-37)
(39) (41-42)
Fresh, Sandy or Coarse Loamy
Ecosites 044-059
55 (48-54)
(56-57) (59)
Bw
Dry to Fresh, Fine Loamy or Silty
Ecosites 093-108
104
(97, 98, 101)
Dry to Fresh, Clayey
Ecosites 077-092
88
(82, 83, 85)
Humid, Very Shallow
Ecosites 020-028
28 (23) (25) (27)
119
70 76 (64-66) (69) (74)
Moist, Fine Loamy, Silty or Clayey
Ecosites 109-125
Moist, Sandy or Coarse Loamy
Ecosites 060-076
Hydric, Variable Textures
Ecosites 126-133, 222-224

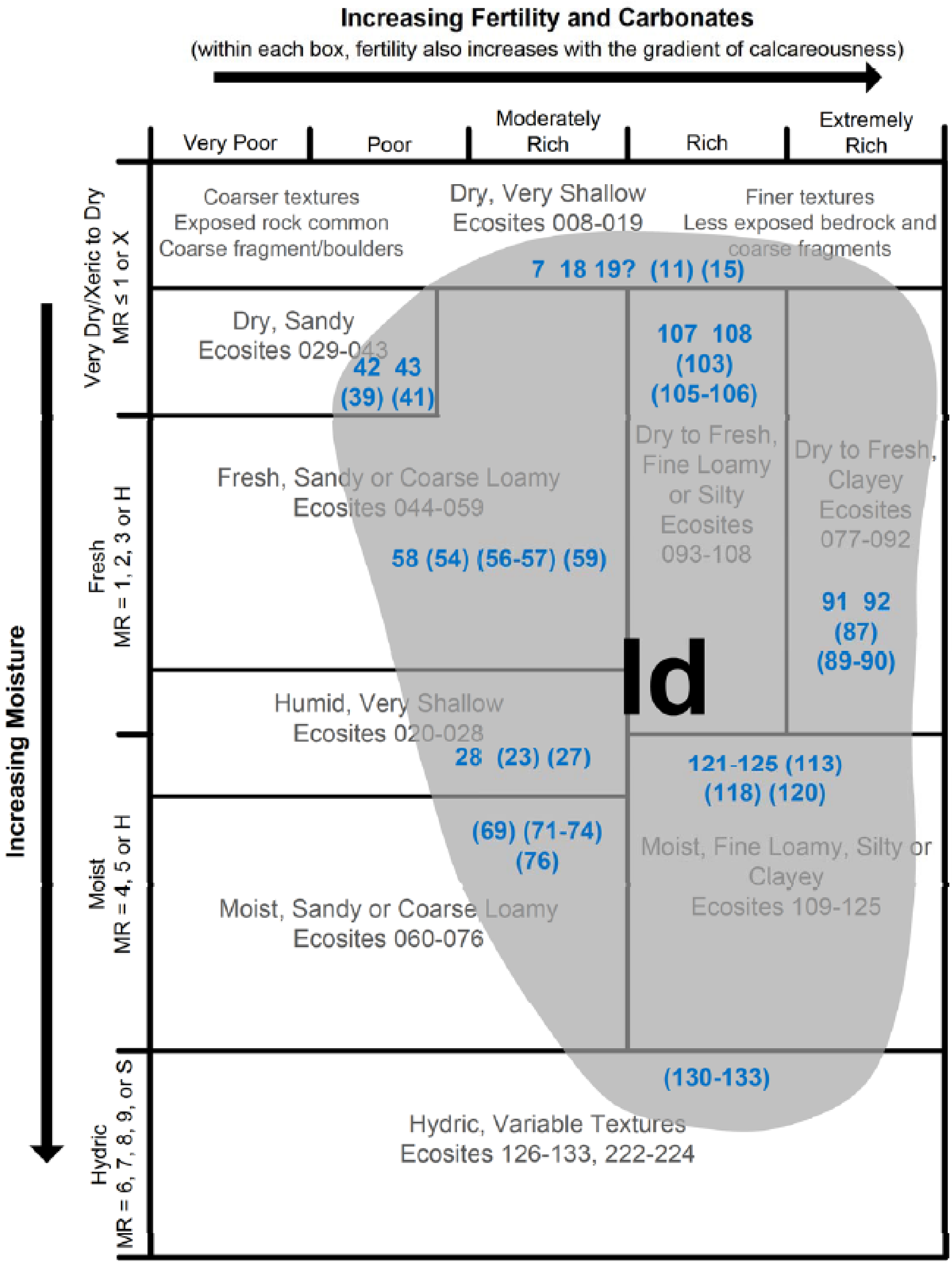

Increasing Fertility and Carbonates
(within each box, fertility also increases with the gradient of calcareousness)
Very Poor
Poor
Moderately Rich
Rich
Extremely Rich
Increasing Moisture
Very Dry/Xeric to Dry MR ≤ 1 or X
Fresh MR = 1, 2, 3 or H
Moist MR = 4, 5 or H
Hydric MR = 6, 7, 8, 9, or S
Coarser textures
Exposed rock common
Coarse fragment/boulders
Dry, Very Shallow
Ecosites 008-019
Finer textures
Less exposed bedrock and coarse fragments
Dry, Sandy
Ecosites 029-043
Fresh, Sandy or Coarse Loamy
Ecosites 044-059
55 (51-52)
Dry to Fresh, Fine Loamy or Silty Ecosites 093-108
100 104
(107)
Dry to Fresh, Clayey Ecosites 077-092
84
88
(91)
Humid, Very Shallow
Ecosites 020-028
By
Moist, Fine Loamy, Silty or Clayey
Ecosites 109-125
119 123
(115) (120)
(122-124)
Moist, Sandy or Coarse Loamy
Ecosites 060-076
133 (129-132) (224)
Hydric, Variable Textures
Ecosites 126-133, 222-224

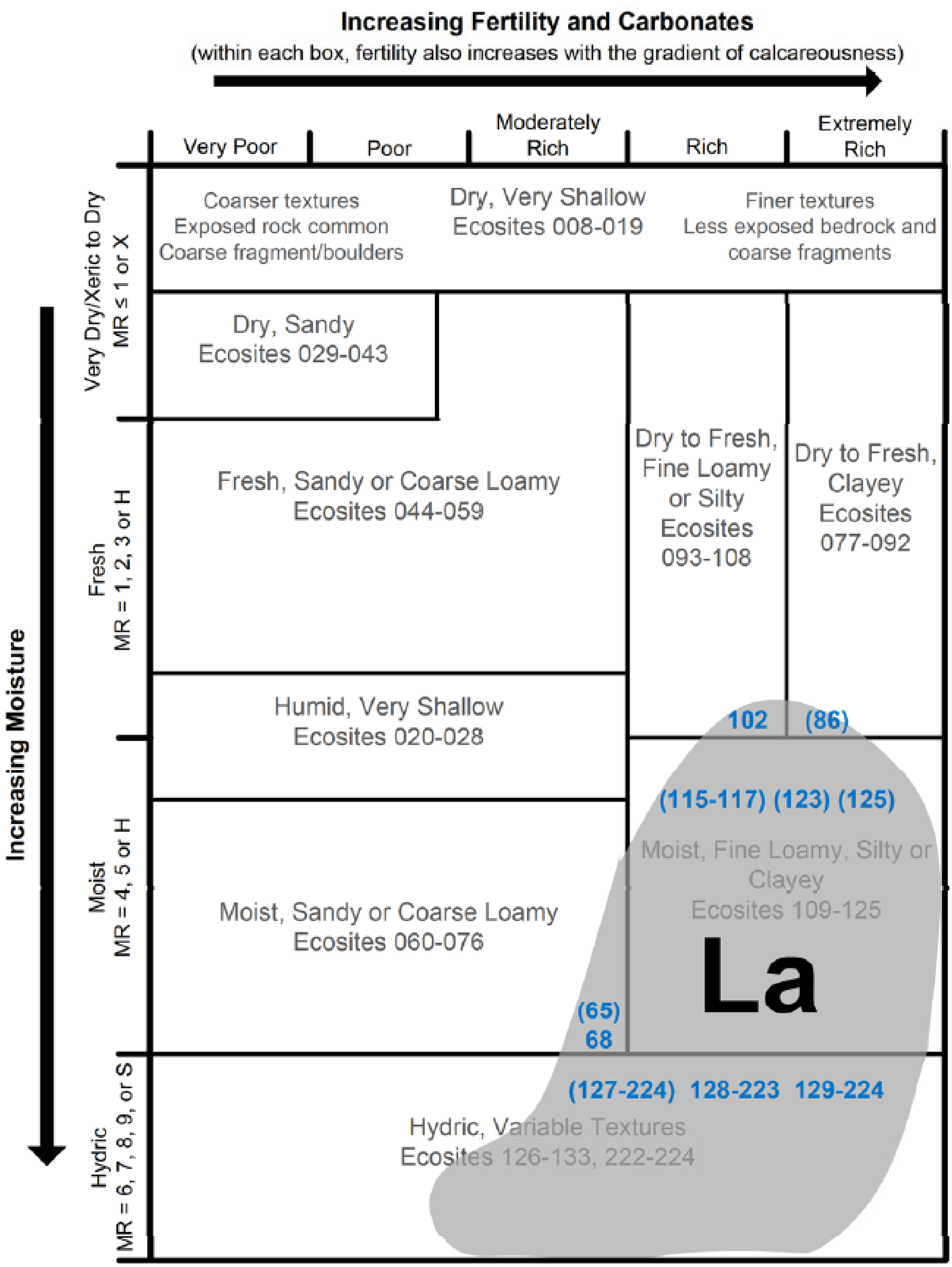

Increasing Fertility and Carbonates
(within each box, fertility also increases with the gradient of calcareousness)
Poor
Moderately Rich
Rich
Extremely Rich
Increasing Moisture
Very Dry/Xeric to Dry MR ≤ 1 or X
Fresh MR = 1, 2, 3 or H
Moist MR = 4, 5 or H
Hydric MR = 6, 7, 8, 9, or S
Coarser textures
Exposed rock common
Coarse fragment/boulders
Dry, Very Shallow
Ecosites 008-019
Finer textures
Less exposed bedrock and coarse fragments
Dry, Sandy
Ecosites 029-043
Fresh, Sandy or Coarse Loamy
Ecosites 044-059
Dry to Fresh Fine Loamy or Silty
Ecosites 093-108
Dry to Fresh, Clayey
Ecosites 077-092
Cb
57-59
106-108
(104)
Humid, Very Shallow
Ecosites 020-028
(121-124)
72-76
Moist, Sandy or Coarse Loamy
Ecosites 060-076
Moist, Fine Loamy, Silty or Clayey
Ecosites 109-125
Hydric, Variable Textures
Ecosites 126-133, 222-224

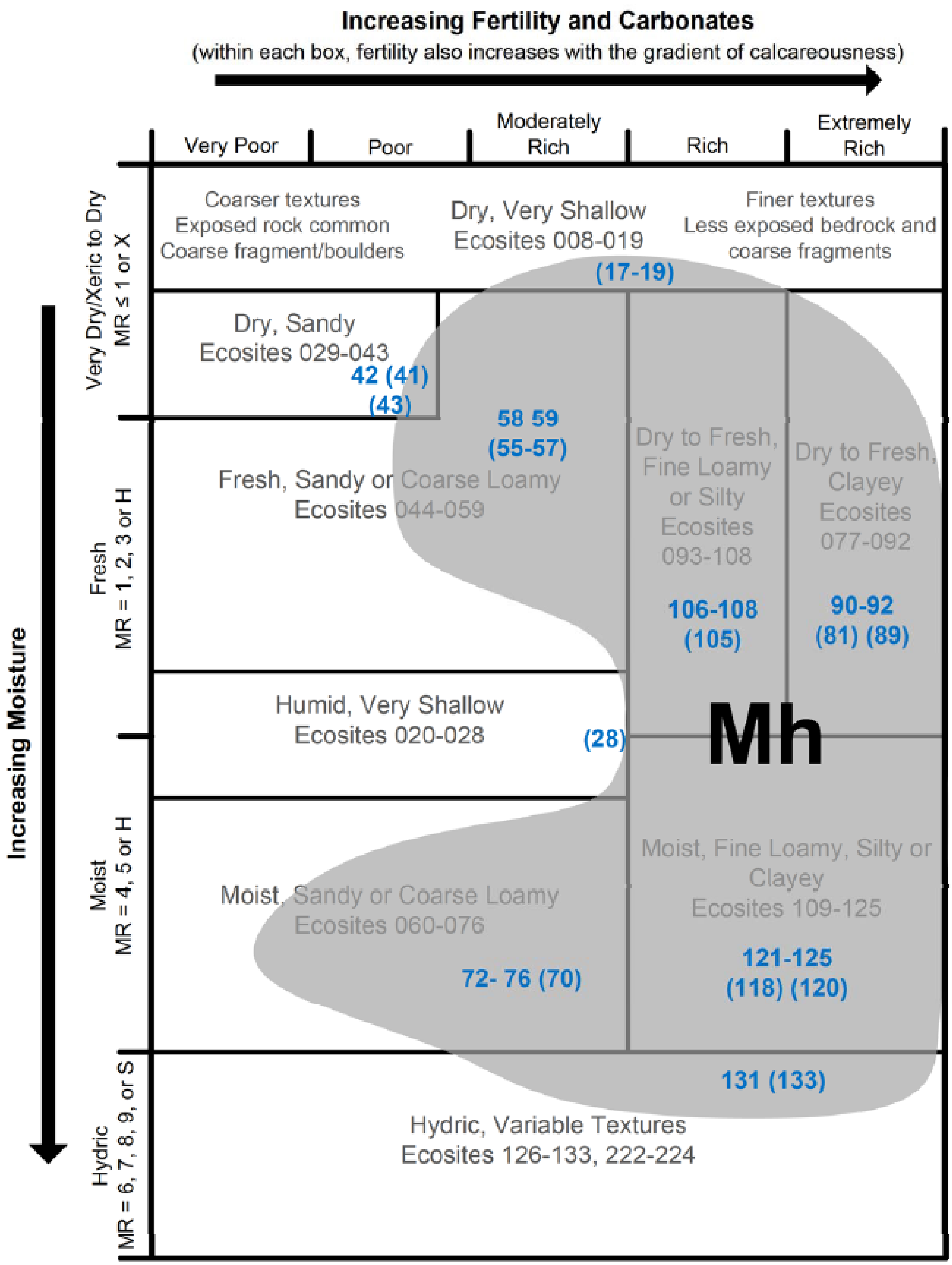

Increasing Fertility and Carbonates
(within each box, fertility also increases with the gradient of calcareousness)
Very Poor
Poor
Moderately Rich
Rich
Extremely Rich
Increasing Moisture
Very Dry/Xeric to Dry MR ≤ 1 or X
Fresh MR = 1, 2, 3 or H
Moist MR = 4, 5 or H
Hydric MR = 6, 7, 8, 9, or S
Coarser textures
Exposed rock common
Coarse fragment/boulders
Dry, Very Shallow
Ecosites 008-019
13 (14)
Finer textures
Less exposed bedrock and coarse fragments
Dry, Sandy
Ecosites 029-043
100
(97) (99)
(101-102)
Dry to Fresh, Fine Loamy or Silty
Ecosites 093-108
Dry to Fresh, Clayey
Ecosites 077-092
Fresh, Sandy or Coarse Loamy
Ecosites 044-059
51
(50) (52-53)
84
(83)
(86)
Ce
Humid, Very Shallow
Ecosites 020-028
25
(26)
66 (68)
(70-71)
(73-74)
Moist, Sandy or Coarse Loamy
Ecosites 060-076
Moist, Fine Loamy, Silty or Clayey
Ecosites 109-125
115 117
(113) (116)
(119) (123?)
129 224
(128, 223)
(130-133)
Hydric, Variable Textures
Ecosites 126-133, 222-224

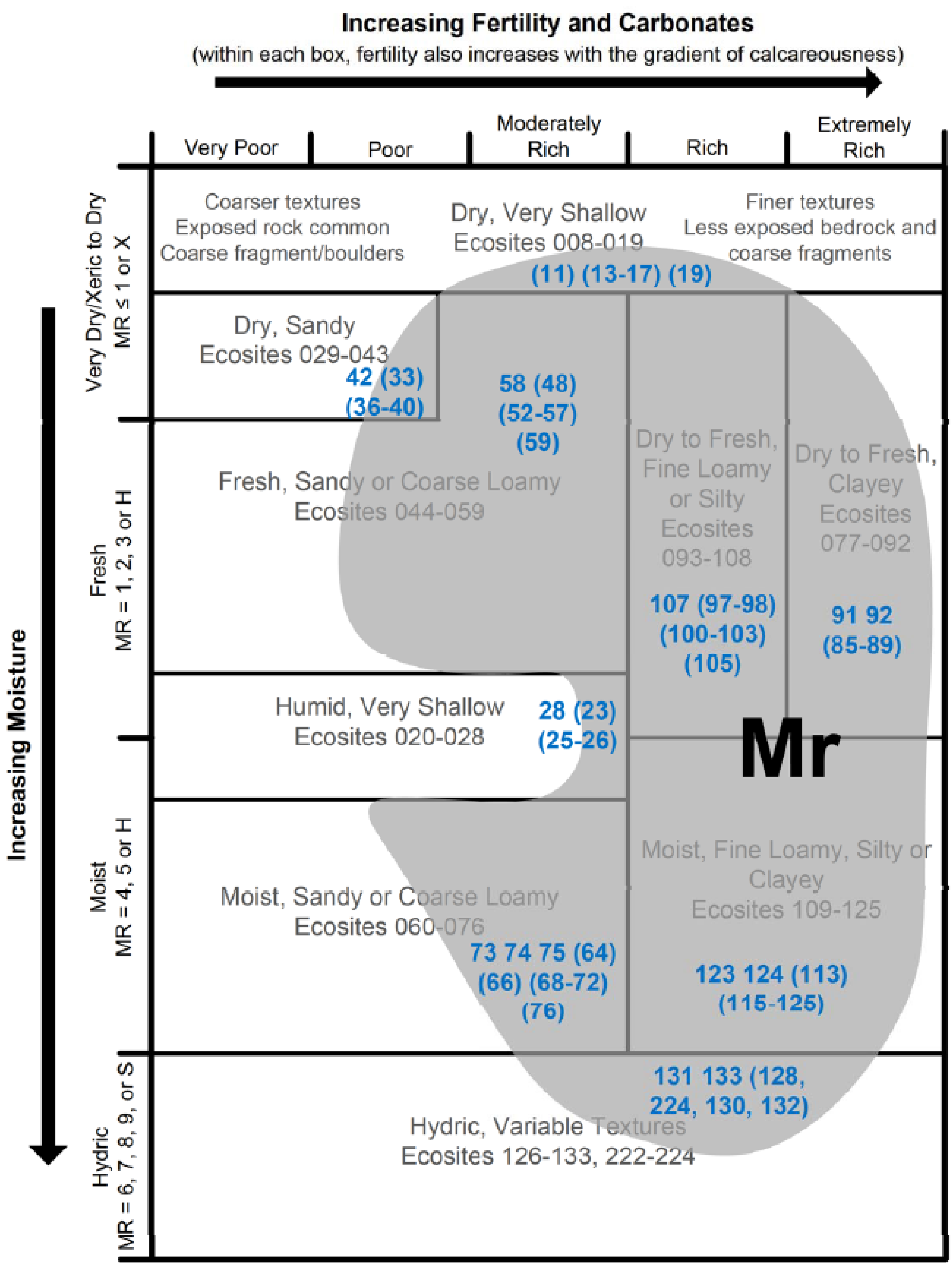

Increasing Fertility and Carbonates
(within each box, fertility also increases with the gradient of calcareousness)
Very Poor
Poor
Moderately Rich
Rich
Extremely Rich
Increasing Moisture
Very Dry/Xeric to Dry MR ≤ 1 or X
Fresh MR = 1, 2, 3 or H
Moist MR = 4, 5 or H
Hydric MR = 6, 7, 8, 9, or S
Coarser textures
Exposed rock common
Coarse fragment/boulders
Dry, Very Shallow
Ecosites 008-019
Finer textures
Less exposed bedrock and coarse fragments
Dry, Sandy
Ecosites 029-043
Fresh, Sandy or Coarse Loamy
Ecosites 044-059
Dry to Fresh, Fine Loamy or Silty
Ecosites 093-108
Dry to Fresh, Clayey
Ecosites 077-092
56
105
89
Humid, Very Shallow
Ecosites 020-028
Ew
Moist, Sandy or Coarse Loamy
Ecosites 060-076
71
Moist, Fine Loamy, Silty or Clayey
Ecosites 109-125
120 (124-125)
130 (131) (133)
Hydric, Variable Textures
Ecosites 126-133, 222-224

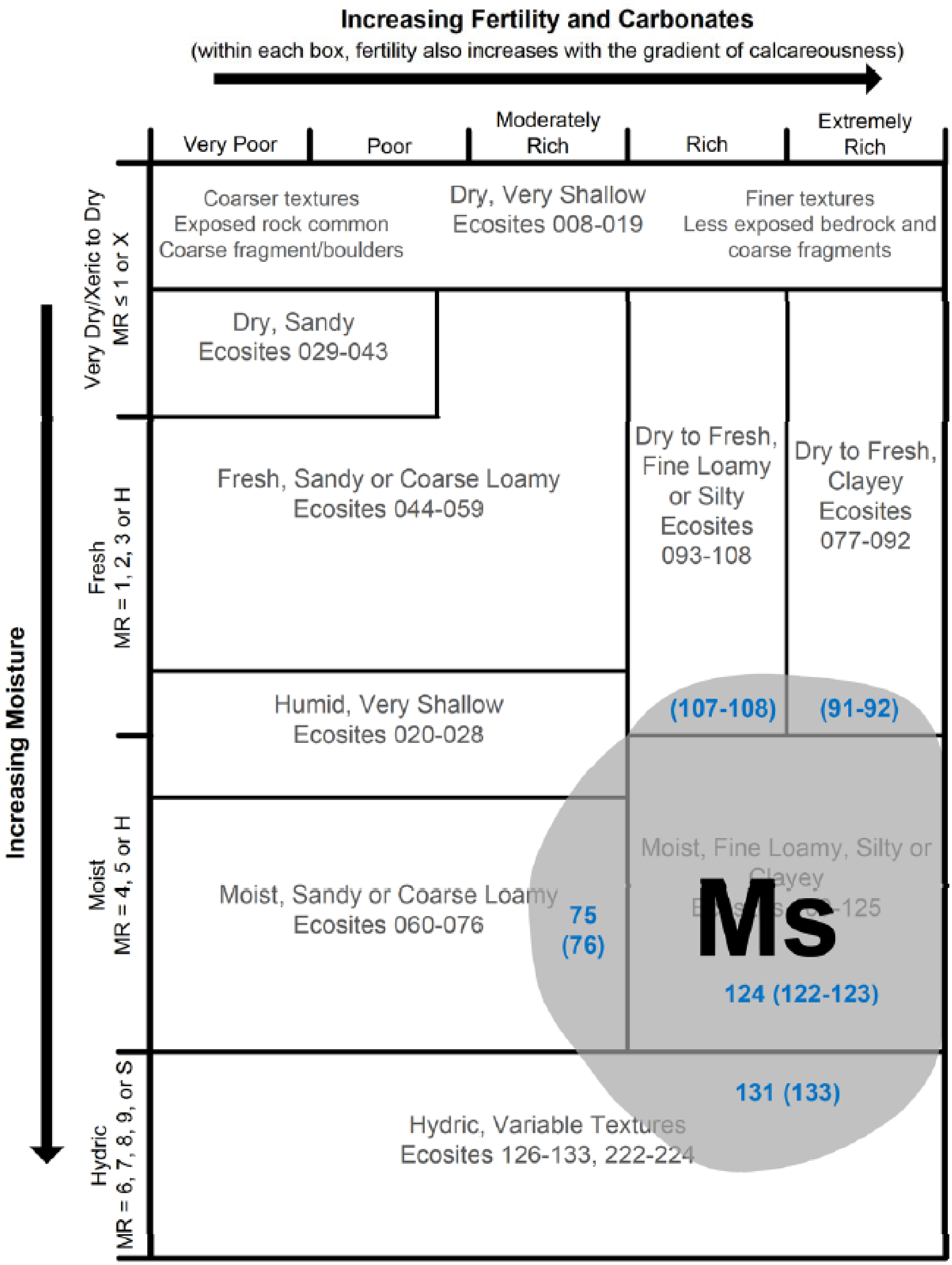

Increasing Fertility and Carbonates
(within each box, fertility also increases with the gradient of calcareousness)
Very Poor
Poor
Moderately Rich
Rich
Extremely Rich
Increasing Moisture
Very Dry/Xeric to Dry
MR ≤ 1 or X
Fresh
MR = 1, 2, 3 or H
Moist
MR = 4, 5 or H
Hydric
MR = 6, 7, 8, 9, or S
Coarser textures
Exposed rock common
Coarse fragment/boulders
Dry, Very Shallow
Ecosites 008-019
Finer textures
Less exposed bedrock and coarse fragments
Dry, Sandy
Ecosites 029-043
36
Fresh, Sandy or Coarse Loamy
Ecosites 044-059
51 (58)
Dry to Fresh, Fine Loamy or Silty
Ecosites 093-108
100
Dry to Fresh, Clayey
Ecosites 077-092
Humid, Very Shallow
Ecosites 020-028
25 (28)
He
115
(121-123)
Moist, Fine Loamy, Silty or Clayey
Ecosites 109-125
Moist, Sandy or Coarse Loamy
Ecosites 060-076
66 (73) (76)
129 224
Hydric, Variable Textures
Ecosites 126-133, 222-224

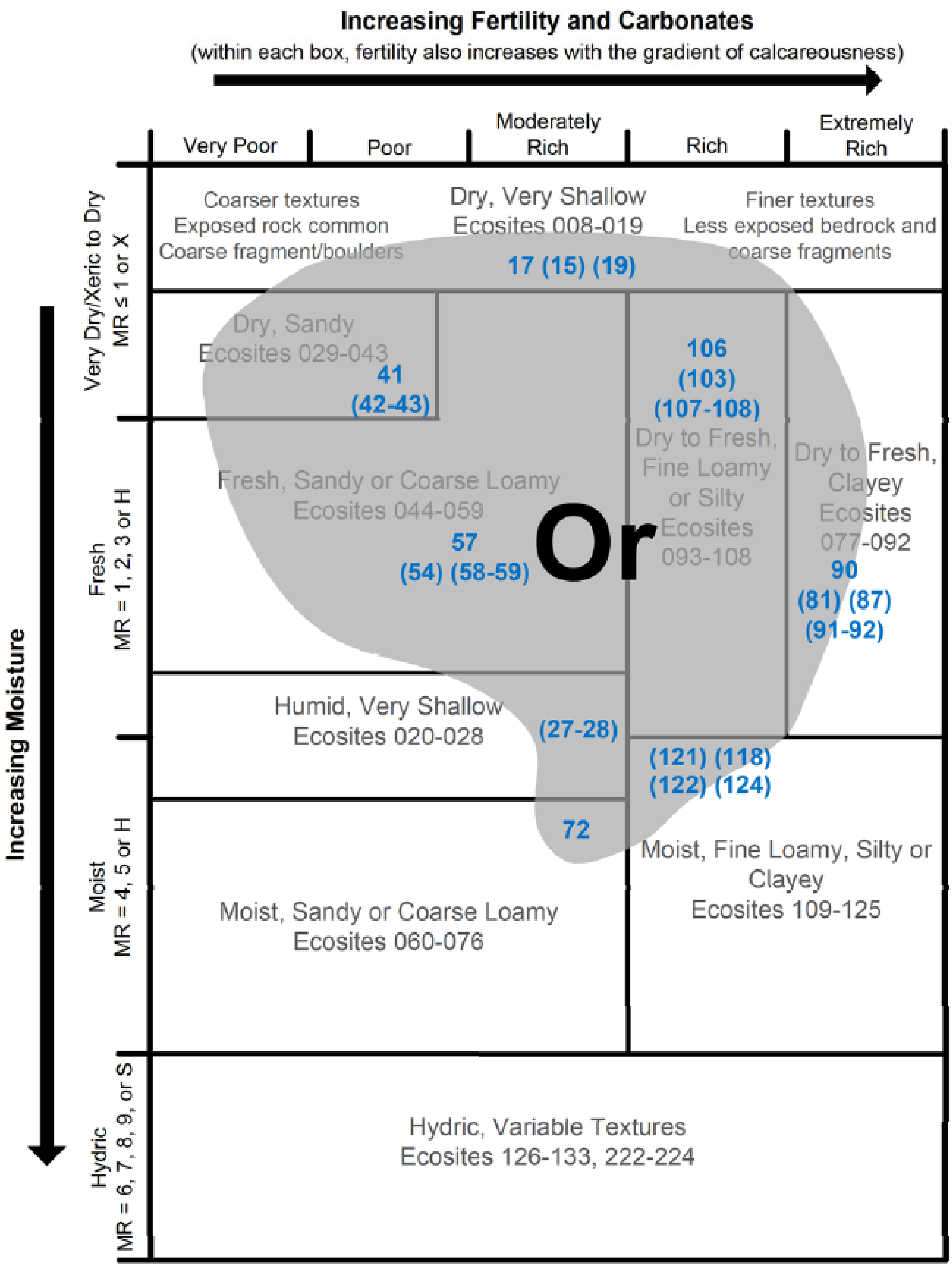

Increasing Fertility and Carbonates
(within each box, fertility also increases with the gradient of calcareousness)
Very Poor
Poor
Moderately Rich
Rich
Extremely Rich
Increasing Moisture
Very Dry/Xeric to Dry MR ≤ 1 or X
Fresh MR = 1, 2, 3 or H
Moist MR = 4, 5 or H
Hydric MR = 6, 7, 8, 9, or S
Coarser textures
Exposed rock common
Coarse fragment/boulders
Dry, Very Shallow
Ecosites 008-019
Finer textures
Less exposed bedrock and coarse fragments
7 18 19? (11) (15)
Dry, Sandy
Ecosites 029-043
42 43
(39) (41)
107 108
(103)
(105-106)
Fresh, Sandy or Coarse Loamy
Ecosites 044-059
58 (54) (56-57) (59)
Dry to Fresh, Fine Loamy or Silty
Ecosites 093-108
Dry to Fresh, Clayey
Ecosites 077-092
91 92
(87)
(89-90)
Id
Humid, Very Shallow
Ecosites 020-028
28 (23) (27)
121-125 (113)
(118) (120)
(69) (71-74)
(76)
Moist, Fine Loamy, Silty or Clayey
Ecosites 109-125
Moist, Sandy or Coarse Loamy
Ecosites 060-076
(130-133)
Hydric, Variable Textures
Ecosites 126-133, 222-224


Increasing Fertility and Carbonates
(within each box, fertility also increases with the gradient of calcareousness)
Very Poor
Poor
Moderately Rich
Rich
Extremely Rich
Increasing Moisture
Very Dry/Xeric to Dry MR ≤ 1 or X
Fresh MR = 1, 2, 3 or H
Moist MR = 4, 5 or H
Hydric MR = 6, 7, 8, 9, or S
Coarser textures
Exposed rock common
Coarse fragment/boulders
Dry, Very Shallow
Ecosites 008-019
Finer textures
Less exposed bedrock and coarse fragments
Dry, Sandy
Ecosites 029-043
Fresh, Sandy or Coarse Loamy
Ecosites 044-059
Dry to Fresh, Fine Loamy or Silty
Ecosites 093-108
Dry to Fresh, Clayey
Ecosites 077-092
Humid, Very Shallow
Ecosites 020-028
102
(86)
(115-117) (123) (125)
Moist, Fine Loamy, Silty or Clayey
Ecosites 109-125
La
Moist, Sandy or Coarse Loamy
Ecosites 060-076
(65)
68
(127-224) 128-223 129-224
Hydric, Variable Textures
Ecosites 126-133, 222-224

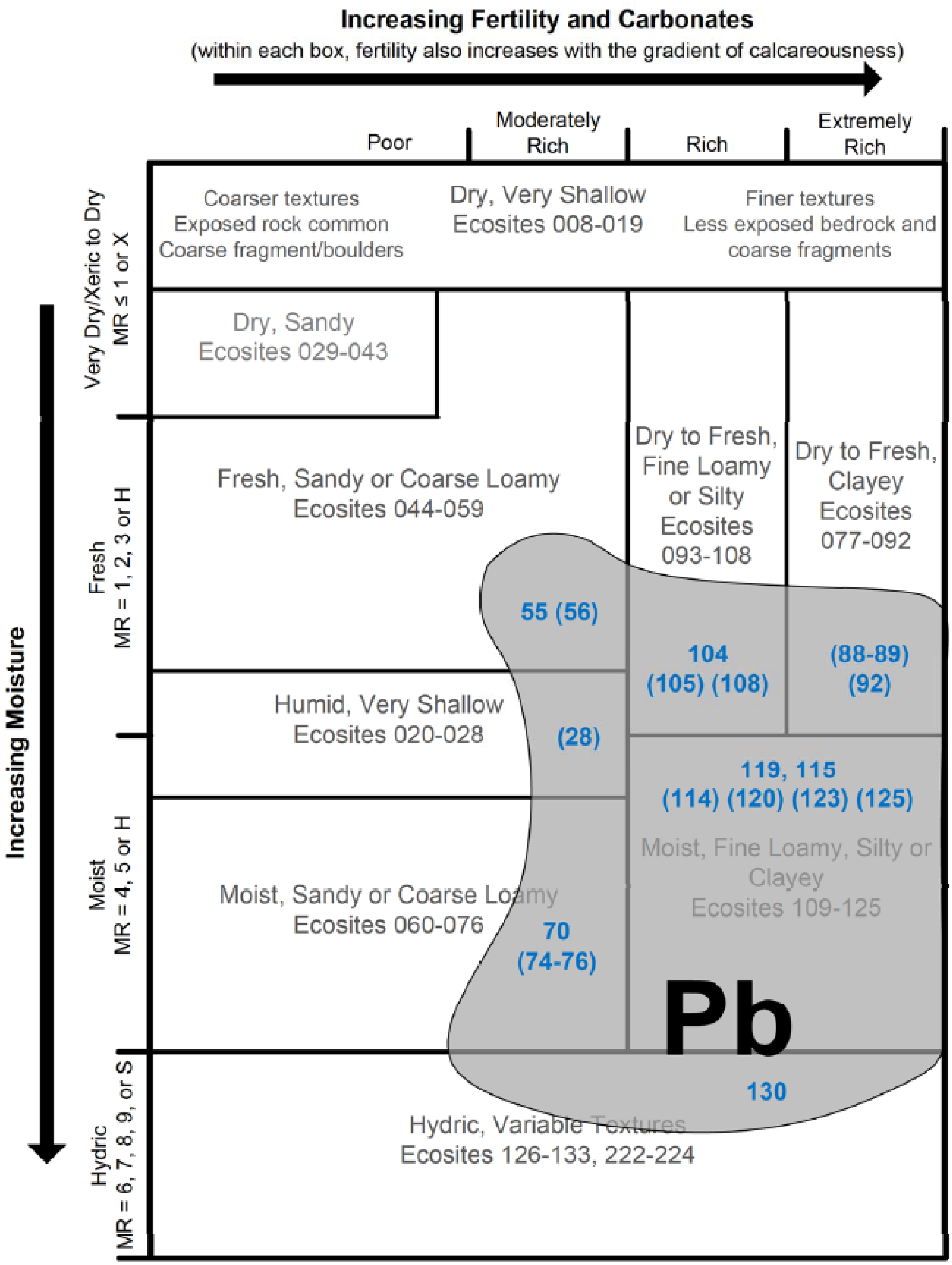

Increasing Fertility and Carbonates
(within each box, fertility also increases with the gradient of calcareousness)
Very Poor
Poor
Moderately Rich
Rich
Extremely Rich
Increasing Moisture
Very Dry/Xeric to Dry MR ≤ 1 or X
Fresh MR = 1, 2, 3 or H
Moist MR = 4, 5 or H
Hydric MR = 6, 7, 8, 9, or S
Coarser textures
Exposed rock common
Coarse fragment/boulders
Dry, Very Shallow
Ecosites 008-019
(17-19)
Finer textures
Less exposed bedrock and
coarse fragments
Dry, Sandy
Ecosites 029-043
42 (41)
(43)
58 59
(55-57)
Fresh, Sandy or Coarse Loamy
Ecosites 044-059
Dry to Fresh,
Fine Loamy
or Silty
Ecosites
093-108
106-108
(105)
Dry to Fresh,
Clayey
Ecosites
077-092
90-92
(81) (89)
Humid, Very Shallow
Ecosites 020-028
(28)
Mh
Moist, Sandy or Coarse Loamy
Ecosites 060-076
72- 76 (70)
Moist, Fine Loamy, Silty or
Clayey
Ecosites 109-125
121-125
(118) (120)
131 (133)
Hydric, Variable Textures
Ecosites 126-133, 222-224

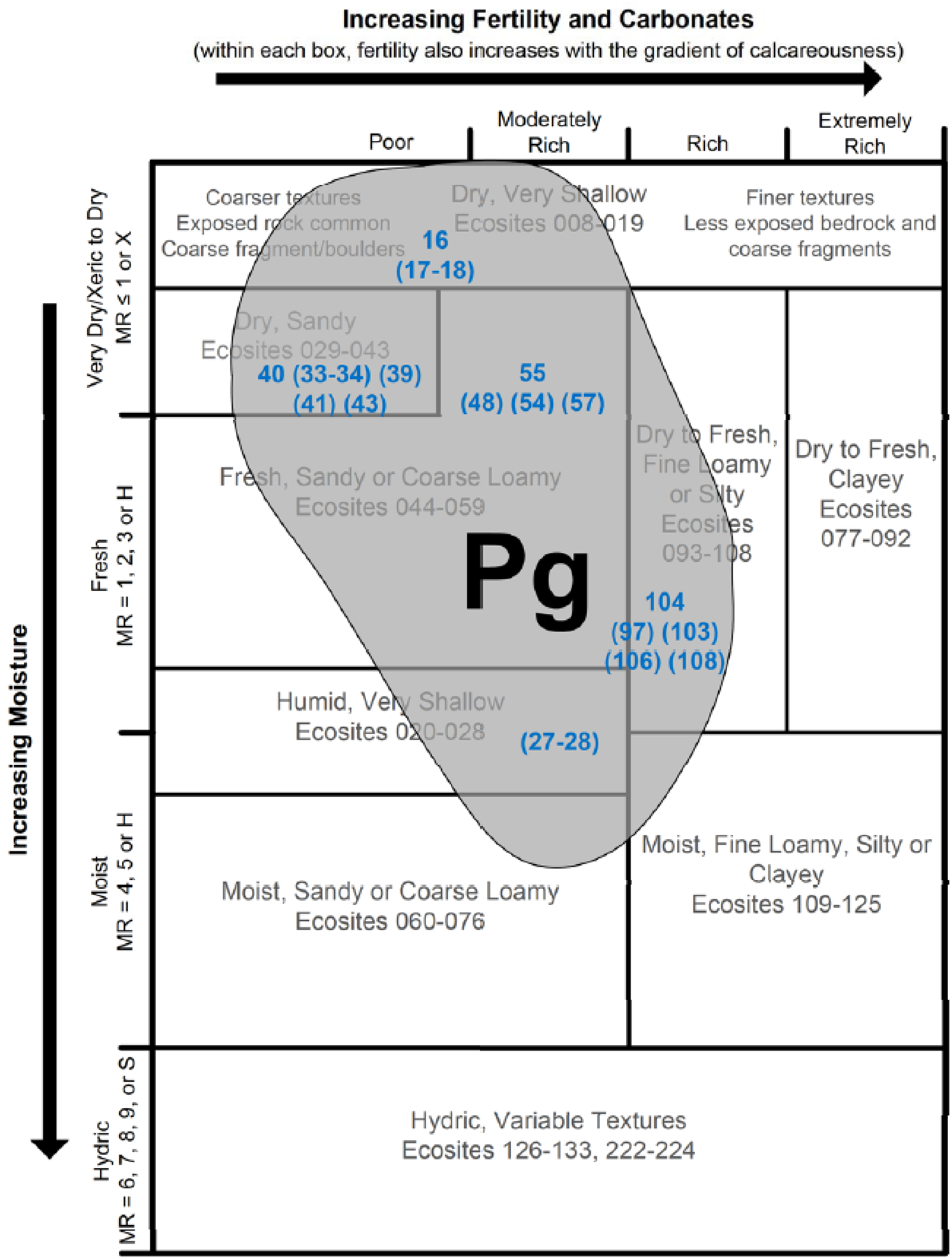

Increasing Fertility and Carbonates
(within each box, fertility also increases with the gradient of calcareousness)
Very Poor
Poor
Moderately Rich
Rich
Extremely Rich
Increasing Moisture
Very Dry/Xeric to Dry MR ≤ 1 or X
Fresh MR = 1, 2, 3 or H
Moist MR = 4, 5 or H
Hydric MR = 6, 7, 8, 9, or S
Coarser textures
Exposed rock common
Coarse fragment/boulders
Dry, Very Shallow
Ecosites 008-019
(11) (13-17) (19)
Finer textures
Less exposed bedrock and coarse fragments
Dry, Sandy
Ecosites 029-043
42 (33)
(36-40)
58 (48)
(52-57)
(59)
Fresh, Sandy or Coarse Loamy
Ecosites 044-059
Dry to Fresh,
Fine Loamy
or Silty
Ecosites
093-108
107 (97-98)
(100-103)
(105)
Dry to Fresh,
Clayey
Ecosites
077-092
91 92
(85-89)
Humid, Very Shallow
Ecosites 020-028
28 (23)
(25-26)
Mr
Moist, Sandy or Coarse Loamy
Ecosites 060-076
73 74 75 (64)
(66) (68-72)
(76)
Moist, Fine Loamy, Silty or Clayey
Ecosites 109-125
123 124 (113)
(115-125)
131 133 (128,
224, 130, 132)
Hydric, Variable Textures
Ecosites 126-133, 222-224

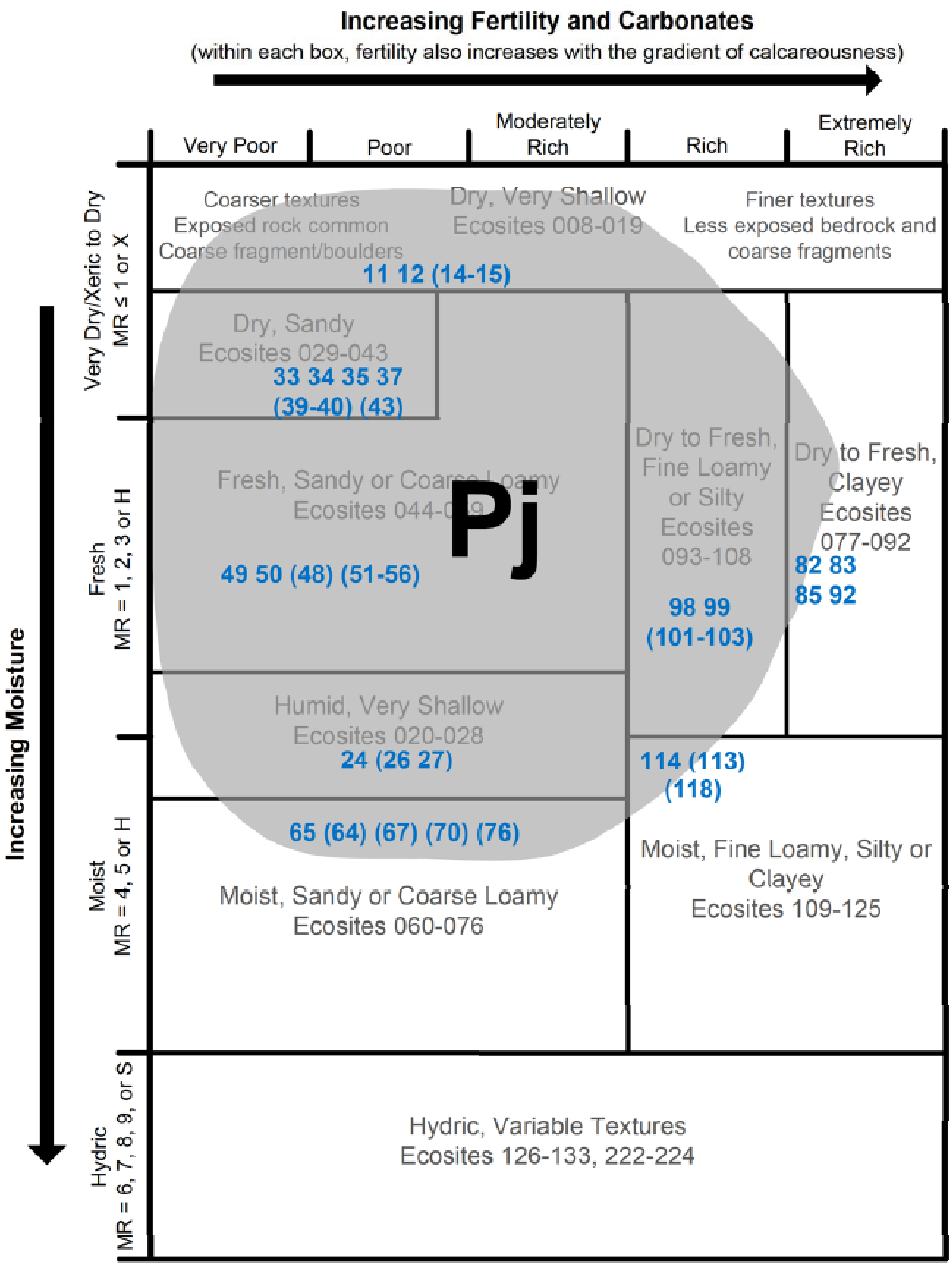

Increasing Fertility and Carbonates
(within each box, fertility also increases with the gradient of calcareousness)
Very Poor
Poor
Moderately Rich
Rich
Extremely Rich
Increasing Moisture
Very Dry/Xeric to Dry MR ≤ 1 or X
Fresh MR = 1, 2, 3 or H
Moist MR = 4, 5 or H
Hydric MR = 6, 7, 8, 9, or S
Coarser textures
Exposed rock common
Coarse fragment/boulders
Dry, Very Shallow
Ecosites 008-019
Finer textures
Less exposed bedrock and coarse fragments
Dry, Sandy
Ecosites 029-043
Fresh, Sandy or Coarse Loamy
Ecosites 044-059
Dry to Fresh, Fine Loamy or Silty
Ecosites 093-108
Dry to Fresh, Clayey
Ecosites 077-092
Humid, Very Shallow
Ecosites 020-028
(107-108)
(91-92)
Moist, Sandy or Coarse Loamy
Ecosites 060-076
75
(76)
Moist, Fine Loamy, Silty or Clayey
Ms
124 (122-123)
131 (133)
Hydric, Variable Textures
Ecosites 126-133, 222-224

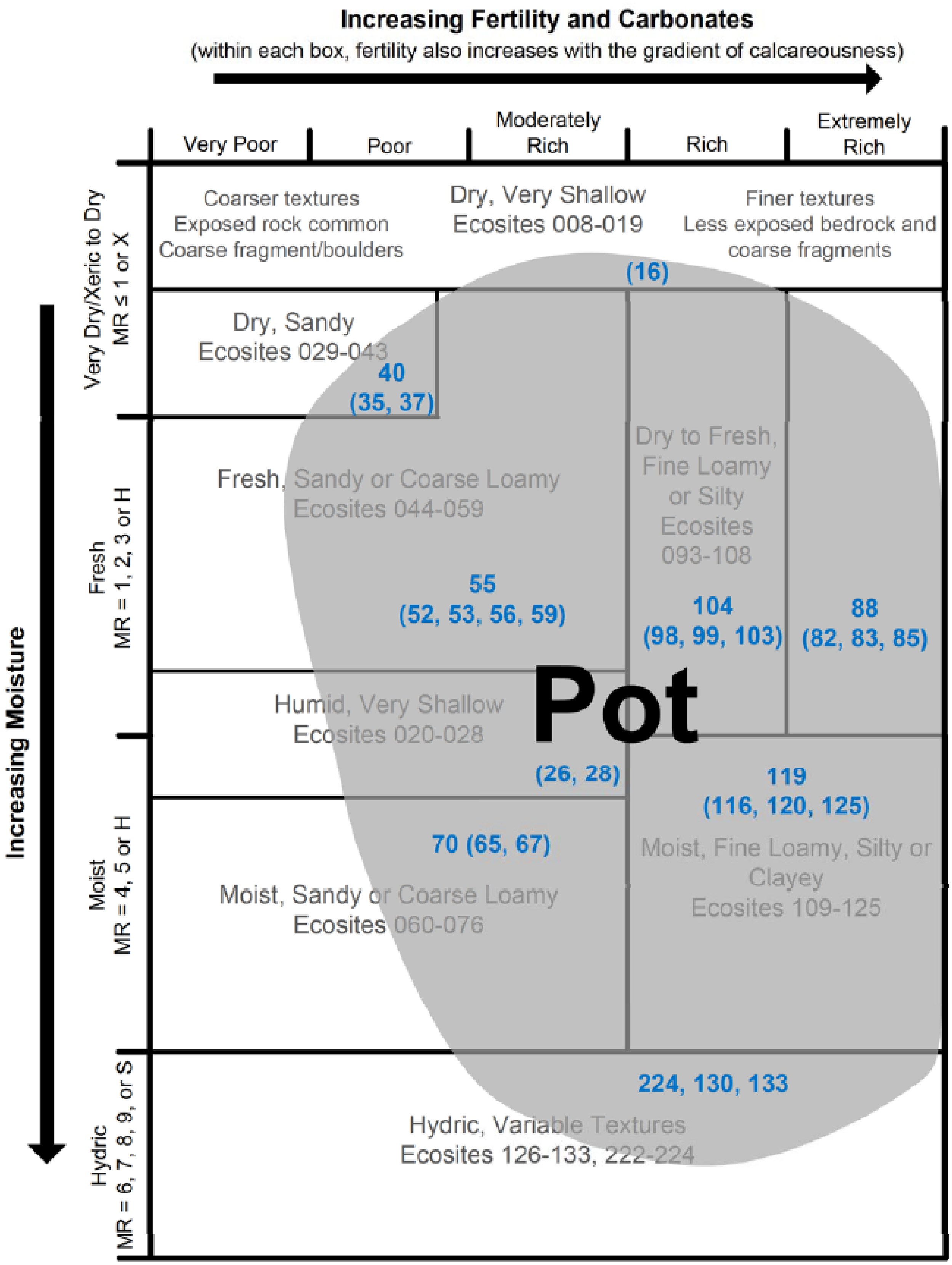


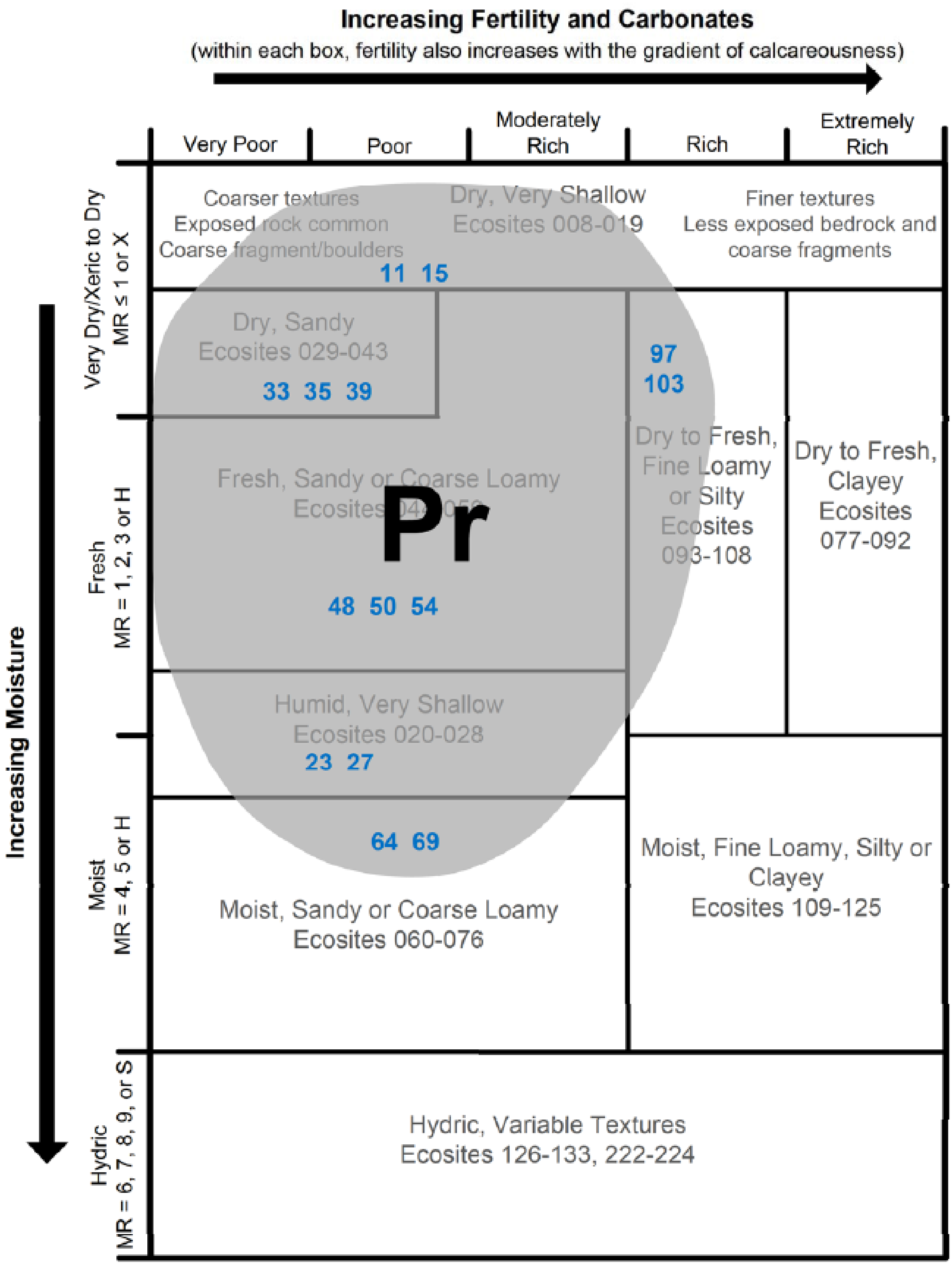
Increasing Fertility and Carbonates
(within each box, fertility also increases with the gradient of calcareousness)
Very Poor
Poor
Moderately Rich
Rich
Extremely Rich
Increasing Moisture
Very Dry/Xeric to Dry MR ≤ 1 or X
Fresh MR = 1, 2, 3 or H
Moist MR = 4, 5 or H
Hydric MR = 6, 7, 8, 9, or S
Coarser textures
Exposed rock common
Coarse fragment/boulders
Dry, Very Shallow
Ecosites 008-019
17 (15) (19)
Finer textures
Less exposed bedrock and coarse fragments
Dry, Sandy
Ecosites 029-043
41
(42-43)
106
(103)
(107-108)
Dry to Fresh, Fine Loamy or Silty Ecosites 093-108
Fresh, Sandy or Coarse Loamy
Ecosites 044-059
57
(54) (58-59)
Or
Dry to Fresh, Clayey Ecosites 077-092
90
(81) (87)
(91-92)
Humid, Very Shallow
Ecosites 020-028
(27-28)
(121) (118)
(122) (124)
72
Moist, Fine Loamy, Silty or Clayey
Ecosites 109-125
Moist, Sandy or Coarse Loamy
Ecosites 060-076
Hydric, Variable Textures
Ecosites 126-133, 222-224

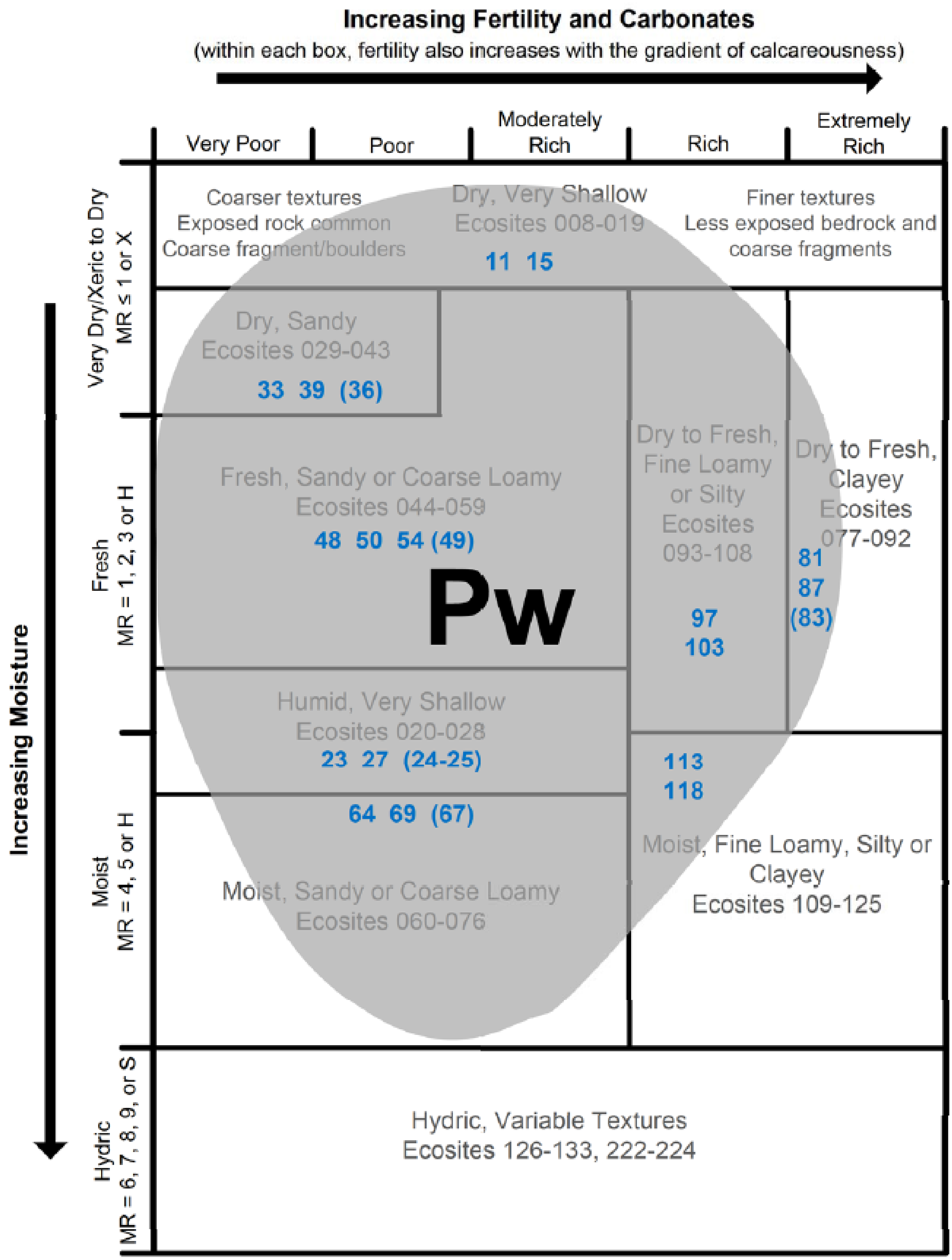

Increasing Fertility and Carbonates
(within each box, fertility also increases with the gradient of calcareousness)
Poor
Moderately Rich
Rich
Extremely Rich
Increasing Moisture
Very Dry/Xeric to Dry
MR ≤ 1 or X
Fresh
MR = 1, 2, 3 or H
Moist
MR = 4, 5 or H
Hydric
MR = 6, 7, 8, 9, or S
Coarser textures
Exposed rock common
Coarse fragment/boulders
Dry, Very Shallow
Ecosites 008-019
Finer textures
Less exposed bedrock and coarse fragments
Dry, Sandy
Ecosites 029-043
Fresh, Sandy or Coarse Loamy
Ecosites 044-059
Dry to Fresh, Fine Loamy or Silty
Ecosites 093-108
Dry to Fresh, Clayey
Ecosites 077-092
55 (56)
104
(105) (108)
(88-89)
(92)
Humid, Very Shallow
Ecosites 020-028
(28)
119, 115
(114) (120) (123) (125)
Moist, Fine Loamy, Silty or Clayey
Ecosites 109-125
Moist, Sandy or Coarse Loamy
Ecosites 060-076
70
(74-76)
Pb
130
Hydric, Variable Textures
Ecosites 126-133, 222-224

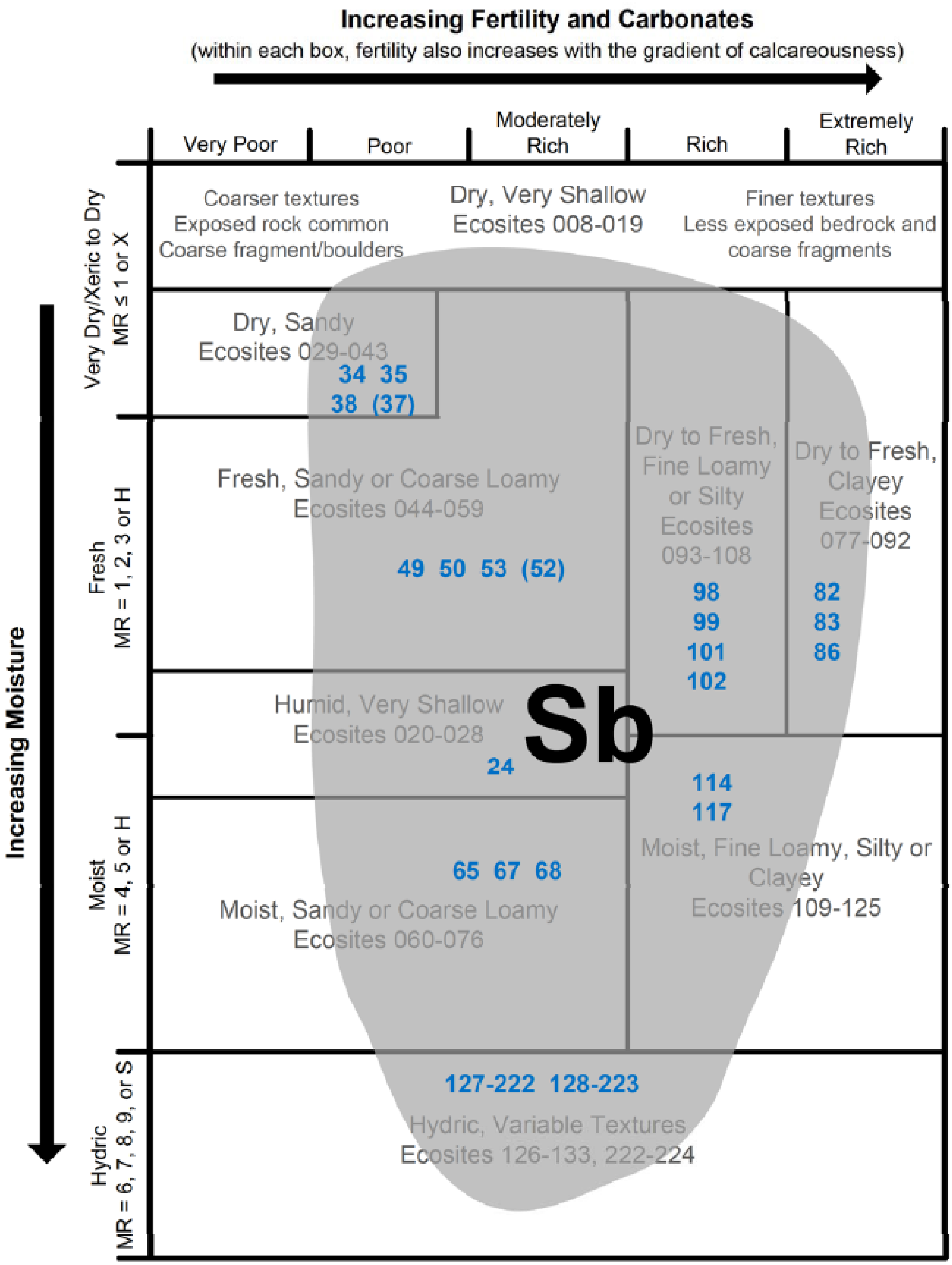

Increasing Fertility and Carbonates
(within each box, fertility also increases with the gradient of calcareousness)
Poor
Moderately Rich
Rich
Extremely Rich
Increasing Moisture
Very Dry/Xeric to Dry
MR ≤ 1 or X
Fresh
MR = 1, 2, 3 or H
Moist
MR = 4, 5 or H
Hydric
MR = 6, 7, 8, 9, or S
Coarser textures
Exposed rock common
Coarse fragment/boulders
Dry, Very Shallow
Ecosites 008-019
Finer textures
Less exposed bedrock and coarse fragments
16
(17-18)
Dry, Sandy
Ecosites 029-043
40 (33-34) (39)
(41) (43)
55
(48) (54) (57)
Dry to Fresh, Fine Loamy or Silty
Ecosites 093-108
Dry to Fresh, Clayey
Ecosites 077-092
Fresh, Sandy or Coarse Loamy
Ecosites 044-059
Pg
104
(97) (103)
(106) (108)
Humid, Very Shallow
Ecosites 020-028
(27-28)
Moist, Fine Loamy, Silty or Clayey
Ecosites 109-125
Moist, Sandy or Coarse Loamy
Ecosites 060-076
Hydric, Variable Textures
Ecosites 126-133, 222-224


Increasing Fertility and Carbonates
(within each box, fertility also increases with the gradient of calcareousness)
Very Poor
Poor
Moderately Rich
Rich
Extremely Rich
Increasing Moisture
Very Dry/Xeric to Dry MR ≤ 1 or X
Fresh MR = 1, 2, 3 or H
Moist MR = 4, 5 or H
Hydric MR = 6, 7, 8, 9, or S
Coarser textures
Exposed rock common
Coarse fragment/boulders
Dry, Very Shallow
Ecosites 008-019
Finer textures
Less exposed bedrock and coarse fragments
11 12 (14-15)
Dry, Sandy
Ecosites 029-043
33 34 35 37
(39-40) (43)
Fresh, Sandy or Coarse Loamy
Ecosites 044-059
49 50 (48) (51-56)
Pj
Dry to Fresh, Fine Loamy or Silty
Ecosites 093-108
98 99
(101-103)
Dry to Fresh, Clayey
Ecosites 077-092
82 83
85 92
Humid, Very Shallow
Ecosites 020-028
24 (26 27)
114 (113)
(118)
65 (64) (67) (70) (76)
Moist, Sandy or Coarse Loamy
Ecosites 060-076
Moist, Fine Loamy, Silty or Clayey
Ecosites 109-125
Hydric, Variable Textures
Ecosites 126-133, 222-224


Increasing Fertility and Carbonates
(within each box, fertility also increases with the gradient of calcareousness)
Very Poor
Poor
Moderately Rich
Rich
Extremely Rich
Increasing Moisture
Very Dry/Xeric to Dry MR ≤ 1 or X
Fresh MR = 1, 2, 3 or H
Moist MR = 4, 5 or H
Hydric MR = 6, 7, 8, 9, or S
Coarser textures
Exposed rock common
Coarse fragment/boulders
Dry, Very Shallow
Ecosites 008-019
Finer textures
Less exposed bedrock and coarse fragments
(16)
Dry, Sandy
Ecosites 029-043
40
(35, 37)
Fresh, Sandy or Coarse Loamy
Ecosites 044-059
55
(52, 53, 56, 59)
Dry to Fresh, Fine Loamy or Silty
Ecosites 093-108
104
(98, 99, 103)
88
(82, 83, 85)
Pot
Humid, Very Shallow
Ecosites 020-028
(26, 28)
119
(116, 120, 125)
70 (65, 67)
Moist, Sandy or Coarse Loamy
Ecosites 060-076
Moist, Fine Loamy, Silty or Clayey
Ecosites 109-125
224, 130, 133
Hydric, Variable Textures
Ecosites 126-133, 222-224


Increasing Fertility and Carbonates
(within each box, fertility also increases with the gradient of calcareousness)
Very Poor
Poor
Moderately Rich
Rich
Extremely Rich
Increasing Moisture
Very Dry/Xeric to Dry MR ≤ 1 or X
Fresh MR = 1, 2, 3 or H
Moist MR = 4, 5 or H
Hydric MR = 6, 7, 8, 9, or S
Coarser textures
Exposed rock common
Coarse fragment/boulders
Dry, Very Shallow
Ecosites 008-019
Finer textures
Less exposed bedrock and coarse fragments
11 15
Dry, Sandy
Ecosites 029-043
33 35 39
97
103
Dry to Fresh, Fine Loamy or Silty Ecosites 093-108
Dry to Fresh, Clayey Ecosites 077-092
Fresh, Sandy or Coarse Loamy
Ecosites 044-059
Pr
48 50 54
Humid, Very Shallow
Ecosites 020-028
23 27
64 69
Moist, Sandy or Coarse Loamy
Ecosites 060-076
Moist, Fine Loamy, Silty or Clayey
Ecosites 109-125
Hydric, Variable Textures
Ecosites 126-133, 222-224


Increasing Fertility and Carbonates
(within each box, fertility also increases with the gradient of calcareousness)
Very Poor
Poor
Moderately Rich
Rich
Extremely Rich
Increasing Moisture
Very Dry/Xeric to Dry MR ≤ 1 or X
Fresh MR = 1, 2, 3 or H
Moist MR = 4, 5 or H
Hydric MR = 6, 7, 8, 9, or S
Coarser textures Exposed rock common Coarse fragment/boulders
Dry, Very Shallow Ecosites 008-019
11 15
Finer textures Less exposed bedrock and coarse fragments
Dry, Sandy Ecosites 029-043
33 39 (36)
Fresh, Sandy or Coarse Loamy Ecosites 044-059
48 50 54 (49)
Pw
Dry to Fresh, Fine Loamy or Silty Ecosites 093-108
97
103
Dry to Fresh, Clayey Ecosites 077-092
81
87
(83)
Humid, Very Shallow Ecosites 020-028
23 27 (24-25)
64 69 (67)
Moist, Sandy or Coarse Loamy Ecosites 060-076
113
118
Moist, Fine Loamy, Silty or Clayey Ecosites 109-125
Hydric, Variable Textures Ecosites 126-133, 222-224


Increasing Fertility and Carbonates
(within each box, fertility also increases with the gradient of calcareousness)
Very Poor
Poor
Moderately Rich
Rich
Extremely Rich
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Coarser textures
Exposed rock common
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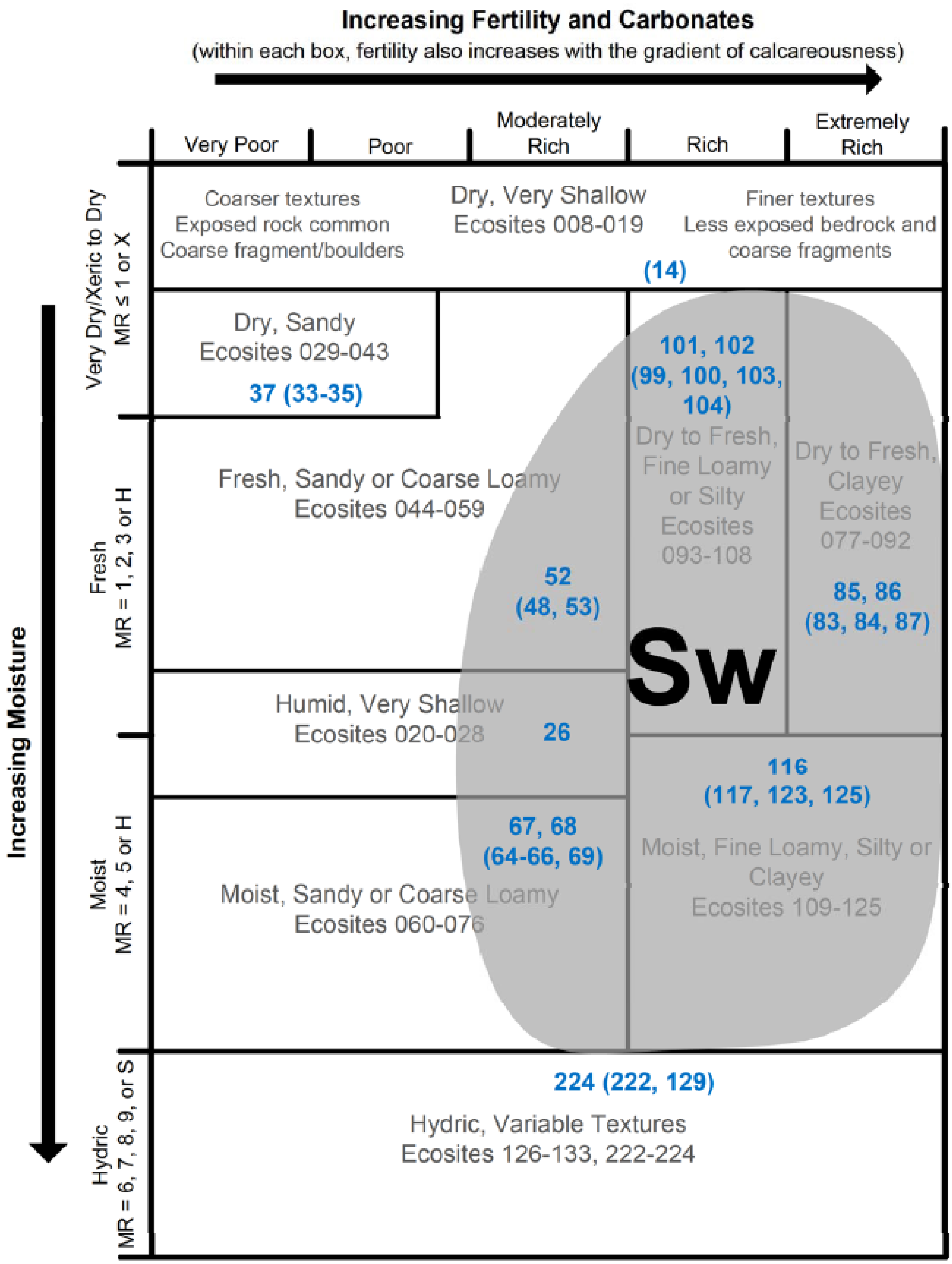
Dry, Very Shallow
Ecosites 008-019
Finer textures
Less exposed bedrock and coarse fragments
Dry, Sandy
Ecosites 029-043
34 35
38 (37)
Fresh, Sandy or Coarse Loamy
Ecosites 044-059
49 50 53 (52)
Dry to Fresh, Fine Loamy or Silty Ecosites 093-108
98
99
101
102
Dry to Fresh, Clayey Ecosites 077-092
82
83
86
Humid, Very Shallow
Ecosites 020-028
24
Sb
114
117
Moist, Fine Loamy, Silty or Clayey
Ecosites 109-125
65 67 68
Moist, Sandy or Coarse Loamy
Ecosites 060-076
127-222 128-223
Hydric, Variable Textures
Ecosites 126-133, 222-224


Increasing Fertility and Carbonates
(within each box, fertility also increases with the gradient of calcareousness)
Very Poor
Poor
Moderately Rich
Rich
Extremely Rich
Increasing Moisture
Very Dry/Xeric to Dry MR ≤ 1 or X
Fresh MR = 1, 2, 3 or H
Moist MR = 4, 5 or H
Hydric MR = 6, 7, 8, 9, or S
Coarser textures Exposed rock common Coarse fragment/boulders
Dry, Very Shallow Ecosites 008-019
Finer textures Less exposed bedrock and coarse fragments
(14)
Dry, Sandy Ecosites 029-043
37 (33-35)
101, 102 (99, 100, 103, 104)
Dry to Fresh, Fine Loamy or Silty Ecosites 093-108
Dry to Fresh, Clayey Ecosites 077-092
Fresh, Sandy or Coarse Loamy Ecosites 044-059
52 (48, 53)
85, 86 (83, 84, 87)
Sw
Humid, Very Shallow Ecosites 020-028
26
116 (117, 123, 125)
67, 68 (64-66, 69)
Moist, Sandy or Coarse Loamy Ecosites 060-076
Moist, Fine Loamy, Silty or Clayey Ecosites 109-125
224 (222, 129)
Hydric, Variable Textures Ecosites 126-133, 222-224

Appendix 3 - Factsheet by Species

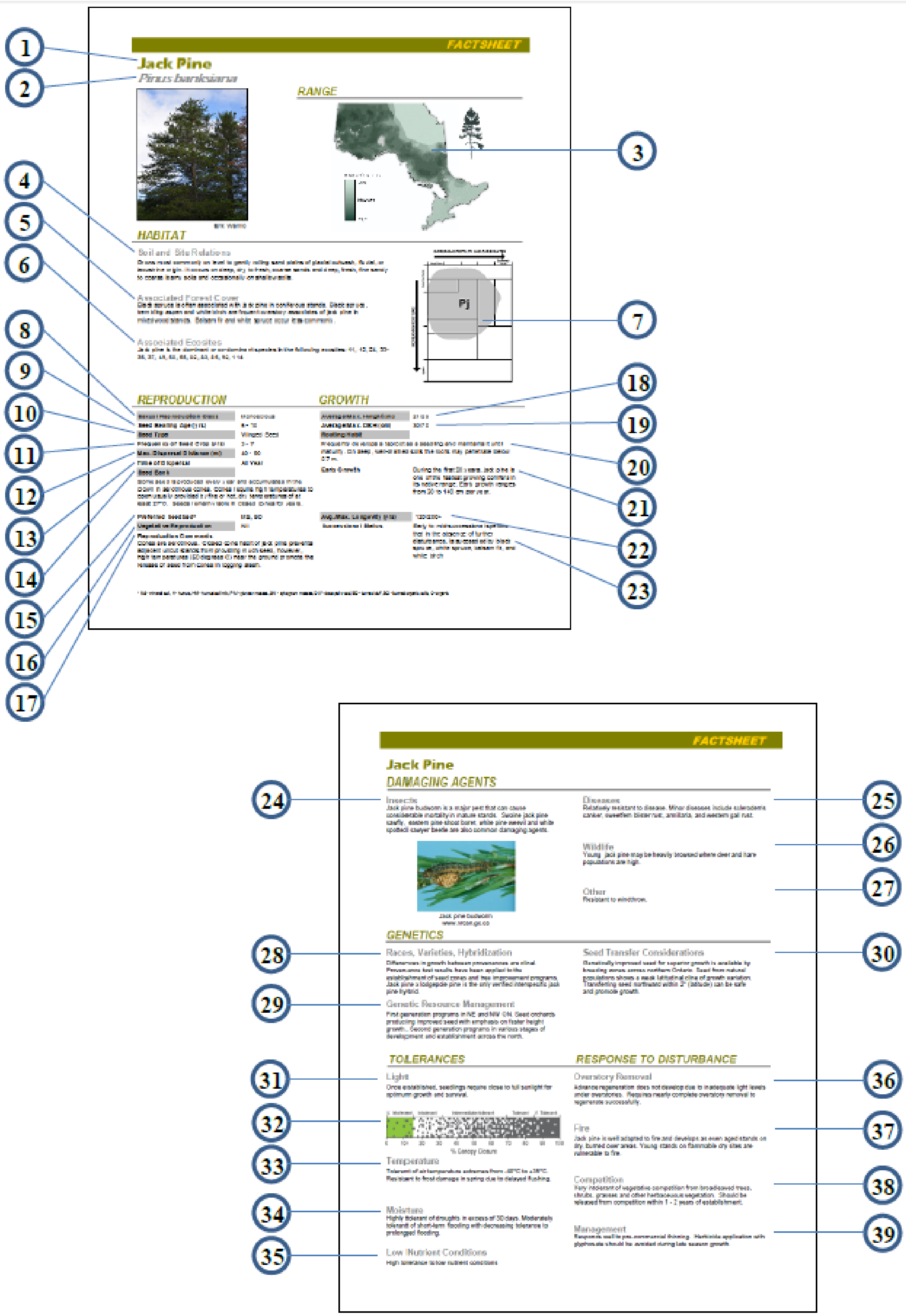
Introduction

This section contains tree species factsheets for each of the 25 main species that are managed on Crown land in the Area of the Undertaking.

The tree species factsheets provide detailed information on distribution, habitat, reproduction, growth, damaging agents, genetics, tolerances and response to disturbance. These factsheets are intended as a quick reference to refresh your knowledge on the silvics of less familiar species when planning and carrying out forest management activities. The factsheets include information on where a species grows best, successional status, preferred seedbed, response to competition and other valuable management information.

The information found in the factsheets is non-authoritative and meant only as general information. A combination of Ontario inventory data, expert experience and common literature was used to develop the material; some interpretation has occurred.

Use the following diagram and subsequent glossary of headings to find out specifics on the type of information provided on the factsheets and any additional source data.


FACTSHEET
Jack Pine
Pinus banksiana
RANGE
HABITAT
Soil and Site Relations
Associated Forest Cover
Associated Ecosites
Pj
REPRODUCTION
GROWTH
FACTSHEET
Jack Pine
DAMAGING AGENTS
Insects
Diseases
Wildlife
Other
GENETICS
Races, Varieties, Hybridization
Seed Transfer Considerations
Genetic Resource Management
TOLERANCES
RESPONSE TO DISTURBANCE
Light
Overstory Removal
Fire
Temperature
Competition
Moisture
Management
Low Nutrient Conditions
1
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3
4
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Factsheet Heading Explanations

1. **Common Name:** is the name that the species is most commonly known by in Ontario.
2. **Scientific Name:** the species name in latin binomial nomenclature which is the formal system of naming species.
3. **Range:** where the species can be found growing in Ontario. Colouration on maps depicts low to high relative occurrences across the province from Ontario Forest Resource Inventory Data. Single colour distribution maps were developed by Natural Resources Canada.
4. **Site/Soil:** common sites and soil types that the species can be found growing on including variations on texture, moisture, depth, and slope position.
5. **Associated Forest Cover:** a list of species that are often found growing with the targeted species including regional variations.
6. **Associated Ecosites:** ecosites where the targeted species can be found occupying a significant (generally >20%) portion of the stand as a dominant or co-dominant tree. For tree species that rarely occupy a significant portion of the stand a lower threshold was used.
7. **Edatope:** a basic version of the chart is shown to indicate where the targeted species grows on a gradient of moisture and nutrient regime. See Appendix 2 for more detailed diagrams.
8. **Sexual Reproduction:** indicates if the species is monoecious, dioecious, perfect or polygamo-dioecious.
9. **Seed Bearing Age:** is the typical age at which significant seed bearing begins.
10. **Seed Type:** seeds are classified as one of nut, samara, seed, or winged seed.
11. **Frequency of Seed Crop:** the average number of years between good seed crops.
12. **Max. Dispersal Distance:** maximum distance seed is dispersed from the producing tree.
13. **Time of Dispersal:** the months of year when seed dispersal typically occurs.
14. **Seedbank:** indicates if the species has the ability to seedbank in the soil and how long the seed can remain viable on the ground.
15. **Preferred Seedbed:** the type of seedbed that provides good germination and establishment results for the species. Types of seedbed include MS (mineral soil), H (humus), HM (humus/soil mix), PM (pioneer mosses), SM (sphagnum mosses), DW (decayed wood), BD (burned duff), BO (burned organic soils) and O (organic).
16. **Vegetative Reproduction:** indicates if the species is able to reproduce vegetatively and if it can, lists the methods.
17. **Reproduction Comments:** additional information on the nuances specific to the species.
18. **Average/Maximum Height:** approximate average and maximum height of healthy mature Ontario species. Average data obtained from Forest Resource Inventory (FRI) and maximum heights from Ontario Forestry Association’s Honour Roll of Trees.
19. **Average/Maximum DBH:** approximate average and maximum dbh of healthy mature species. Average dbh data obtained from *Trees in Canada,* expert opinion, and other reputable sources such as the United States Department of Agriculture (USDA). Maximum dbh data is from Ontario Forestry Association’s Honour Roll of Trees.
20. **Rooting Habit:** describes the typical root formation of the tree species from shallow spreading to a deep taproot and variations in-between.

21. **Early Growth:** describes speed of early growth, common growth per year and conditions that affect early growth.
22. **Longevity Average/Maximum:** approximate average and maximum ages of healthy mature Ontario species. Data obtained from *Trees in Canada,* expert opinion, and other reputable sources such as the United States Department of Agriculture (USDA).
23. **Successional Status:** indicates if the species is normally an early, mid, or late successional species and how its environment influences its growth.
24. **Insects:** lists both major and common insect pests for each tree species.
25. **Diseases:** lists both major and common diseases for each tree species.
26. **Wildlife:** describes importance of species for animal browse, if damage can be significant and what animals are common pests.
27. **Other:** describes other notable damage agents applicable to a species such as windthrow, frost, and sunscald.
28. **Races, Varieties, Hybridization:** speaks generally about genetics of the species and if hybridization occurs.
29. **Genetic Resource Management:** provides information on the status of tree improvement programs and genetic conservation efforts in Ontario.
30. **Seed Transfer Considerations:** Summary of available information on the theoretical potential for seed movement. The Ontario Seed Zone Policy should be consulted before undertaking the movement of any seed.
31. **Light Tolerance:** describes the need for shade to full sunlight at various stages of growth.
32. **Percent Canopy Closure Image:** shows an approximate shade tolerance based on percentage canopy closure.
33. **Temperature Tolerance:** provides information on tolerance to low and high temperatures, frost during spring, etc.
34. **Moisture Tolerance:** how tolerant the species is of drought and flooding conditions.
35. **Tolerance to Low Nutrient Conditions:** classifies the species with low, moderate or high tolerance to commonly growing well on low nutrient sites.
36. **Response to Overstory Removal:** how suppressed trees and advanced regeneration respond to increased light and space following a harvest.
37. **Response to Fire:** how each tree species responds following a fire.
38. **Response to Competition:** how well seedlings respond to vegetative competition .
39. **Response to Management:** how the species respond to various management techniques including pre-commercial thinning, commercial thinning, site preparation, application of pesticide, etc.

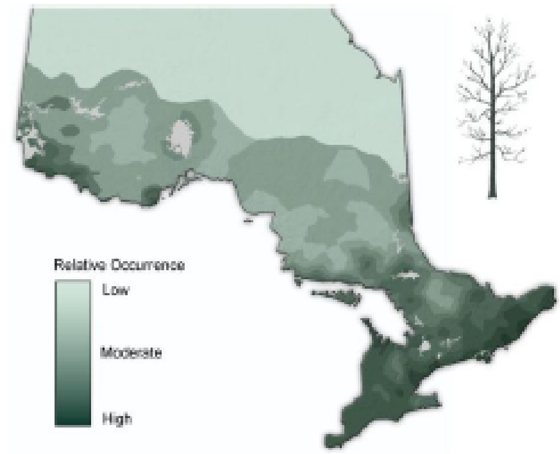
FACTSHEET

Black Ash

Fraxinus nigra

MNR

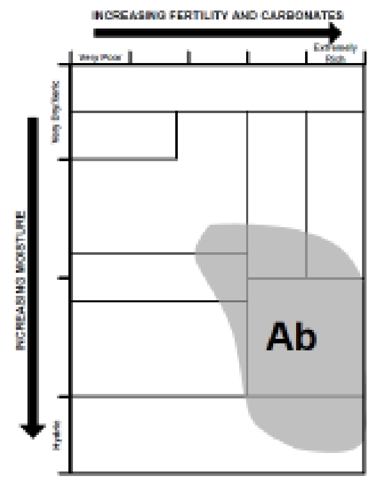
RANGE



HABITAT

Soil and Site Relations

Commonly grows in rich, moist to wet, fine textured mineral or organic soils in swamps, poorly drained depressions and riparian areas.



Associated Forest Cover

Most commonly found in small, isolated, pure stands in lowland hardwood swamps and less frequently mixed with balsam fir, trembling aspen, white birch, white spruce, cedar, red ash, red maple, and American elm.

Associated Ecosites

Black ash may exist in the canopy in the following ecosites: 28, 56, 71, 89, 105, 120, 129, 224, 130, 131

REPRODUCTION

Sexual Reproduction Class	Dioecious
Seed Bearing Age (yrs)	30-40
Seed Type	Samara
Frequency of Seed Crop (yrs)	1 - 8
Max. Dispersal Distance (m)	150 m
Time of Dispersal	Oct. - early spring
Seed Bank	

Because of dormancy, black ash seed does not normally germinate under natural conditions until the second year. Black ash seeds may remain viable for 8 years or more under natural conditions.

Preferred Seedbed*	MS
Vegetative Reproduction	Stump sprouts/Root sprout

Reproduction Comments

Seed germination usually occurs in second year. Seed remains viable for up to 8 years. Readily sprouts from stumps less than 30 cm in diameter.

GROWTH

Average/Max. Height (m)	19/30
Average/Max. DBH (cm)	25/76
Rooting Habit	

Shallow and fibrous root system, particularly well adapted to growth under conditions of high soil moisture.

Early Growth	Seedlings may grow up to 15 cm in height after first year. Stump sprouts may grow up to three times the rate as seedlings.
Avg./Max. Longevity (yrs)	130/250
Successional Status	Black ash is a late successional species in lowland hardwood swamps and a mid-successional species in mixed stands on moderately drained mineral soils.

Black Ash

DAMAGING AGENTS

Insects

Emerald ash borer is an invasive insect causing decline and rapid mortality by feeding on cambium and girdling tree. Oystershell scale is an insect that feeds on twigs, branches and foliage and may occasionally kill trees in small isolated clumps.

Emerald ash borer
www.nrcan.gc.ca

Diseases

Trees greater than 100 years old are susceptible to stem and butt rot resulting most often in stem stain and not decay.

Wildlife

Deer feed on young seedlings where alternate preferred browse is scarce. Beavers occasionally cut down black ash for construction material.

Other

Road construction and harvesting can alter hydrological flow and water stagnation in stands which adversely impacts growth and survival. Due to shallow rooting system, trees on wet soils are susceptible to windthrow.

GENETICS

Races, Varieties, Hybridization

No known races or hybrids of black ash.

Seed Transfer Considerations

No genetic information is available. Local seed is therefore the safest bet.

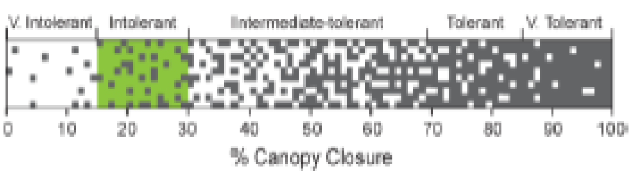
Genetic Resource Management

As a result of the emeral ash borer, there are initiatives to conserve large populations across their range, retain and increase the diversity and regeneration potential within each population, and observe and archive trees which demonstrate tolerance.

TOLERANCES

Light

Young black ash intermediate in shade tolerance but tolerance weakens with age. Regeneration probably grow best in 45 - 50% full sunlight.



Temperature

Young suckers resistant to frost; resistance of seedlings is unkown.

Moisture

Very tolerant of frequent, well-aerated flooding for periods of up to several weeks. Capable of quickly growing new roots after flooding. Sprouts are more flood-tolerant than seedlings.

Low Nutrient Conditions

Low tolerance to low nutrient conditions

RESPONSE TO DISTURBANCE

Overstory Removal

Moderately elastic. In mature stands, seedlings and sprouts grow best in stand openings greater than 0.5 ha in size. Advanced regeneration is minimal under a fully closed canopy.

Fire

Fire hazard rating is low due to wet conditions of sites typically occupied by pure stands.

Competition

Shrub and grass control is required to ensure survival during the establishment phase. Black ash seedlings grow more quickly than American elm and red maple on disturbed mineral soils with a high water table or impeded drainage.

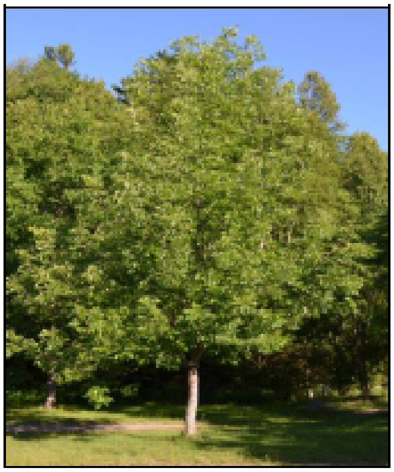
Management

Low-felled stumps typically produce 7 -17 sprouts that grow more vigourously than seedlings. Thinnings are recommended for trees younger than 110 years of age.

FACTSHEET

White Ash

Fraxinus americana



Erik Wainio

RANGE

HABITAT

Soil and Site Relations

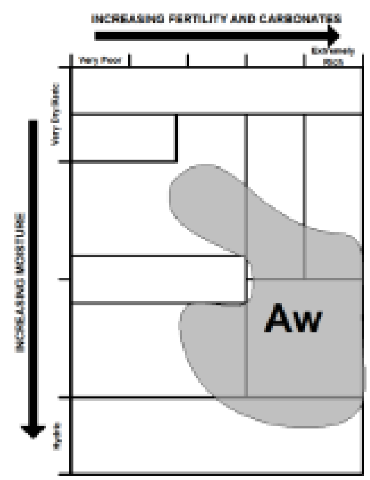
Usually occurs on deep, well-drained, upland soils, mixed with other broadleaf trees and occasional conifers.

Associated Forest Cover

White ash is found in mixed forests and is never a dominant species. Its primary associates are eastern white pine, red oak, sugar maple, red maple, yellow birch, beech, black cherry and hemlock.

Associated Ecosites

White ash may exist in the canopy in the following ecosites: 56, 71, 89, 105, 120



REPRODUCTION

Sexual Reproduction Class	Dioecious
Seed Bearing Age (yrs)	20
Seed Type	Samara
Frequency of Seed Crop (yrs)	3
Max. Dispersal Distance (m)	140 m
Time of Dispersal	September - December
Seed Bank	

Seed remains viable in a seed bank for 3-5 years.

Preferred Seedbed*	H/MS mix
Vegetative Reproduction	Stump sprouts readily

Reproduction Comments

White ash resprouts from the root crown after logging or fire. Sprouting ability decreases with age.

GROWTH

Average/Max. Height (m)	23/31
Average/Max. DBH (cm)	50/127
Rooting Habit	

Generally forms a tap root that in turn branches into a few large roots that grow downward. Single lateral branches develop at intervals.

Early Growth	Typically around 54% germination rate, best in 45% sunlight, seedlings can survive in <3% full sunlight.

Avg./Max. Longevity (yrs)	150/200
Successional Status	White ash is an early and mid-successional species. It owes its position in the final overstory to its ability to persist for a few years in moderately dense shade and to respond quickly to openings in the canopy created by death or other causes.

FACTSHEET

White Ash

DAMAGING AGENTS

Insects

The exotic invasive emerald ash borer is causing widespread mortality of healthy ash in many areas of Ontario.

Emerald ash borer
Dan Rowlinson

Diseases

Seedlings are susceptible to leaf spot and anthracnose.

Wildlife

Ash is easily damaged by browsing but is one of the less preferred deer browse species. Bark is consumed by rabbits, beaver, porcupine, mices and voles.

Other

Ash periodically undergoes declines; the trees exhibit a progressive dieback called "ash yellows"; these declines are probably triggered by climate induced stress, which predisposes them to other damaging agents.

GENETICS

Races, Varieties, Hybridization

Hybridization with other ash species is extremely rare.

Genetic Resource Management

As a result of the emeral ash borer, there are initiatives to conserve large populations across their range, retain and increase the diversity and regeneration potential within each population, and observe and archive trees which demonstrate tolerance.

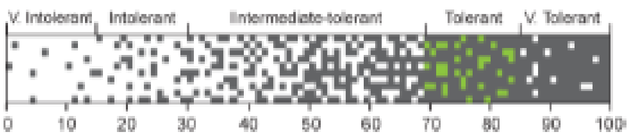
Seed Transfer Considerations

Tree stem dieback caused by fall frost injury is significantly correlated to latitude of seed origin. Local and northern seed sources suffer the least from fall frost and show significantly better survival and growth than southern seed sources at northern planting sites.

TOLERANCES

Light

Although mature white ash is classified as shade intolerant, the seedlings are shade tolerant. A seedling can survive at less than 3% full sunlight for a few years.



Temperature

White ash varies in cold hardiness with the latitude of origin. Trees grown in the north have a lower lethal temperatures than those from the south.

Moisture

Is found growing on dry to moist sites and is intermediately tolerant of temporary flooding.

Low Nutrient Conditions

Low tolerance to low nutrient conditions

RESPONSE TO DISTURBANCE

Overstory Removal

Young stands (5 to 10 years) respond to thinning by increasing height growth but older stands (35 to 85) do not exhibit increased growth from release.

Fire

White ash bark is not fire resistant but resprouts from the root crown after fire.

Competition

Commonly invades old fields and grows rapidly. Seedlings can also survive under a canopy but grow very little until a canopy opening becomes available and then they can respond quickly.

Management

White ash responds well to shelterwood cutting. Advanced regeneration grows best with 60 percent of the overstory removed.

FACTSHEET

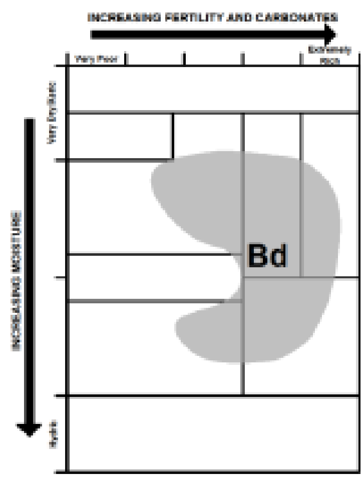
Basswood

Tilia americana

Martin Streit

RANGE

HABITAT



Soil and Site Relations

Commonly occurs on moist slopes that face north or east. Obtains maximum development on finer-textured soils such as sandy loam, loam and silt loam, but also found on sand dunes and dry exposed rock ridges.

Associated Forest Cover

Found in mixed stands with other broadleaf trees such as sugar maple, American beech, white ash and red oak.

Associated Ecosites

Basswood may exist in the canopy in the following ecosites: 90-92, 106-108, 122

REPRODUCTION

Sexual Reproduction Class	Perfect
Seed Bearing Age (yrs)	10
Seed Type	Samara
Frequency of Seed Crop (yrs)	1 - 2
Max. Dispersal Distance (m)	2x tree height, potentially
Time of Dispersal	September - October
Seed Bank	

Seed remains viable in the ground for 2 years.

Preferred Seedbed*	MS/H mix
Vegetative Reproduction	Stump sprouts

Reproduction Comments

Sprouts well from stumps but spouts should be thinned before reaching 5 cm DBH. Seed production is low and in some case 100% of the fruit produces no seed (parthenocarpy). Germination is generally poor regardlesss of seedbed condition.

GROWTH

Average/Max. Height (m)	23/23
Average/Max. DBH (cm)	100/189
Rooting Habit	

Root system largely composed of lateral roots in the shallow range; it usually does not form a taproot

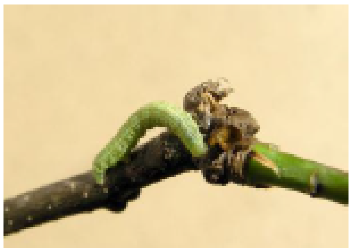
Early Growth	Seeds take 2 years to germinate. Partial shade aids in establishment of seedlings but heavy shade limits growth and development.
Avg./Max. Longevity (yrs)	100/200+
Successional Status	Basswood can be found in all stages of succession but achieves its highest densities in late successional sugar maple-basswood stands. A basswood stump sprout has a higher probability of replacing a parent stem than does a sugar maple seedling.

Basswood

DAMAGING AGENTS

Insects

Many different insects attack basswood but few serious insect problems exist. Local infestations of defoliators such as linden looper and basswood leafminer can occur periodically.



Linden looper
www.nrcan.gc.ca

Diseases

Basswood decays easily and it increases significantly after 120 years of age. It can be the host of many common hardwood decay organisms such as low cap fungi and nectria canker.

Wildlife

Mice, squirrels and chipmunks are common pests of seed. Basswood is a good source for bees as is a heavy nectar producer.

Other

Litte defect is encountered in basswood when harvested before it reaches 120 years of age. Beyond this age, the chances of losses due to decay are greatly increased.

GENETICS

Races, Varieties, Hybridization

Basswood is a single species but highly variable.

Seed Transfer Considerations

Not enough information is available. Local seed is the safest bet

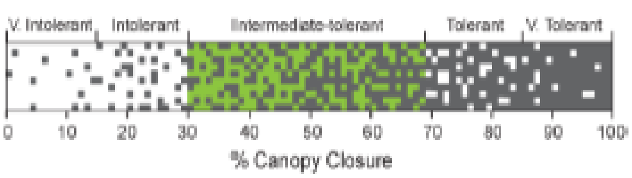
Genetic Resource Management

No tree improvement program

TOLERANCES

Light

Mid tolerant of shade. Shading aids the establishment and initial survival of seedlings.



Temperature

Basswood is one of the hardwood species least susceptible to late spring frosts. The northern limit of basswood approximates the -18° to -17° C isotherm for mean daily minimum January temperature.

Moisture

Moderately tolerant of flooding; occurs on floodplain sites that have probabilities of
annual flooding between 50 and 100 percent.

Low Nutrient Conditions

Moderate tolerance to low nutrient conditions

RESPONSE TO DISTURBANCE

Overstory Removal

Release of seedlings after 3 growing season improves growth. Open-grown trees have short stems and many large branches. Dense stands produce straight, columnar trunks with narrow tops.

Fire

Thin-barked species making it very susceptible to fire damage. However, following a fire the stump often remains viable for the production of a clump of suckers.

Competition

Although basswood is less shade tolerant than sugar maple, vigourous sprouting and rapid sprout growth allow it to persist under the selection system.

Management

Shelterwood can provide partial shade necessary for reproduction from seed. In selection management, stumps should be cut low to the ground to encourage regeneration by sprouting. Sprouts should be thinned before reaching 5 cm DBH.

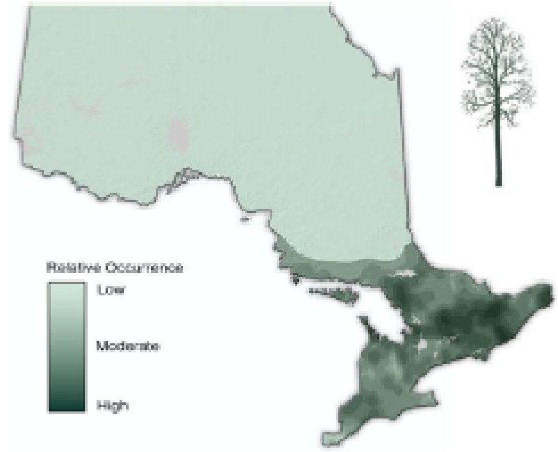
FACTSHEET

American Beech

Fagus grandifolia

Richard Wilson

RANGE



HABITAT

Soil and Site Relations

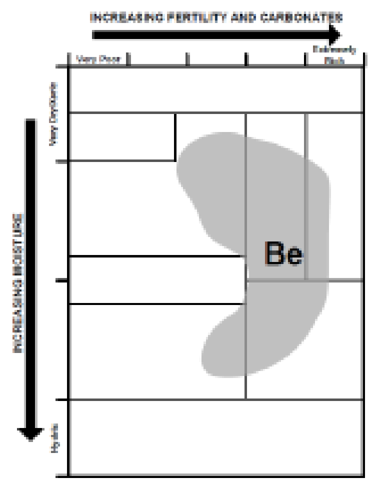
Occurs on moist, well-drained slopes and rich bottomlands. Soils of loamy texture and those with a high humus content are more favorable than lighter soils.

Associated Forest Cover

Associated with large number of trees, included in 20 forest cover types. Beech is a major component in Sugar Maple-Beech-Yellow Birch, Red Spruce-Sugar Maple-Beech, and Beech-Sugar Maple.

Associated Ecosites

Beech is a dominant or co-dominant species in the following ecosites: 57, 59, 76, 107, 108, 122, 124, 125



REPRODUCTION

Sexual Reproduction Class	Monoecious
Seed Bearing Age (yrs)	40 - 60
Seed Type	Nut
Frequency of Seed Crop (yrs)	2 - 8
Max. Dispersal Distance (m)	30
Time of Dispersal	Oct. - Nov.
Seed Bank	

Most of the seeds will germinate in the 1st year; after that, the seeds lose viability.

Preferred Seedbed*	MS, HM
Vegetative Reproduction	Root sprouts/Stem sprouts

Reproduction Comments

Seeds are relatively heavy and most simply drop to the ground, and dispersal is quite restricted. Seeds germinate from early spring to early summer. Spring chilling is rquired to break dormancy. Root sprouts and suckers can develop into trees.

GROWTH

Average/Max. Height (m)	22/28
Average/Max. DBH (cm)	60/92
Rooting Habit	

Initially has a taproot as a seedling but it gradually is obscured by the intensive development of oblique roots in the central mass of which surface lateral roots extend out from this mass.

Early Growth	Seedlings grow best under a moderate canopy or in protected small openings where the soil does not dry out below the depth of the shallow roots
Avg./Max. Longevity (yrs)	250/400
Successional Status	Beech is a late successional species that grows slowly underneath an overstory of conifers or hardwoods.

American Beech

DAMAGING AGENTS

Insects
Thin bark makes it vulnerable to large number of sucking insects (beech blight aphid, giant bark aphid, oystershell scale, beech scale). Defoliated periodically by saddled prominent, forest tent caterpillar, gypsy moth, fall cankerworm and Bruce spanworm.

beech bark disease
www.mnr.gov.on.c

Diseases
More than 70 decay fungi have been reported for beech. Beech bark disease is spreading in Ontario and is initiated when beech scale attacks the bark and renders it susceptible to the bark canker fungi.

Wildlife
Beech is seldom severely browsed by deer. Beech mast is palatable to large variety of birds and mammals.

Other
Long frost cracks in the trunks in regions with low winter temperatures can extend into bole. Can be severely damaged by late spring frosts. Sensitive to flooding but is rather windfirm except on shallow soils.

GENETICS

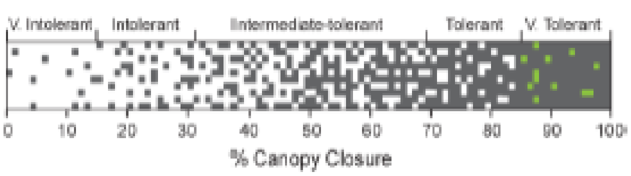
Races, Varieties, Hybridization
No races or varieties are reported with beech. No natural or artificial hybridizations with other species are recognized in North America.

Seed Transfer Considerations
Not enough information is available. Local seed is the best bet.

Genetic Resource Management
Initiatives to conserve large populations across their range, retain and increase the diversity and regeneration potential within each population, and observe and archive trees which demonstrate tolerance to beech bark disease.

TOLERANCES

Light
Very tolerant partly due to its very low respiration rate and the quick response of the stomata. May be less tolerant on very poor soils or in very cold climates.



Temperature
Beech trees can be severely damaged by late spring frosts. The flowers are also quite vulnerable to damage by spring frosts.

Moisture
During the growing season, beech is one of the least tolerant of flooding. Howerver, in winter an 18-day flooding had no apparent adverse effect.

Low Nutrient Conditions
Moderate tolerance to low nutrient conditions

RESPONSE TO DISTURBANCE

Overstory Removal
Clearcutting or heavy cutting results in fewer beech in new stands because beech is quickly overtopped by associated species like birches and white ash. Partial cuttings allow very tolerant beech to develop.

Fire
The thin bark of beech renders it highly vulnerable to injury by fire and the large shallow roots are especially vulnerable.

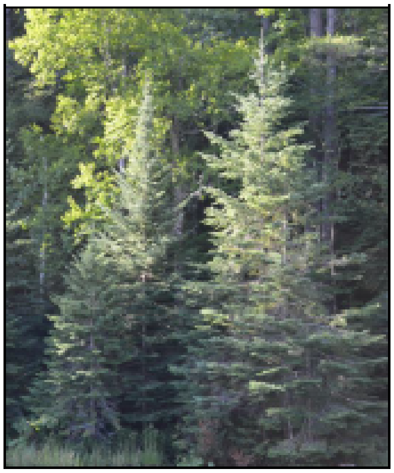
Competition
Very tolerant of shade partly due to very low respiration rate and quick response of stomata to light. May be less tolerant on very poor soils or very cold climates; may be more competitive under adverse site and climate conditions.

Management
Even-aged silviculture adversely affects beech production and favours production of associated hardwoods. Beech seedlings may be overtopped in clearcuts by less shade-tolerant species such as birches and oaks.

FACTSHEET

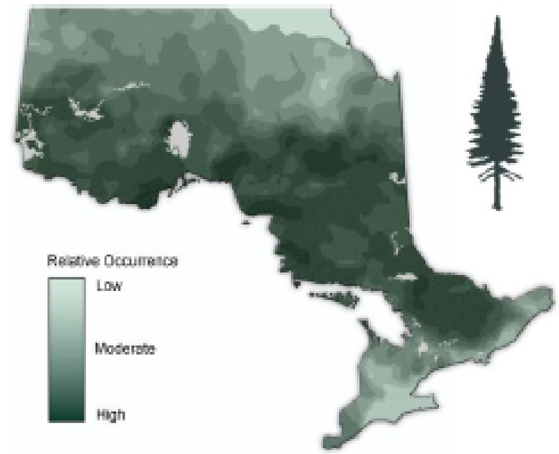
Balsam Fir

Abies balsamea



Erik Wainio

RANGE



HABITAT

Soil and Site Relations

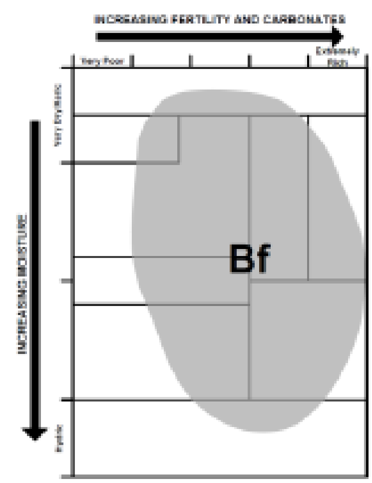
Grows on a very wide range of sites and soils from deep to shallow, coarse to fine textured, fresh to wet, mineral and organic soils.

Associated Forest Cover

Commonly occurs in mixed stands under several age classes. Boreal associates include white spruce, trembling aspen, black spruce, jack pine and white birch. GLSL associates include yellow birch, hemlock, white pine, beech, sugar maple, and red maple.

Associated Ecosites

Balsam fir is a dominant or co-dominant species (with white spruce) in the following ecosites: 26, 37, 52, 53, 58, 64, 67, 81, 85, 86, 101, 113, 116, 128-130, 223, 224



REPRODUCTION

Sexual Reproduction Class	Monoecious
Seed Bearing Age (yrs)	20
Seed Type	Winged Seed
Frequency of Seed Crop (yrs)	2 - 4
Max. Dispersal Distance (m)	60 - 160 (in open)
Time of Dispersal	September
Seed Bank	

Seeds remain viable for less than 1 year under natural conditions.

Preferred Seedbed*	MS, DW, BD, PM
Vegetative Reproduction	Layering

Reproduction Comments

Few seeds remain viable for more than 1 year on the forest floor. Germination is best if canopy closure is less than 80%. Layering is not an important means of reproduction.

GROWTH

Average/Max. Height (m)	17/31
Average/Max. DBH (cm)	45/47
Rooting Habit	

The root system is mostly confined to the duff layer and to the upper few centimeters of mineral soil.

Early Growth	Early growth is relatively slow (30 cm in 5 years, 90 cm in 9 years) under full sunlight, however once established, average annual height growth can reach 30 cm.
Avg./Max. Longevity (yrs)	100/150
Successional Status	Balsam fir is mid-successional to late successional species that is relatively short-lived. In the absence of fire, it often presents as an understory species in late successional stands.

FACTSHEET

Balsam Fir

DAMAGING AGENTS

Insects

Preferred tree species of spruce budworm. Feeds on emerging foliage causing root starvation and mortality. Successive infestations can lead to reduced growth (after 1 - 2 years) and top and whole tree mortality (after 2 - 4 years).

Spruce budworm
www.nrcan.gc.ca

Diseases

Susceptible to root rots (shoestring root rot, armillaria root rot) and butt rots (brown cubical butt rots) which reduce growth and increase risk of windthrow. Trunk rot fungus causes significant decay in upper portions of living trees.

Wildlife

Moose may browse on balsam fir during winter months when preferred browse species are not available.

Other

Root system is confined to duff and upper few centimeters of soil which make balsam fir susceptible to windthrow.

GENETICS

Races, Varieties, Hybridization

A variety of balsam fir, the bracted balsam fir (Abies balsamea var. phanerolepis), is found infrequently in Ontario. No distinct races or hybrids of balsam fir have been identified.

Genetic Resource Management

No tree improvement program

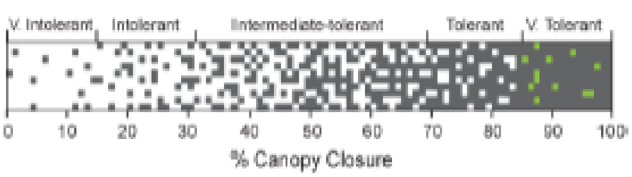
Seed Transfer Considerations

Natural populations show a west-east trend of variation. Western (including northwestern Ontario) populations generally break bud earlier, grow slower and suffer more spring frost damage. Eastern populations may, however, be more susceptible to balsam twig aphid attack.

TOLERANCES

Light

Very shade tolerant; can establish under 10% of full sunlight and survive low light levels for up to 50 years or more. Best growth is obtained at >45% of full sunlight.



Temperature

Seedlings have low to moderate tolerance to spring frost due to early flushing habit. Saplings and mature trees can resist frost damage.

Moisture

Moderately tolerant of short-term flooding (>6 weeks) and intolerant to more prolonged flooding.

Low Nutrient Conditions

Moderate tolerance to low nutrient conditions

RESPONSE TO DISTURBANCE

Overstory Removal

Elastic; capable of responding to release from long term suppression. Early release of vigourous trees (>15 cm height growth/year) is recommended to maximize growth response. Older suppressed trees with <5 cm growth/year will not respond to release.

Fire

Highly flammable due to thin, resinous bark, waxy needles, poor self-pruning and shallow rooting habits. Overmature and budworm killed stands on dry soils are most susceptible to fire while balsam fir mixedwood stands on moist soils are least susceptible.

Competition

Tolerant of vegetative competition as it is capable of growing and surviving under low light. Raspberry, grass, beaked hazel, and mountain maple are serious competitors. Partial shade from an aspen overstory may benefit early establishment of seedlings.

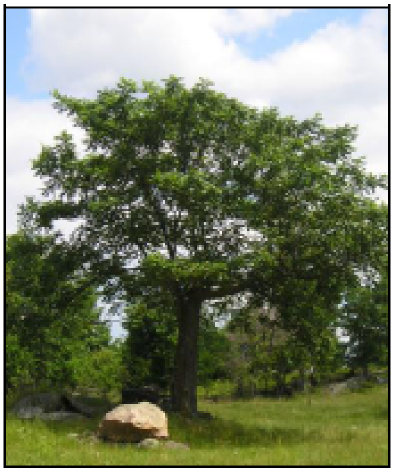
Management

Advanced regeneration is typically present in fir stands and if managed, can contribute significantly to the composition of the future stand. Susceptibility to spruce budworm and decay may warrant mixed species management and early harvesting.

FACTSHEET

Butternut

Juglans cinerea



Rose Fleguel

RANGE

HABITAT

Soil and Site Relations

Occurs on a variety of sites, including dry rocky soils (particularly those of limestone origin) but grows best on well-drained, fertile soils in shallow valleys or on gradual slopes.

Associated Forest Cover

Found singly or in small groups mixed with other species. Commonly assoicated with black walnut, hickory and white ash.

Associated Ecosites

insufficient data

REPRODUCTION

Sexual Reproduction Class	Monoecious
Seed Bearing Age (yrs)	20
Seed Type	Nut
Frequency of Seed Crop (yrs)	2 - 3
Max. Dispersal Distance (m)	vicinity of parent tree, unle
Time of Dispersal	September - October
Seed Bank	

Seed remains viable in the ground for 2 years.

Preferred Seedbed*	MS/H mix
Vegetative Reproduction	Stump sprouting from you

Reproduction Comments

Germination occurs in spring following seedfall. Species is fast growing.

GROWTH

Average/Max. Height (m)	20/25
Average/Max. DBH (cm)	60/116
Rooting Habit	

Deep, wide spreading, usually with a taproot.

Early Growth	Seedlings require forest gaps for growth and have no shade requirements.

Avg./Max. Longevity (yrs)	75/80
Successional Status	Although young butternut can tolerate partial shade, butternut must be in the overstory to thrive and is classified as an early successional species.

Butternut

DAMAGING AGENTS

Insects
Common defoliators can reduce butternut leaf cover periodically. Nut weevils can cause damage to seed.

Diseases
Leaf spot can be an issue in seedlings but butternut canker is a serious problem for all stages of growth including mature trees.

Butternut canker
MNR

Wildlife
Nuts provide food for squirrels and other rodents and deer find the leaves palatable. Where common grackle populations are high they can also consume large amounts of seed.

Other
Subject to storm damage, although generally windfirm. Frequently an associate of other rare species.

GENETICS

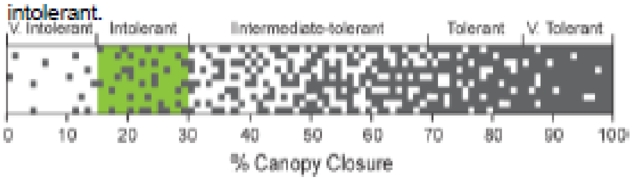
Races, Varieties, Hybridization
Hybridizes with other species of the same genus, except black walnut.

Genetic Resource Management
Initiatives to conserve large populations across their range, retain and increase the diversity and regeneration potential within each population, and observe and archive trees which demonstrate tolerance and could be the basis for long term recovery.

Seed Transfer Considerations
Genetic resistance to S. clavigignenti-juglandacearum is overly weak. Rare disease-free trees surrounded by infected trees may possess stronger genetic resistance. Resistant trees from the US may be used to enhance butternut genetic diversity in Canada. Natural hybridization with Japanese walnut threats the purity of butternut on the landscape.

TOLERANCES

Light
Although young trees may withstand competition from the side, butternut does not survive under shade from above. It must be in the overstory to thrive and is classified as shade intolerant.



Temperature
Butternut is generally considered to be more winter-hardy than black walnut. Cold stratification for 90 to 120 days at temperatures of 20°-30°C overcomes dormancy.

Moisture
Requires fresh sites and seldom found on dry, compact or infertile soils.

Low Nutrient Conditions
Low tolerance to low nutrient conditions

RESPONSE TO DISTURBANCE

Overstory Removal
no data

Fire
Butternut is very susceptible to fire. Aboveground portions are easily killed by fire, and sprouting from the root crown or stump is rare.

Competition
Releases toxin (juglone) found in leaves, bark, nut husks and roots which is an antagonism to other plants growing in its root zone.

Management
All butternut are protected under the Endangered Species Act until formally assessed. Trees that are tolerating the butternut canker, amidst declining trees should be reported. Refer to the Stand and Site Guide, habitat regulation, and related documents.

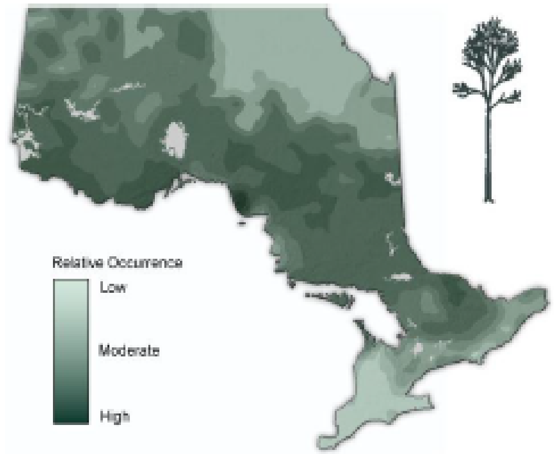
FACTSHEET

White Birch

Betula papyrifera

Erik Wainio

RANGE



HABITAT

Soil and Site Relations

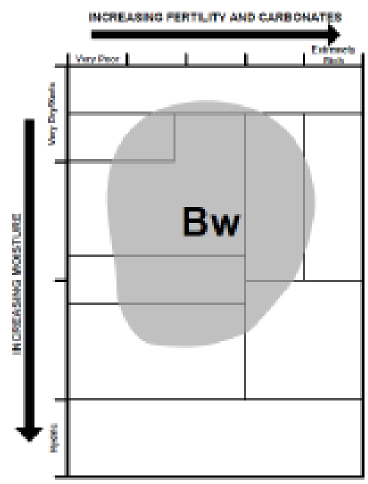
Grows on a very wide range of sites and soils from deep to shallow, coarse to silty textured, fresh to wet, mineral and organic soils. Highest densities occur along the north shore of Lake Superior.

Associated Forest Cover

Can form pure stands or be mixed with other species including trembling aspen, black spruce, white spruce, balsam fir, jack pine, white pine and red maple.

Associated Ecosites

White birch is a dominant or co-dominant species in the following ecosites: 16, 19, 28, 40, 43, 55, 70, 76, 88, 104, 119



REPRODUCTION

Sexual Reproduction Class	Monoecious
Seed Bearing Age (yrs)	15
Seed Type	Samara
Frequency of Seed Crop (yrs)	2 - 4
Max. Dispersal Distance (m)	60 - 200 (in open)
Time of Dispersal	July - Sept.
Seed Bank	

A small percentage of the seeds can remain viable on the forest floor for several years.

Preferred Seedbed*	MS, HM, DW
Vegetative Reproduction	Stem sprouts

Reproduction Comments

Seed regeneration predominates over vegetative reproduction. Sprouting ability is lost after 60 years of age. Can be reproduced through layering, cuttings, budding, and grafting.

GROWTH

Average/Max. Height (m)	20/27
Average/Max. DBH (cm)	40/118
Rooting Habit	

Generally shallow rooted with the bulk of the roots in the top 60 cm of soil; taproots do not form.

Early Growth	Seedlings average 10 cm in height after first year and 1 m after 4 years. Sprouts capable of more rapid height growth averaging 60 cm after first year and 2 m after 4 years.

Avg./Max. Longevity (yrs)	90/140
Successional Status	White birch is an early successional species that is often replaced by balsam fir, white spruce, white pine, and cedar in the absence of fire.

White Birch

DAMAGING AGENTS

Insects
Bronze birch borer attacks overmature or weakened trees. Common defoliators include forest tent caterpillar, birch skeletonizer, leafminer, leaf-mining sawflies, casebearer, saddled prominent and gypsy moth.

Forest tent caterpillar
www.nrcan.gc.ca

Diseases
Decay fungi, stem cankers, and root-rotting fungus infect birch trees. Red heart very common in some areas. Root-rotting can cause cracks at base of the stem and uprooting by wind.

Wildlife
Moose and deer over-browsing at seedling stage reduces amount of dominant birch. Porcupines and sapsuckers damage larger trees. Hares and other small mammals clip small seedlings.

Other
Birch dieback during the late 1930-40's has subsided. Postlogging decadence resembling dieback sometimes develops in residual trees following partial cutting, especially in older stands.

GENETICS

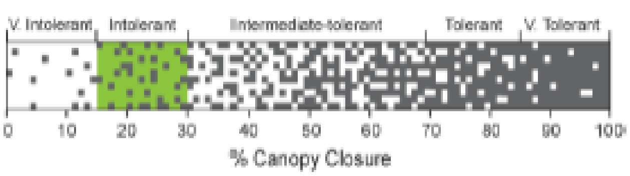
Races, Varieties, Hybridization
White birch hybridizes naturally with almost every other native species in the genus.

Seed Transfer Considerations
A short-term farm field test (Thunder Bay) indicated superior growth of more southerly seed sources, but information is insufficient for making safe seed movement recommendations.

Genetic Resource Management
No tree improvement program

TOLERANCES

Light
Intolerant to shade but partial shade may benefit early establishment, growth, and survival; continued growth and survival requires greater than 50% of full sunlight.



Temperature
Tolerant of low temperatures below -40°C.

Moisture
Seedlings can tolerate some degree of flooding and resume rapid growth following receding water levels.

Low Nutrient Conditions
High tolerance to low nutrient conditions

RESPONSE TO DISTURBANCE

Overstory Removal
Inelastic. Advanced regeneration does not develop due to inadequate light levels in the understories. Requires openings greater than 0.5 ha in size and less than 20% canopy closure to reproduce from seed or sprouts.

Fire
Fire is responsible for establishment of many stands. Bark is thin and highly flammable and even large trees may be killed by moderate fires.

Competition
Shade intolerant and usually lasts only one generation and then is replaced by more tolerant species. Often requires release from faster growing species (aspen, pin cherry) in early stages of regeneration.

Management
Residual white birch often exhibit post-logging decadence with symptoms including low vigor and growth, dieback and mortality.

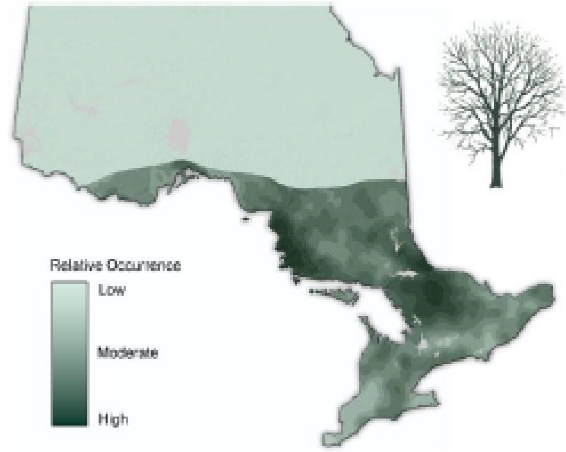
FACTSHEET

Yellow Birch

Betula alleghaniensis

Larry Watkins

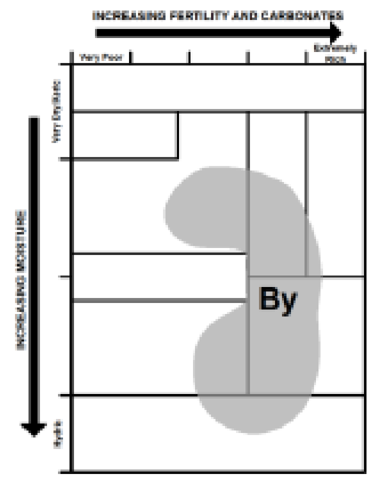
RANGE



HABITAT

Soil and Site Relations

Commonly found on fresh to wet, moderately fertile sites with deep loamy soils.



Associated Forest Cover

Grows individually or in small pure groups mixed with hardwoods (predominantly sugar maple) on upland sites and with hemlock and eastern white cedar near waterbodies.

Associated Ecosites

Yellow birch is the dominant or co-dominant species in the following ecosites: 55, 84, 88, 100, 104, 119, 123, 133

REPRODUCTION

Sexual Reproduction Class	Monoecious
Seed Bearing Age (yrs)	40
Seed Type	Samara
Frequency of Seed Crop (yrs)	Annually
Max. Dispersal Distance (m)	100 - 200 (in open)
Time of Dispersal	Aug. - Oct.
Seed Bank	

Seeds fall with cold weather in October through winter and germinate in June so no banking occurs. Seed viability is usually good in years with heavy seed crops and poor in years with light crops.

Preferred Seedbed*	MS, BD, HM, DW
Vegetative Reproduction	Stem sprouts

Reproduction Comments

Does not establish on undisturbed litter because small germinant radicle is not strong enough to penetrate matted litter. Seedlings and small saplings reproduce from sprouts when cut, but sprouting from larger stems is very poor.

GROWTH

Average/Max. Height (m)	22/25
Average/Max. DBH (cm)	60/173
Rooting Habit	

Adaptable root system capable of either spreading horizontally through shallow soil, or penetrating to depths of more than 1.5 m

Early Growth	Optimum seedling survival occurs on disturbed humus or mixed humus mineral soil seedbeds in the absence of competition by advance regeneration. Growth is slow and surviving early seedlings often
Avg./Max. Longevity (yrs)	150/300+
Successional Status	Yellow birch is present in all stages of succession. It tends to be replaced by more shade-tolerant species including sugar maple and beech.

FACTSHEET

Yellow Birch

DAMAGING AGENTS

Insects
Birch leaf miner, birch leaf skeletonizer, and forest tent catepillar consume foliage and reduce growth. When weakened, yellow birch may be attacked by bronze birch borer often resulting in mortality.

Birch skeletonizer
MNR

Diseases
Considered one of the most defective hardwoods in Ontario. Brown stain causes significant volume loss followed by yellow-brown stringy rot, white spongy rot, and incipient yellow rot.

Wildlife
Favoured browse species of deer and hare. Yellow bellied sapsucker may girdle trees from repeated drilling. Porcupines may strip bark and branches.

Other
Subject to windthrow on shallow, poorly drained soils. The fine branching habit makes it susceptible to damage from accumulating ice or snow loads. Winter sunscald can be a problem on S and SW sides of birch boles.

GENETICS

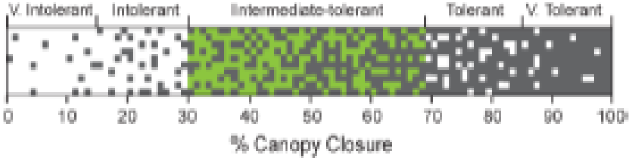
Races, Varieties, Hybridization
Yellow birch shows great phenotypic variability. It hybridizes with white birch as well as many other birch species.

Seed Transfer Considerations
No clear geographic pattern of growth variation is evident. Northern seed sources set buds earlier and survive significantly better at northern sites in the US. Research data are not available from Ontario, thus caution should be exercised in moving seed northward.

Genetic Resource Management
No tree improvement program

TOLERANCES

Light
Requires partial shade for establishment and overhead light to grow adequately relative to its more tolerant associates, hard maple, beech, and hemlock.



Temperature
Low to moderate tolerance to frost.

Moisture
Intolerant of drought and flooding.

Low Nutrient Conditions
Moderate tolerance to low nutrient conditions

RESPONSE TO DISTURBANCE

Overstory Removal
Relatively inelastic; does not respond to release from severe suppression and responds only moderately to release from light suppression. Excessive release may cause epicormic branches.

Fire
Thin-barked yellow birch is susceptible to fire injury. Seedlings and saplings are killed outright by even light surface fires.

Competition
Seedlings cannot compete successfully with advanced regeneration, grass, and herbaceous plants. Given adequate light, yellow birch will outcompete sugar maple and beech given adequate light.

Management
Residual yellow birch often exhibit post-logging decadence with symptoms including low vigor and growth, dieback and mortality.

FACTSHEET

Black Cherry

Prunus serotina

Karla Falk

RANGE

HABITAT

Soil and Site Relations

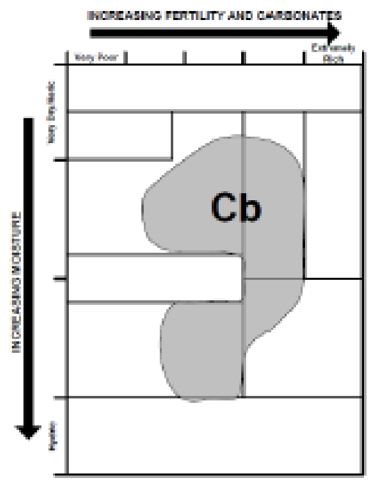
Tolerates a wide range of conditions from wet to dry sites. However, growth is poor on very wet or very dry sites.

Associated Forest Cover

Grows well mixed with other broadleaf species, such as sugar maple, white ash, basswood, yellow birch, white oak, shagbark hickory, and tulip-tree.

Associated Ecosites

Black cherry may exist in the canopy in the following ecosites: 57-59, 72-76, 106-108



REPRODUCTION

Sexual Reproduction Class	Perfect
Seed Bearing Age (yrs)	10
Seed Type	Seed
Frequency of Seed Crop (yrs)	3 - 4
Max. Dispersal Distance (m)	33 - 400 m if by birds or m
Time of Dispersal	August - September
Seed Bank	

Considerable amounts of seed are stored in the soil and can remain viable for >3 years.

Preferred Seedbed*	H, seedlings do not like co
Vegetative Reproduction	Stump sprouts

Reproduction Comments

Readily sprouts from stumps with maximum sprouting ability by trees <40 years old.

GROWTH

Average/Max. Height (m)	22/28
Average/Max. DBH (cm)	40/111
Rooting Habit	

Shallow and spreading root system; most roots within 60 cm of soil surface

Early Growth	Grows faster than assoicates in seedling, sapling and pole stages. Seedlings are shade tolerant for 3-5 years, but do not persist beyond without overstory release. Seedlings produce a taproot in the 1st year.
Avg./Max. Longevity (yrs)	100/150
Successional Status	Black cherry is an early successional species. It rarely occurs in the canopy of late successional deciduous forests but buried seed and seedlings are often present in the understory.

FACTSHEET

Black Cherry

DAMAGING AGENTS

Insects
In seedlings eastern tent caterpillar and cherry leaf spot can be a problem. Cherry scallopshell moth is defoliator that can affect any age of tree.


Black knot
www.nrcan.gc.ca

Diseases
Black knot is detrimental at both seedling and mature tree stages.

Wildlife
Rabbits and hares can pose problems at the seedling stage. Deer can cause damage throughout the life of the tree, as can porcupine, mice and voles who girdle stems.

Other
Low tolerance to browsing and susceptible to damage from storms. Soil scarification following cutting is not necessary.

GENETICS

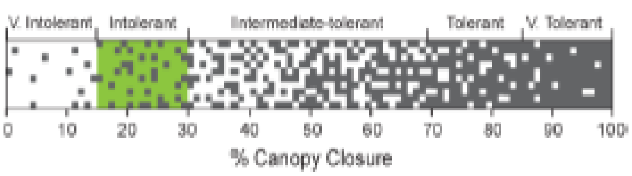
Races, Varieties, Hybridization
Four varieties of black cherry have been recognized in the southern part of the range. Provenance testing has identified several traits that are related to geographic origin.

Genetic Resource Management
No tree improvement program

Seed Transfer Considerations
Information is unavailable from field trials in Canada. Provenance tests in northern US indicated that seed sources from Pennsylvanian may have superior genetic quality they exhibited better survival, faster growth and straighter tree form, while Ontario seed source showed slowest growth.

TOLERANCES

Light
Intolerant of shade excect for first 3-5 years during early seedling growth.



Temperature
Late spring frosts may damage the flowers before they open, and frosts occasionally cause large numbers of newly set fruits to fall from the pedicels without maturing

Moisture
Prefers well-drained soils but can exist on very wet or very dry sites although growth is poor. However, cherry is intolerant to flooding.

Low Nutrient Conditions
Moderate tolerance to low nutrient conditions

RESPONSE TO DISTURBANCE

Overstory Removal
Seedlings are only shade tolerant to 3-5 years old and then require an overstory release as they do not persist without it. Slight to moderate growth increase as response to release in dominant and codominant crown classes aged 50-60 years.

Fire
Thin bark makes it very susceptible to fire injury but it then typically resprouts from the root crown or stump.

Competition
Maintains growth advantage over associated species for 60-80 years. Mortality increases after 80-100 years.

Management
Sprouts originating low on stumps should not be descriminated against in silvicultural operations. It is recommended to protect regeneration in areas of high deer browsing.

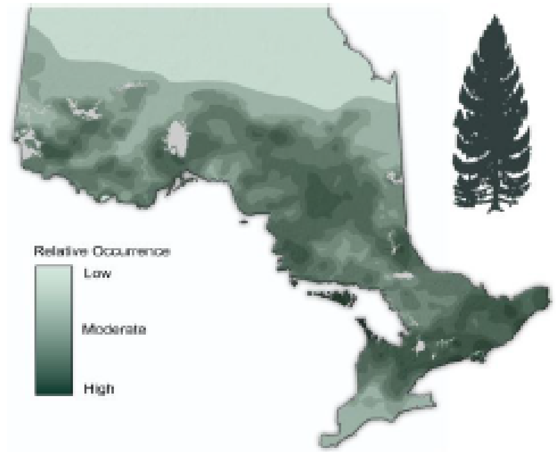
FACTSHEET

Eastern White Cedar

Thuja occidentalis

Larry Watkins

RANGE



HABITAT

Soil and Site Relations

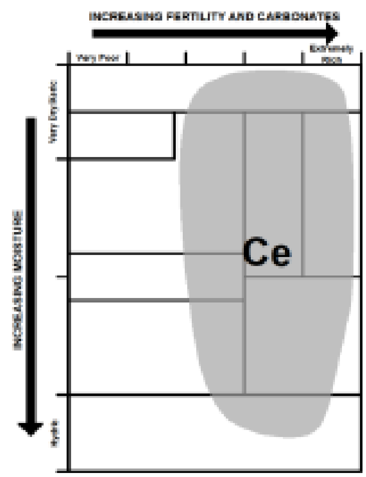
Most commonly found on cool, low-lying and humid sites with wet, very poorly drained, nutrient-rich, organic soils.

Associated Forest Cover

Grows in both pure and mixed stands. Black spruce is often associated with cedar on organic soils and balsam fir is the most common co-dominant species on upland sites. White birch, tamarack, white spruce, and trembling aspen are also found with cedar.

Associated Ecosites

Eastern white cedar is the dominant or co-dominant species in the following ecosites: 13, 25, 51, 66, 84, 100, 115, 117, 129, 224



REPRODUCTION

Sexual Reproduction Class	Monoecious
Seed Bearing Age (yrs)	30, as early as 6
Seed Type	Winged Seed
Frequency of Seed Crop (yrs)	2 - 5
Max. Dispersal Distance (m)	45 - 60
Time of Dispersal	September
Seed Bank	

Seeds do not remain viable on the forest floor longer than 1 year, as dormancy is broken while seeds lie on the ground during the first winter.

Preferred Seedbed*	DW, MS, H, SM, BO
Vegetative Reproduction	Layering

Reproduction Comments

Layering accounts for a considerable amount of white cedar reproduction. It is very common on organic soils and seedlings may reproduce by layering at age 5 or earlier.

GROWTH

Average/Max. Height (m)	16/18
Average/Max. DBH (cm)	30/178
Rooting Habit	

Generally develops a shallow, wide-spreading root system and natural root grafts are fairly common.

Early Growth	Early growth is slow averaging 8 cm per year for the first several years.
Avg./Max. Longevity (yrs)	200/400+
Successional Status	Cedar is a late successional species on lowland sites and a mid-successional species in upland mixedwood stands.

FACTSHEET

Eastern White Cedar

DAMAGING AGENTS

Insects

Insect damage to eastern white cedar is minor. Common insect pests to damaged and stressed trees include the carpenter ant, northern cedar bark beetle, and the cedar leafminer.

Cedar leafminer damage
MNR

Diseases

Minor diseases of eastern white cedar include brown cubical butt rot and white stringy butt rot on drier lowland soils.

Wildlife

Cedar is an important winter browse species for deer and hares. Porcupine will partially or completely girdle trees and red squirrels eat flower buds and clip cone-bearing branches.

Other

Can withstand physical damage from ice storms. Large trees in older stands with high basal defect susceptible to windthrow and breakage.

GENETICS

Races, Varieties, Hybridization

No races or varieties are reported with eastern white cedar. No natural or artificial hybridization with other species are recognized.

Seed Transfer Considerations

Inadequate information available

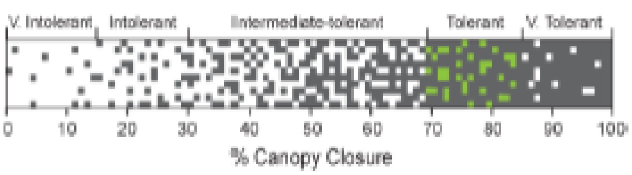
Genetic Resource Management

No tree improvement program

TOLERANCES

Light

Seedling survival and growth is best between 45-50% full sunlight but seedlings will tolerate full shade.



Temperature

Once established, highly frost-resistant as it survives on low-lying sites susceptible to late-spring and early-fall frosts.

Moisture

Very tolerant of frequent well-aerated flooding for short periods of time (less than 2 months).

Low Nutrient Conditions

Moderate tolerance to low nutrient conditions

RESPONSE TO DISTURBANCE

Overstory Removal

Suppressed cedar trees are elastic and are able to respond in increased growth with increasing light conditions even after extended periods of suppression.

Fire

Cedar commonly grows on wet organic soils where risk of fire is low. If fire does occur, cedar is very susceptible to damage due to its thin, flammable, shaggy bark and shallow rooting habit.

Competition

Tolerant of vegetative competition. Vegetative reproduction is considered more tolerant than reproduction from seedlings.

Management

Mechanical site preparation may stimulate seedbank competition on upland sites. Response to thinning is good on productive, well-drained lowland sites with good waterflow.

FACTSHEET

White Elm
Ulmus americana

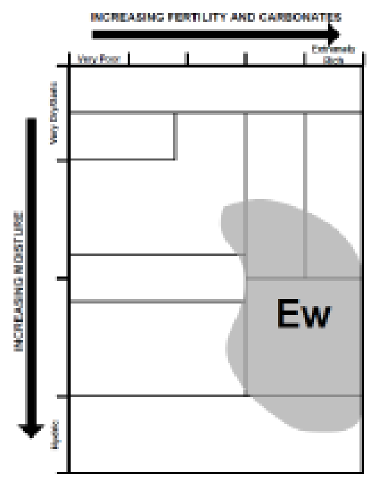
Erik Wainio

RANGE

HABITAT

Soil and Site Relations

White elm grows best on rich, well-drained loams. Common on bottom-land soils, but found on many great soil groups including well-drained sands, organic bogs, silts, and poorly drained clays.



Associated Forest Cover

Seldom found in pure stands, mainly found in mixtures with balsam poplar, balsam fir, yellow birch, black ash, red maple, and silver maple. Minor component in 20 other forest types.

Associated Ecosites

White elm may exist in the canopy in the following ecosites: 56, 71, 89, 105, 120, 130

REPRODUCTION

Sexual Reproduction Class	Perfect
Seed Bearing Age (yrs)	15-300
Seed Type	Samara
Frequency of Seed Crop (yrs)	Annually
Max. Dispersal Distance (m)	150m-0.4km
Time of Dispersal	June

Seed Bank

Seed usually germinates soon after it falls, although some seed may remain dormant until the following spring.

Preferred Seedbed*	MS
Vegetative Reproduction	Stump sprouts/Root sucke

Reproduction Comments

Reproduction from seed is most common and seeds usually germinate soon after they fall, although some seeds remain dormant until the following spring. American elm will produce fairly vigourous stump sprouts from small trees.

GROWTH

Average/Max. Height (m)	24/38
Average/Max. DBH (cm)	40/151

Rooting Habit

Roots widespreading and 0.9-1.2 m deep on wet soils, taproot forms on drier soils

Early Growth	Although they do grow in full sunlight, seedlings perform best with about one-third full sunlight during the first year. After the first year or two, they grow best in full sunlight.
Avg./Max. Longevity (yrs)	200/300
Successional Status	Elm can be an early, mid, or late successional species. It can quickly become established in fields. It responds well to release and once it becomes dominant in a mixed hardwood stand, it is seldom overtaken by other species.

White Elm

DAMAGING AGENTS

Insects

Feeding by European and native elm bark beetles introduce Dutch elm disease fungus into the sap stream. Hundreds of insect species attack elm (defoliators, bark beetles, borers, leaf rollers and miners, twig girdlers, leaf hoppers, sucking insects).

Dutch elm disease
MNR

Diseases

Dutch elm disease, verticillium wilt, leaf black spot, twig blight, cankers, elm wetwood, and wood rot fungi are common diseases of black cherry.

Wildlife

Animal damage from sapling stage to maturity is not a serious problem except for sapsucker injury that degrades the wood.

Other

Climatic factors can have survival impacts (young trees may sunscald after harvesting; open grown trees susceptible to injury by snow and ice damage; drought or flooding).

GENETICS

Races, Varieties, Hybridization

No success in hybridization of white elm which has a chromosome number twice of all other elms.

Genetic Resource Management

No tree improvement program

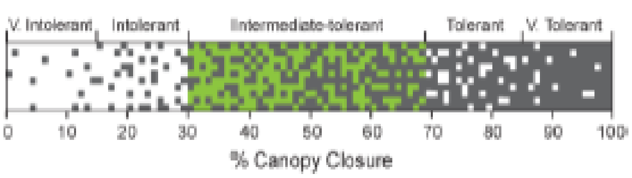
Seed Transfer Considerations

Maintaining genetic diversity is an important consideration in restoring white elm under the threat of Dutch elm disease. Besides silvicultural approaches and chemical protection, genetic resistance to DED may be helpful. Resistant genotypes selected in Canada and the US may be tested at Ontario planting sites.

TOLERANCES

Light

Intermediate in shade tolerance among eastern hardwoods.



Temperature

Adverse weather may reduce the seed crop. Spring frosts can injure and kill both flowers and fruit.

Moisture

Can withstand flooding in the dormant season, but dies if flooding is prolonged into the growing season.

Low Nutrient Conditions

Low tolerance to low nutrient conditions

RESPONSE TO DISTURBANCE

Overstory Removal

Usually it responds well to release, often growing more rapidly than its associates at advanced ages.

Fire

Fires can kill seedling and sapling sized trees and wound larger trees, admitting heartrot fungi.

Competition

Once dominant in a mixed hardwood stand, it is seldom overtaken by other species. Persists in the understory of some early successional species but dies if suppressed by sugar maple or beech.

Management

Management has been at primarily aimed at breeding for Dutch elm disease and phloem necrosis resistance. Thousands of attempts to cross the American with the Siberian elm have failed and successful hybridizations are rare.

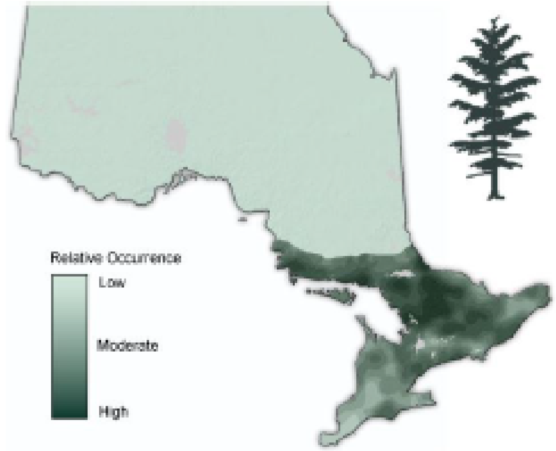
FACTSHEET

Eastern Hemlock

Tsuga canadensis

Daniel Tigner

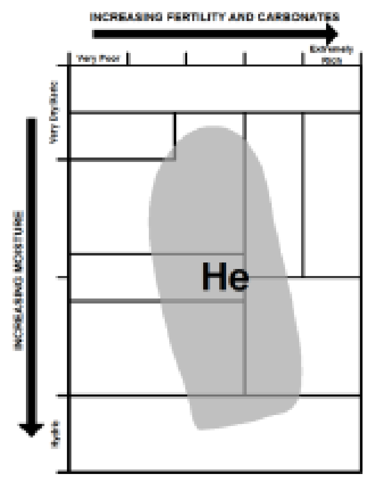
RANGE



HABITAT

Soil and Site Relations

Prefers cool, moist, well drained sites with a range of soil types. Commonly found in riparian areas where humidity is higher. Can also be found on drier, shallow soils on slopes and ridgetops.



Associated Forest Cover

Can form pure stands or be mixed with other species including white pine, cedar, balsam fir, white spruce, sugar maple, red maple, yellow birch, white birch and beech.

Associated Ecosites

Eastern hemlock is a dominant or co-dominant species (with eastern white cedar) in the following ecosites: 25, 36, 51, 66, 100, 115, 129, 224

REPRODUCTION

Sexual Reproduction Class	Monoecious
Seed Bearing Age (yrs)	40
Seed Type	Winged Seed
Frequency of Seed Crop (yrs)	2 - 3
Max. Dispersal Distance (m)	30 - 40
Time of Dispersal	Oct. - Nov.
Seed Bank	

Seeds do not remain viable if they do not germinate the first spring after seedfall.

Preferred Seedbed*	MS, BD, DW
Vegetative Reproduction	Nil

Reproduction Comments

One of the most frequent and abundant seed producers of the eastern conifers. However, seeds do not remain viable if they do not germinate the first spring after seedfall. Suppressed trees may never produce seed.

GROWTH

Average/Max. Height (m)	23/30
Average/Max. DBH (cm)	80/105
Rooting Habit	

Site conditions determine the rooting habits of hemlock. When the watertable is near the surface, root systems are shallow. On better drained sites, deeper rooting patterns may be observed.

Early Growth	Seedling are slow growing, usually 2-3 cm in height in first year with future growth dependent on light level (2 cm/year in low light, 20 - 30 cm/yr in light to moderate shade, 45 cm/year in full sun)
Avg./Max. Longevity (yrs)	300/400+
Successional Status	Hemlock is a late successional species that is well adapted to the cool microclimate of mature forests because of its shade tolerance, longevity, and large size.

Eastern Hemlock

DAMAGING AGENTS

Insects

Hemlock wooly adelgid is a non-native insect that feeds on eastern hemlock causing decline and significant mortality. Hemlock looper and hemlock borer are also common damaging agents.

Hemlock wooly adelgid
Rebecca Lidster

Diseases

Seeds and seedlings are susceptible to damping-off fungi. Root rot (Armillaria sp.) colonizes overmature trees and trees weakened by drought.

Wildlife

Can be heavily browsed by deer and moose which greatly reduces seedling devleopment. Hare also feed on young seedling. Porcupine feed on bark causing tree decline and mortality

Other

Prone to uprooting and windthrow after excessive release due to shallow rooting habit. Older trees susceptible to radial stress cracks and ring shake.

GENETICS

Races, Varieties, Hybridization

Research focuses on propagation of variants for ornamental purposes only.

Seed Transfer Considerations

Inadequate information available

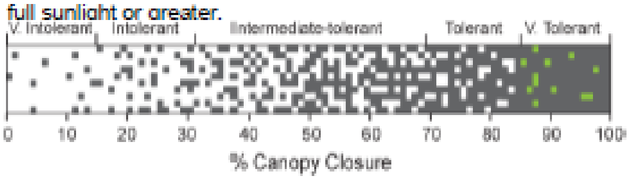
Genetic Resource Management

No tree improvement program

TOLERANCES

Light

Most shade tolerant of all Ontario tree species. Capable of regenerating at 5% of full sunlight and growing in as little as 20 - 25% light. Optimal height growth occurs at 50 - 55% of full sunlight or greater.



Temperature

Moderately tolerant to frost.

Moisture

Seedlings intolerant of drought and excessive soil moisture evaporation associated with open, fully-exposed sites. Susceptible to winter dessication of foliage.

Low Nutrient Conditions

Moderate tolerance to low nutrient conditions

RESPONSE TO DISTURBANCE

Overstory Removal

Highly elastic; understory advanced regeneration with >50% crown ratio responds quickly to release. Hemlock growing under a hardwood canopy and older saplings will respond better to release than those under a hemlock canopy and younger saplings.

Fire

Young trees highly vulnerable to fire damage and mortality. Low intensity prescribed burning creates suitable seedbed conditions for natural regeneration.

Competition

Considered the most shade tolerant of all competitive associates, however, seedlings cannot compete with sugar maple due to slow height growth.

Management

Advanced regeneration growth and survival is maximized when kept partially shaded until at least 1.5 - 3.0m in height. Natural regeneration is promoted with opening widths less than the height of adjacent residuals and adequate seed supply.

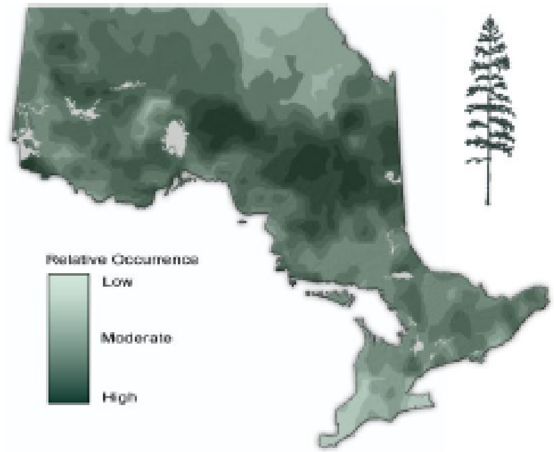
FACTSHEET

Tamarack (Eastern Larch)

Larix laricina

Erik Wainio

RANGE



HABITAT

Soil and Site Relations

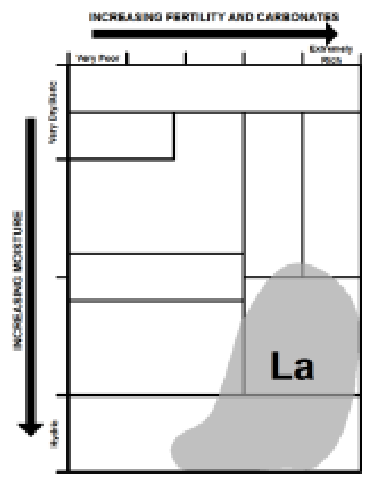
Typically occupies cool, low-lying, peatland sites with deep, very poorly drained, organic soils. It occurs less frequently on moist to wet silty, fine loamy and clayey soils, and on shallow organic soils.

Associated Forest Cover

Grows in pure stands, however commonly exists in mixed stands. Black spruce is often associated with tamarack in wet, open and forested peatlands. Balsam fir, white spruce and eastern white cedar are also infrequently associated with tamarack.

Associated Ecosites

Tamarack is the dominant or co-dominant species in the following ecosites: 68, 102, 127-129, 223, 224



REPRODUCTION

Sexual Reproduction Class	Monoecious
Seed Bearing Age (yrs)	12 - 15
Seed Type	Winged Seed
Frequency of Seed Crop (yrs)	3 - 6
Max. Dispersal Distance (m)	60
Time of Dispersal	Sept. - Oct.
Seed Bank	

Under forest conditions any existing dormancy is broken while the seed lies on the ground during the first winter. Seed remains viable for 4 years or more when stored in sealed containers at 2 to 5 percent moisture content and -8° to -6°C.

Preferred Seedbed*	MS, O, SM, BO
Vegetative Reproduction	Layering

Reproduction Comments

Layering may occur but is not a significant means of natural reprodcution. Dominant and co-dominant trees with well-established crowns produce highest number of cones.

GROWTH

Average/Max. Height (m)	17/29
Average/Max. DBH (cm)	40/67
Rooting Habit	

Typically has a shallow, spreading root system.

Early Growth	One of the fastest growing conifers with seedling growth up to 30 cm per year in first 3 years and 80 cm per year until crown closes.
Avg./Max. Longevity (yrs)	150/180
Successional Status	Tamarack is an early successional species. It is often the first tree to invade open bogs and burned peatlands. It is often succeeded by the more shade tolerant black spruce on bogs, and cedar, balsam fir, and hardwoods in swamps.

FACTSHEET

Tamarack (Eastern Larch)

DAMAGING AGENTS

Insects
Larch sawfly is a serious pest of tamarack. Trees typically die after 8 successive years of defoliation. The larch casebearer also defoliates tamarack. The eastern larch beetle damages the tree by colonizing the phloem.

Larch sawfly
www.nrcan.gc.ca

Diseases
Minor diseases of tamarack include heart rot, butt rot, and root rot. Seeds and seedlings are susceptible to damping-off fungi.

Wildlife
Porcupine feed on inner bark, girdling stems which causes reduced growth or mortality.

Other
Moderately windfirm species with higher susceptibility to uprooting on organic soil where rooting is shallow.

GENETICS

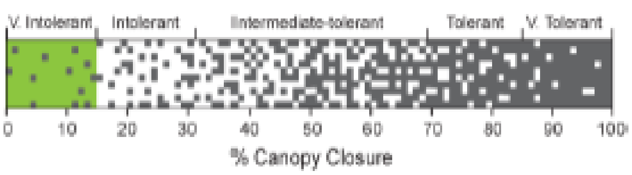
Races, Varieties, Hybridization
No races or ecotypes are presently recognized. Tamarack has been crossed with Japanese larch and European larch. No natural hybridization has been reported with other species.

Seed Transfer Considerations
Geographic populations show a latitudinal cline of growth variation with more southerly seed sources showing superior growth. Populations, however, vary in cold hardiness in relatively short distance. Safe transfer distance is about 0.5° (latitude) from seed origin.

Genetic Resource Management
No tree improvement program

TOLERANCES

Light
Seedlings tolerant of moderate shade for up to 4 years, however, once established they require full sunlight for optimum growth and survival.



Temperature
Tamarack is resistant to frost as it survives on low-lying sites susceptible to late-spring and early-fall frosts.

Moisture
Very tolerant of short to medium duration flooding.

Low Nutrient Conditions
Low tolerance to low nutrient conditions

RESPONSE TO DISTURBANCE

Overstory Removal
Advance regeneration does not develop due to inadequate light levels under overstories. Requires nearly complete overstory removal to regenerate successfully.

Fire
Mature tamarack is moderately tolerant to fire due to thick bark and self-pruning habit. Tamarack seedlings on upland sites are more susceptible to fire damage as well as trees on organic soils due to shallow rooting habit.

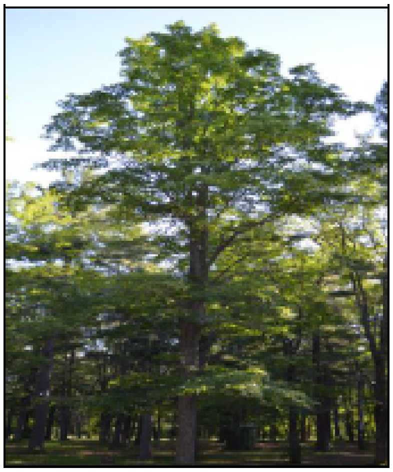
Competition
Usually outcompeted on upland, mineral soil sites. Rapid resurgence of grasses, and swamp shrubs (alder, labrador tea) reduce tamarack establishment and survival on lowland sites.

Management
Grows rapidly during early years but growth drops sharply when the crowns close or after the age of 40-50 years. Intensively managed plantations can produce two to three times more biomass than conventionally tended stands.

FACTSHEET

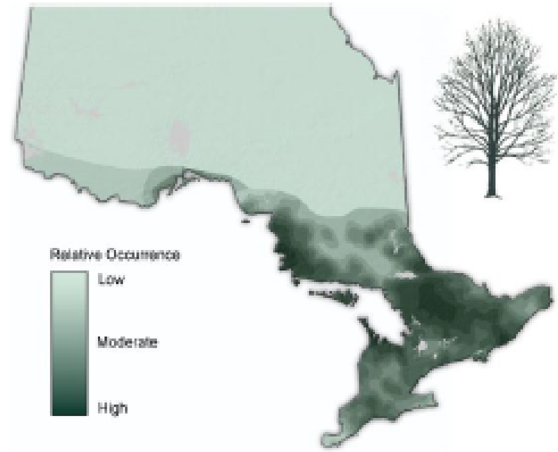
Sugar Maple (Hard Maple)

Acer saccharum



Erik Wainio

RANGE



HABITAT

Soil and Site Relations

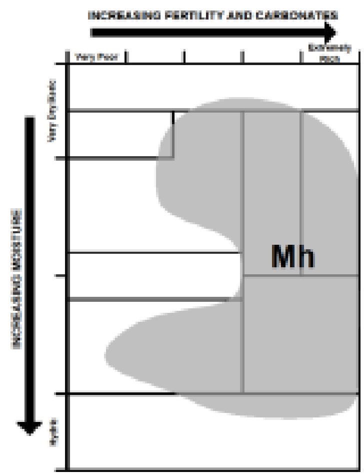
Performs best on sandy loams, loamy sands and silt loams, with a pH >5.5 in upper soil horizons, yet will commonly grow in more acid soils and texture ranging from sandy to fine loamy/clayey

Associated Forest Cover

Frequently mixed with beech on upland sites and yellow birch on moist sites in uneven-aged stands. Mixed withblack cherry, white ash, basswood and yellow birch in even-aged stands.

Associated Ecosites

Sugar maple is the dominant or co-dominant species in the following ecosites: 42, 58, 59, 72-76, 90-92, 106-108, 121-125, 131



REPRODUCTION

Sexual Reproduction Class	Monoecious
Seed Bearing Age (yrs)	40 - 60
Seed Type	Samara
Frequency of Seed Crop (yrs)	Annually
Max. Dispersal Distance (m)	100
Time of Dispersal	June - Sept.
Seed Bank	

In natural stands, few if any seeds remain viable on the forest floor beyond the first year.

Preferred Seedbed*	MS
Vegetative Reproduction	Stem sprouts

Reproduction Comments

Seeds produce vigourous radicle which can easily penetrate undisturbed litter. Stump sprouting is most vigourous and long-lived in small stumps (less than 15 cm DBH).

GROWTH

Average/Max. Height (m)	22/25
Average/Max. DBH (cm)	50/191
Rooting Habit	

Strong, oblique laterals with extensive branching. Roots on the upper side of the laterals grow upward into the humus layers and those on the lower side grow downward.

Early Growth	Height growth for juvenile trees averaging 30 cm per year under moderate stocking levels.
Avg./Max. Longevity (yrs)	200/300+
Successional Status	Sugar maple is a late successional species that is well adapted to the cool microclimate of mature forests.

FACTSHEET

Sugar Maple (Hard Maple)

DAMAGING AGENTS

Insects

Fairly resistant to insect damage. Common defoliating insects are forest tent catepillar, Bruce spanworm, greenstriped mapleworm and gypsy moth. Sugar maple borer may degrade stem quality and cause tree mortality through breakage.

Forest tent caterpillar
MNR

Diseases

Decay losses are high from trunk and butt brown stain infection in unmanaged stands. Damaging agents include anthracnose and tar spot.

Wildlife

Red-backed voles can girdle stems of saplings causing mortality during population peaks.

Other

Climate related damage (frost cracking, sunscalding, ice storm breakage) results in wounds that can damage tree form, cause forking, and provide infection courts for insects and disease.

GENETICS

Races, Varieties, Hybridization

Sugar maple could be grouped into three major geographic races, each containing a parallel clinal variation. Hybrids have been reported with black and red maples.

Seed Transfer Considerations

Not enough information is available to guide seed movement. Local seed is thus the best bet.

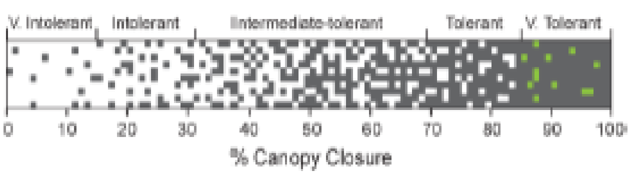
Genetic Resource Management

No tree improvement program

TOLERANCES

Light

Seedlings very tolerant of shade and can survive long periods of suppression (can persist for several years in 5% full sunlight).



Temperature

Low to moderate tolerance to frost.

Moisture

Intolerant of drought and flooding.

Low Nutrient Conditions

Moderate tolerance to low nutrient conditions

RESPONSE TO DISTURBANCE

Overstory Removal

Highly elastic species with both increased height and diameter growth response to release in both lightly and severely suppressed young trees. Excessive release may cause epicormic branches, forks and sunscald.

Fire

Thin-barked sugar maple is easily damaged by even light ground fires. Cambial injury can occur even in trees that show little external damage. Large trees occasionally survive light fires and may exhibit visible fire scars.

Competition

Seedlings of sugar maple are very shade tolerant and can survive long periods of suppression. Growth and survival can be reduced by competing species including striped maple, black cherry, yellow poplar and oaks.

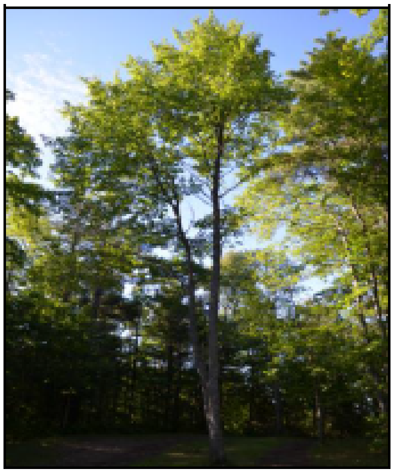
Management

Many stands have been highgraded in the past but quality is improving with the use of tree marking for single tree selection.

FACTSHEET

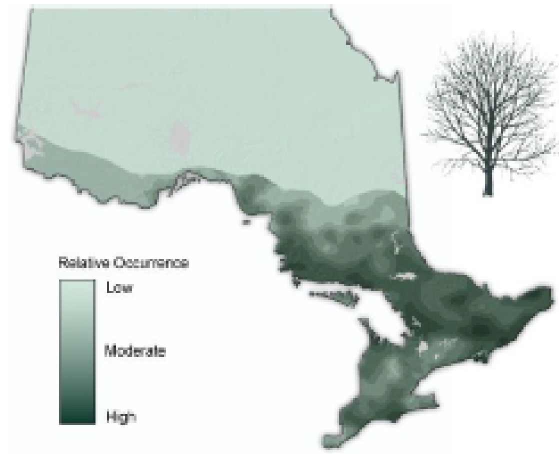
Red Maple (Soft Maple)

Acer rubrum



Erik Wainio

RANGE



HABITAT

Soil and Site Relations

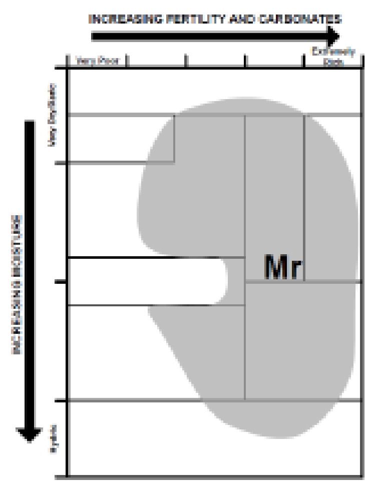
Grows on a wider range of soil types, textures, moisture, pH, and elevation than any other forest species in North America. It develops best on moderately well-drained, moist sites at low to intermediate elevations

Associated Forest Cover

It is associated with more than 70 different commercial tree species. More common associates include red spruce, balsam fir, white pine, sugar maple, beech, yellow birch, white birch, hemlock, cedar, aspen among many others.

Associated Ecosites

Red maple is a dominant or co-dominant species in the following ecosites: 28, 42, 58, 73-75, 91, 92, 107, 123, 124, 131, 133



REPRODUCTION

Sexual Reproduction Class	Polygamo-dioecious
Seed Bearing Age (yrs)	4
Seed Type	Samara
Frequency of Seed Crop (yrs)	1-2
Max. Dispersal Distance (m)	long distance via wind
Time of Dispersal	June - July
Seed Bank	

Red maple seed germinates with the first 10 days after seedfall but some seed survives in the duff and germinates the following year.

Preferred Seedbed*	MS, HM, BD, BO
Vegetative Reproduction	Stump sprouts

Reproduction Comments

Trees can bear seed at a very early age species tends toward dioeciousness. Seeds can germinate immediately after ripening and red maple has few germination requirements. Its great stump sprouting capacity accounts for it to be found in sprout clumps.

GROWTH

Average/Max. Height (m)	22/31
Average/Max. DBH (cm)	45/127
Rooting Habit	

Roots are primarily horizontal, form in the upper 25 cm of soil and may be up to 25 m long.

Early Growth	Under favourable light and moisture, seedlings can grow 0.3 m the first year and as much as 0.6 m each yaer for the next few years. Some sprouts grow 0.9 m+ in the first year, then slow to the same rate as seedlings.
Avg./Max. Longevity (yrs)	100/150
Successional Status	Red maple is early and mid successional species that is more shade tolerant and longer lived than the usual early successional species, such as poplar (aspen) and pin cherry.

FACTSHEET

Red Maple (Soft Maple)

DAMAGING AGENTS

Insects

Many different insects feed on red maple. They reduce vigor and growth leaving the tree more susceptible to attack from fungi. Insect feeding also may hasten the death of weakened trees. One of the common defoliators is greenstriped mapleworm.

Greenstriped mapleworm
www.nrcan.gc.ca

Diseases

Many trunk rot fungi and stem diseases attack red maple. Red maple is susceptible to many leaf diseases, generally of minor importance.

Wildlife

Red maple is a desirable deer food and reproduction may be almost completely suppressed in areas of excessive deer populations. Snowshoe hares may also reduce the amount of red maple reproduction. Sapsucker damage may also result in

Other

Red maple is generally considered very susceptible to defect. Especially on poor sites, it has poor form and considerable internal defect. Sprout clumps present some serious problems. It is especially sensitive to wounding.

GENETICS

Races, Varieties, Hybridization

Experimental crosses of red and silver maple have been made. Also, red maple is known to hybridize naturally with silver maple.

Seed Transfer Considerations

Seed sources from between 42°and 46°N (latitude) showed better growth, more intense fall colour and straighter stems than those outside the range in northern US field provenance tests. Information is lacking from Ontario studies.

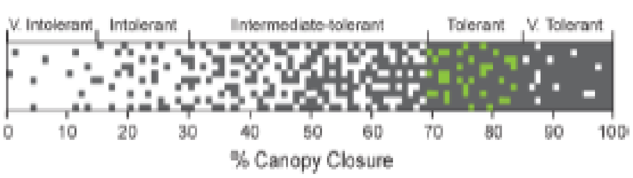
Genetic Resource Management

No tree improvement program

TOLERANCES

Light

Red maple can most accurately be classed as tolerant of shade. Seedlings are more shade tolerant than larger trees and can exist in the understory for several years.



Temperature

Red maple is one of the first trees to flower in early spring.

Moisture

Moist mineral soil seems the best seedbed. Seedlings are classified as moderately tolerant of soil saturation. Very tolerant of flooding, showing no sign of stem or leaf damage after 60 days of flooding.

Low Nutrient Conditions

Moderate tolerance to low nutrient conditions

RESPONSE TO DISTURBANCE

Overstory Removal

Seedlings are more shade tolerant than larger trees and respond rapidly to release and can occupy overstory space. Harvesting can cause red maple to increase in stocking where it previously occurred as only scattered trees.

Fire

Very sensitive to fire injury, and can be killed by fire of moderate intensity. Disturbance such as fire has caused red maple to increase in stocking where it previously occurred as only scattered trees. Fire stimulates stump sprout buds.

Competition

Red maple can most accurately be classed as tolerant of shade. Seedlings are more shade tolerant than larger trees and can exist in the understory for several years. They respond rapidly to release and can occupy over-story space.

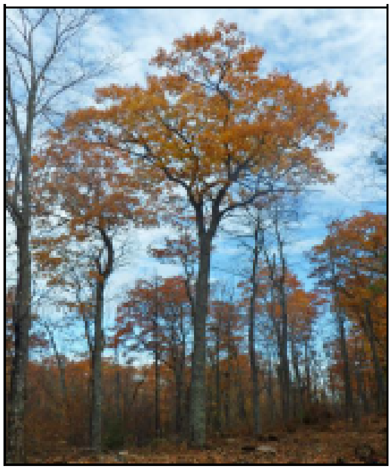
Management

Growth during early life is rapid but slows after trees pass the pole stage. Red maple responds well to thinning. Early crop tree release of red maple seedlings and sprouts is feasible in young, even-aged stands.

FACTSHEET

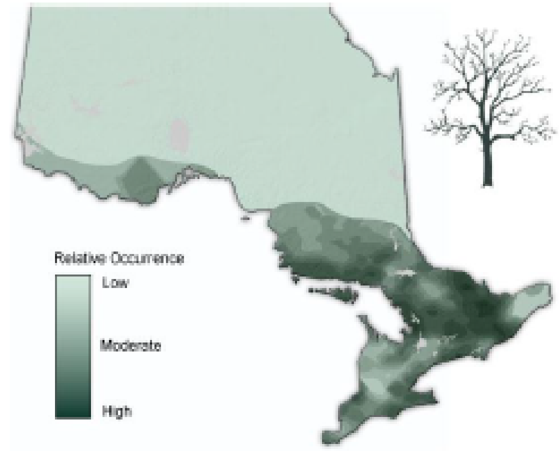
Red Oak

Quercus rubra



Martin Streit

RANGE



HABITAT

Soil and Site Relations

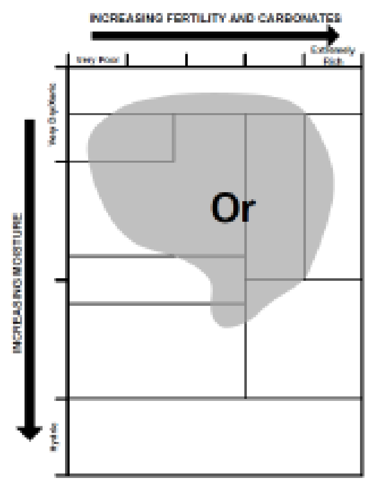
Grows on variety from clay to loamy sands and some with high content of rock fragments. Grows best on deep, well drained loam to silty, clay loam soils. Grows best on lower/middle slopes with northerly or easterly aspects, deep ravines and valley floors.

Associated Forest Cover

Includes pure stands or stands in which it is predominant. Major component with white pine and red maple in north. Principal species with white and black oak in central region. Associated with many species.

Associated Ecosites

Red oak is a dominant or co-dominant species in the following ecosites: 17, 41, 57, 72, 90, 106



REPRODUCTION

Sexual Reproduction Class	Monoecious
Seed Bearing Age (yrs)	25-50
Seed Type	Nut
Frequency of Seed Crop (yrs)	2-5
Max. Dispersal Distance (m)	very short distances
Time of Dispersal	Sept. - Oct.
Seed Bank	

Under natural conditions, acorns generally germinate in the spring after dormancy is broken by over-wintering. Under carefully controlled conditions, acorns can be stored for up to 2 or 3 years.

Preferred Seedbed*	MS
Vegetative Reproduction	Stump sprouts and sprouts

Reproduction Comments

Begins to bear fruit at age 25 but usually does not produce seeds abundantly until about age 50. Acorn production is highly variable among trees even in good seed years. As many as 500 acorns may be required to produce one 1-yr-old seedling.

GROWTH

Average/Max. Height (m)	21/31
Average/Max. DBH (cm)	90/194
Rooting Habit	

Generally have a strongly developed taproot and a network of deep, spreading laterals.

Early Growth	Advance reproduction, seedlings, and sprouts growth is slow and generally restricted to one growth flush under undisturbed or lightly disturbed forest stands; at best it averages only a few centimeters annually.
Avg./Max. Longevity (yrs)	125/150
Successional Status	Red oak is a mid successional species as it isn't an aggressive early successional species and is often replaced by later successional, more shade-tolerant, species such as sugar maple and basswood.

FACTSHEET

Red Oak

DAMAGING AGENTS

Insects
The carpenterworm, Columbian timber beetle, oak timberworm, red oak borer, and twolined chestnut borer tunnel into wood. Gypsy moth, oakleaf caterpillar, orangestriped oakworm, oak leafshredder, and the browntail moth defoliate.

Oak leaf shredder
www.nrcan.gc.ca

Diseases
Oak wilt and shoestring root rot both can kill individuals or small groups of trees. Limited effects from foliage diseases suck as anthracnose, leaf blister, powdery mildews and eastern gall rust.

Wildlife
Acorns are an important food for squirrels, bears, deer, turkey, mice, voles, and other mammals and birds.

Other
Acorns affected by nut weevils, cynipids, filbertworm, and acorn moth. In years of poor acorn production, they can destroy the entire crop.

GENETICS

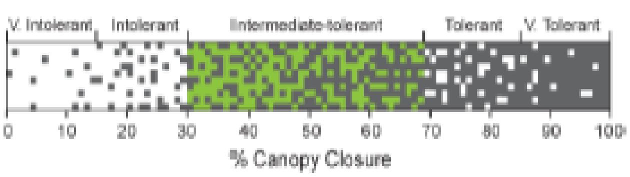
Races, Varieties, Hybridization
Red oak hybridizes with many oaks including black, swamp and northern pin oaks.

Seed Transfer Considerations
Geographic pattern of growth variation is evident. Seed sources from between 43° and 46°N are more productive than those outside the range. Southern Ontario seed source is among the best across several US test sites. No information is available from Ontario tests.

Genetic Resource Management
No tree improvement program

TOLERANCES

Light
Classed as intermediate in shade tolerance. Among the oaks, it is less shade tolerant than white and chestnut and about equal with black and scarlet.



Temperature
Cold, rainy weather during flowering can result in poor seed production.

Moisture
Moisture can be a critical factor affecting first year survival of seedlings but it is usually adequate at the time acorns germinate and seedlings can survive considerable moisture stress later in the growing season.

Low Nutrient Conditions
High tolerance to low nutrient conditions

RESPONSE TO DISTURBANCE

Overstory Removal
Small advanced oak regeneration and young trees up to the age 30 respond well to release.

Fire
Wildfires seriously damages red oak by killing the cambial tissue at the base of tree and creates an entry point for decay-causing fungi. Wildfires can be severe enough to top kill pole and sawtimber size trees. Prescribed fire can kill seedlings.

Competition
Seedlings can survive at low light levels but little growth will occur. Has the ability to compete better on low quality drier sites compared to on better quality sites where it competes less effectively with shade tolerant species.

Management
When regenerating red oak it is important to control competing vegetation, reduce overstory density, establish seedlings or sprouts, and remove overstory after seedling establishement.

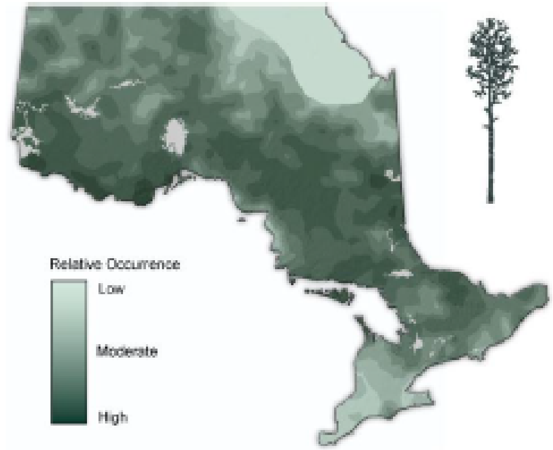
FACTSHEET

Balsam Poplar

Populus balsamifera

Mike Brienesse

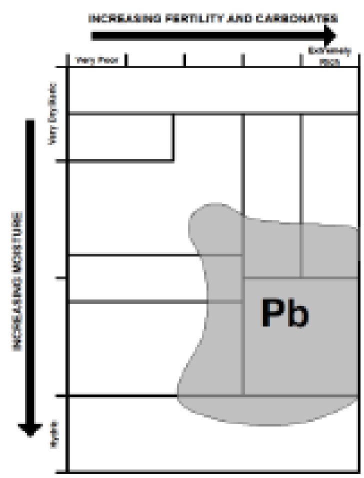
RANGE



HABITAT

Soil and Site Relations

Commonly grows on fresh to moist, fine textured, alluvial soils associated with river flats, sand bars, and inundated riparian areas.



Associated Forest Cover

Most commonly found in small, isolated, mixed stands with other species including trembling aspen, black spruce, white spruce, balsam fir and white birch.

Associated Ecosites

Balsam poplar may exist in the canopy in the following ecosites: 55, 70, 104, 115, 119, 130

REPRODUCTION

Sexual Reproduction Class	Dioecious
Seed Bearing Age (yrs)	8 - 10
Seed Type	Seed
Frequency of Seed Crop (yrs)	Annually
Max. Dispersal Distance (m)	200
Time of Dispersal	June - July
Seed Bank	

Seeds remain viable for 2 to 4 weeks but will germinate immediately following arrival on a suitable seedbed

Preferred Seedbed*	MS
Vegetative Reproduction	Root sprouts/Stem sprouts

Reproduction Comments

Root suckering is less than that of trembling aspen, but is the most common means of reproduction. Also regenerates from seed and buried branches and stems. Seed viability declines rapidly within a few weeks of dispersal.

GROWTH

Average/Max. Height (m)	20/31
Average/Max. DBH (cm)	50/140
Rooting Habit	

Multilayered root system on flood plains, lateral root spread on upland sites is at least 8-12 m

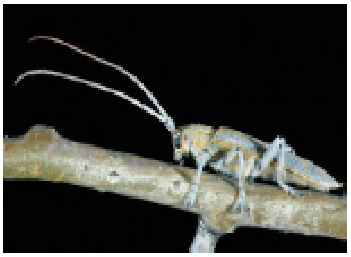
Early Growth	Vegetative reproduction growth potential is greater than that of seedlings. Suckers average 1 m in height after 3 years with maximum heights of 2.5 - 3.0 m.
Avg./Max. Longevity (yrs)	70/200
Successional Status	Balsam poplar is an early successional species found both on flood plains and upland sites. Clonal expansion through suckers is an important means of colonization on flood plains.

FACTSHEET

Balsam Poplar

DAMAGING AGENTS

Insects
The poplar and willow borer, bronze poplar borer, and poplar borer girdle trees causing reduced growth and mortality. Forest tent catepillars will defoliate balsam poplar, when trembling aspen is not available.



Bronze poplar borer
www.nrcan.gc.ca

Diseases
False tinder fungus causes decay but does not contribute significantly to tree decline and mortality. Leaf spot and shoestring root rot are also common but species is less suscetipble than trembling aspen.

Wildlife
Browse species for moose in winter months. Hares deterred from browising buds due to resin. Beavers use balsam poplar for food and construction material.

Other
River bank erosion and channel changes can destroy established stands.

GENETICS

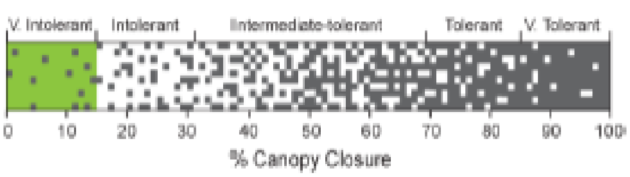
Races, Varieties, Hybridization
Balsam poplar rarely hybridizes with trembling aspen but does with a variety of other poplar species.

Seed Transfer Considerations
Climate driven local adaptation is evidenced by molecular marks and tree phenology and growth traits. Southern seed sources tend to growth taller at northern planting site through extended shoot elongation period. Information is however insufficient to determine safe seed transfer distance.

Genetic Resource Management
No tree improvement program

TOLERANCES

Light
Very shade intolerant; requires full sunlight to survive and grow.



Temperature
Frost resistant as it has a high tolerance to extracellular freezing. Survives on low-lying sites susceptible to late-spring and early-fall frosts.

Moisture
Very tolerant of flooding most likely due to ability to form new roots quickly from pre-formed root primordia. Regeneration very susceptible to dessication for several weeks after germination.

Low Nutrient Conditions
Low tolerance to low nutrient conditions

RESPONSE TO DISTURBANCE

Overstory Removal
Inelastic. Advance regeneration does not develop due to inadequate light levels under overstories. Requires nearly complete overstory removal and suppression of apical dominance of parent trees to regenerate successfully.

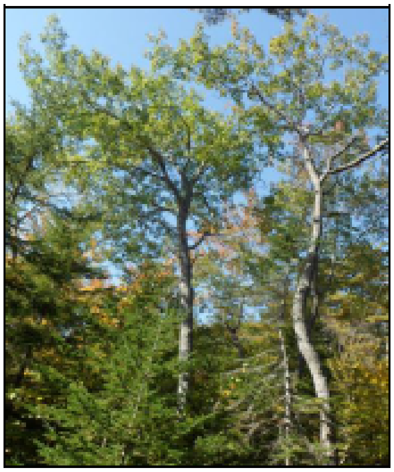
Fire
Burned areas provide favourable soil temperatures and exposure for suckering and seeding immediately after fire. Fire hazard rating is low due to moisture in foliage and typical site conditions. Thick bark of mature trees resistant to fire.

Competition
Can usually outcompete most other tree, shrub, and herbaceous species when grown in full light. Grass and shrub dominated sites can reduce root suckering by competing for light and root space, and reducing soil temperature.

Management
Compared to trembling aspen, balsam poplar has a broader range of reproduction means. Seeding and sprouting from buried branches and stems is promoted by harvesting and site preparation that creates high levels of soil disturbance.

FACTSHEET

Largetooth Aspen
Populus grandidentata


Martin Streit

RANGE

HABITAT

Soil and Site Relations

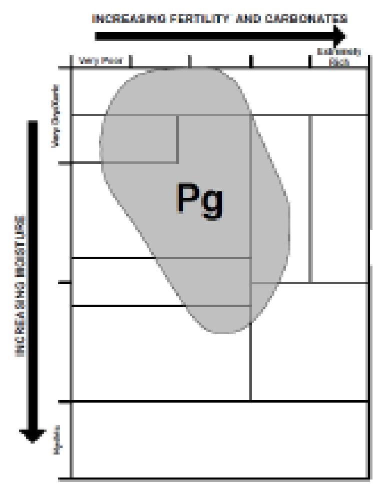
Most abundant on sands, loamy sands, and light sandy loams, but it is found as a single tree or minor stand component on any soil, from rock outcrops to heavy clays. Develops best on moist, fertile sandy uplands; depth to water table is no more 1.5m.

Associated Forest Cover

Found in pure aspen forest covers with trembling aspen and balsam poplar. Minor component with trembling aspen, balsam poplar, balsam fir, white birch, gray birch, jack pine, red pine, red maple, and white spruce in northern part of range.

Associated Ecosites

Large-toothed aspen may exist in the canopy in the following ecosites: 16, 40, 55, 104



REPRODUCTION

Sexual Reproduction Class	Dioecious
Seed Bearing Age (yrs)	10
Seed Type	Seed
Frequency of Seed Crop (yrs)	2 - 3
Max. Dispersal Distance (m)	Several km
Time of Dispersal	June
Seed Bank	

Does not bank seeds as seed viability is only 2 or 3 weeks.

Preferred Seedbed*	MS
Vegetative Reproduction	Root sprouts/Stem sprouts

Reproduction Comments

Seed viability declines rapidly within 2 - 3 weeks of dispersal. Root sprouting (suckering) is the predominant method of reproduction for large-toothed aspen. Hormonal suppression of apical dominance following harvest triggers root suckering.

GROWTH

Average/Max. Height (m)	27/28
Average/Max. DBH (cm)	40/69
Rooting Habit	

Shallow and wide spreading with strong, vertical roots near the base of the tree to provide good anchorage. Deeper, less branched and fewer adventitious roots than trembling aspen.

Early Growth	Seedlings do not commonly occur in nature, but if they survive, can take 3 years to grow to ~1m. Suckering is main mode of reproduction.
Avg./Max. Longevity (yrs)	80/100
Successional Status	Large tooth aspen is an early successional species. The tenacity and lateral extensiveness of its roots allow it to regenerate and dominate disturbed sites that only had a minor aspen component in the original stand.

Largetooth Aspen

DAMAGING AGENTS

Insects
Periodic defoliators include forest tent caterpillar and large aspen tortrix. Poplar borers are the most serious wood borer and can provide infection points for hypoxylon canker and other fungi.

Large aspen tortrix
MNR

Diseases
Hypoxylon canker is the most serious disease of aspens but largetooth is much more resistant than trembling. Heart rot can cause serious volume loss beyond rotation age. Shoot blight may repeatedly kill new terminal growth in young stands.

Wildlife
Provides quality feed for moose, deer, and beaver; however, grouse prefer trembling aspen over largetooth. Commonly used by cavity nesters.

Other
In the literature, the management of largetooth aspen is rarely distinguished from that of trembling aspen.

GENETICS

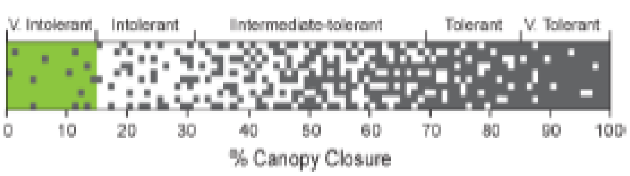
Races, Varieties, Hybridization
Natural hybrids of largetooth aspen and quaking aspen do occur, but less frequently than might be expected, because of differences in time of flowering.

Seed Transfer Considerations
Molecular markers indicate that largetooth aspen may have less genetic variability than trembling aspen. Information is lacking about geographic genetic variation in adaptation and growth traits.

Genetic Resource Management
No tree improvement program

TOLERANCES

Light
Extremely shade intolerant and it cannot successfully reproduce under its own shade.



Temperature
Sucker initiation is attributed to an increase in soil temperature and relief from the apical dominance effect

Moisture
Develops best on moist, fertile sandy uplands where the depth to water table is no more than 1.5 m, and site quality decreases rapidly as the depth to water table approaches 0.6 m.

Low Nutrient Conditions
Moderate tolerance to low nutrient conditions

RESPONSE TO DISTURBANCE

Overstory Removal
Although aspen groves thin naturally, they respond well to additional thinning. When thinning, bigtooth aspen should be favored over trembling aspen because of its superior growth and resistance to disease and insects, especially on dry sites.

Fire
Burned areas provide favourable conditions for rapid suckering immediately after fire. These thin barked trees are susceptible to fire damage.

Competition
Competition from brush and weeds can easily eliminate 1-year-old seedlings. However, sucker growth is rapid enough to outgrow its competition.

Management
Almost any disturbance-tree cutting, brush removal, fire, or ground scarification-can result in some degree of suckering.

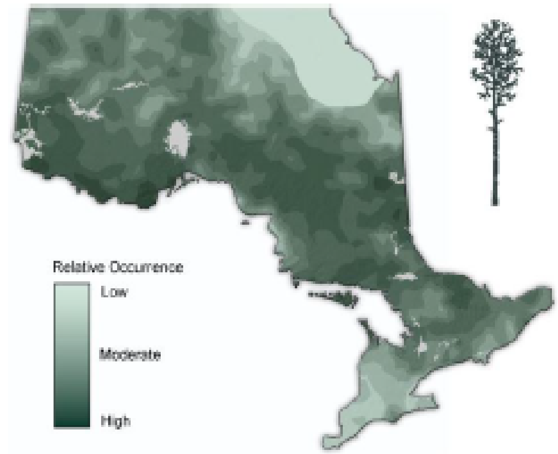
FACTSHEET

Trembling Aspen

Populus tremuloides

Erik Wainio

RANGE



HABITAT

Soil and Site Relations

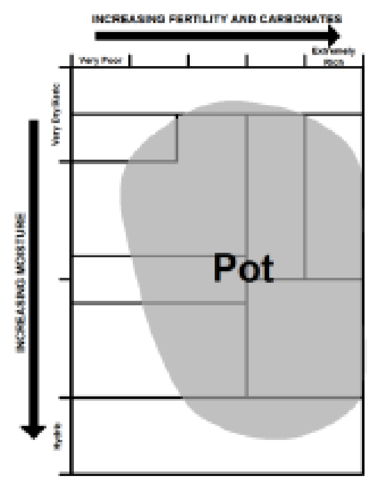
Most widely distributed tree species in North America. Grows on a wide range of sites from dry sands to wet clays. Grows best on deep, fresh to moist loams and moist sandly loams with good drainage.

Associated Forest Cover

Can frequently form coppice origin pure stands or be mixed with other species including white birch, jack pine, white spruce, black spruce, balsam fir, white pine, balsam poplar, large-toothed aspen and red maple.

Associated Ecosites

Aspen is a dominant or co-dominant species in the following ecosites: 40, 55, 70, 88, 104, 119, 224, 130, 133



REPRODUCTION

Sexual Reproduction Class	Dioecious
Seed Bearing Age (yrs)	10 - 20
Seed Type	Seed
Frequency of Seed Crop (yrs)	4 - 5
Max. Dispersal Distance (m)	Several km
Time of Dispersal	June
Seed Bank	

Seed stored at -20°C has retained viability for at least 2 years.

Preferred Seedbed*	MS, H
Vegetative Reproduction	Root sprouts/Stem sprouts

Reproduction Comments

Seed viability declines rapidly within a few weeks of dispersal. Root suckering is the primary means of reproduction for trembling aspen. Hormonal suppression of apical dominance following harvest triggers root suckering.

GROWTH

Average/Max. Height (m)	27/38
Average/Max. DBH (cm)	40/80
Rooting Habit	

Shallow and extensive lateral root system with sinker roots occuring as frequently as every meter on the lateral roots

Early Growth	Suckers capable of rapid growth of 1 - 2 m in first year with subsequent annual growth of between 30 - 60 cm.
Avg./Max. Longevity (yrs)	80/120
Successional Status	Trembling aspen is an early successional species that is often replaced by balsam fir, white spruce, white pine, and cedar in the absence of fire, or once stand starts to break-up due to decay and loss of vigour.

FACTSHEET

Trembling Aspen

DAMAGING AGENTS

Insects

Forest tent catepillar, large aspen tortix and aspen twoleaf tier defoliate trees causing reduced growth. Other damaging insects include aspen twinleaf tier, aspen leaf beetle, and poplar borer.

Hypoxylon canker
www.nrcan.gc.ca

Diseases

False tinder fungus causes significant decay, especially in older stands. Shoot blight infects the shoots of young aspen stems causing blackened "sheperd's crooks". Hypoxylon canker can girdle and kill trees, and armillaria can cause root rot.

Wildlife

Preferred browse species of moose, deer, beavers, porcupine, and hares. Repeated browsing may cause reduced height growth, stem deformities, and mortality.

Other

Severe mechanical wounding (severing and scrapes) to roots increases internal decay and stain which may cause future windthrow, reduced growth, and mortality. Boles susceptible to frost-cracking. Older stands suffer stem breakage from strong winds.

GENETICS

Races, Varieties, Hybridization

Forms natural hybrids with many poplar species including balsam poplar, large-toothed aspen, and eastern cottonwood.

Genetic Resource Management

No tree improvement program

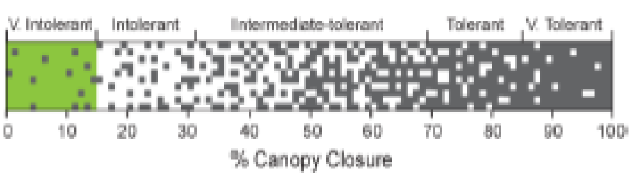
Seed Transfer Considerations

Genetic markers indicate considerable intra- and inter-population genetic variation. While information is limited in Ontario, provenance tests in western Canada indicate considerable gain in growth from seed transfer along a south-northwestern direction for as long as 4° (latitude) without raising frost risk.

TOLERANCES

Light

Very shade intolerant; requires full sunlight to survive and grow.



Temperature

Frost resistant as it has a high tolerance to extracellular freezing. New growth can be killed by late-spring frosts. Suckers are more frost-resistant than seedlings.

Moisture

Mature and young aspen are intolerant to flooding lasting more than 3 weeks. Vegetative reproduction is inhibited by flooding. Suckers are moderately drought tolerant due to pre-existing and established root system and relatively low leaf

Low Nutrient Conditions

Moderate tolerance to low nutrient conditions

RESPONSE TO DISTURBANCE

Overstory Removal

Inelastic. Advance regeneration does not develop due to inadequate light levels under overstories. Requires nearly complete overstory removal and suppression of apical dominance of parent trees to regenerate successfully.

Fire

Burned areas provide favourable conditions for rapid suckering immediately after fire. Young and mature trees susceptible to fire damage, however, fire hazard rating is moderate due to moisture in foliage and soils typically occupied by pure stands.

Competition

Can usually outcompete most other tree, shrub, and herbaceous species when grown in full light. Grass and beaked hazel dominated sites can reduce root suckering by competing for light and root space, and reducing soil temperature.

Management

Soil compaction caused by summer harvesting on finer textured, wet soils with heavy machinery reduces sucker densities and growth. Pre-harvest herbicide reduces sucker regeneration to manage for mixedwoods. Light scarification stimulates root suckering.

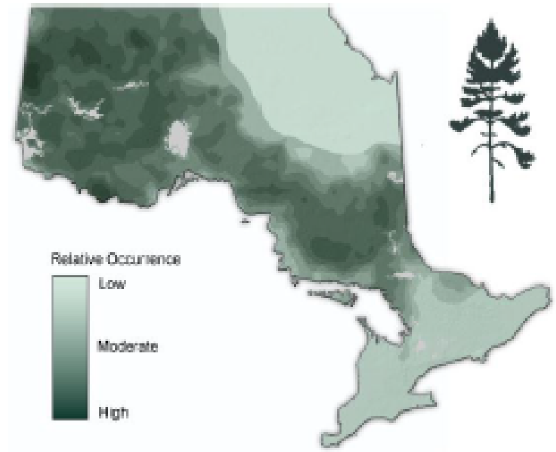
FACTSHEET

Jack Pine

Pinus banksiana

Erik Wainio

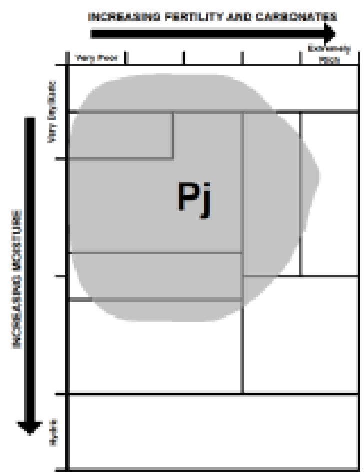
RANGE



HABITAT

Soil and Site Relations

Grows most commonly on level to gently rolling sand plains of glacial outwash, fluvial, or lacustrine origin. It occurs on deep, dry to fresh, coarse sands and deep, fresh, fine sandy to coarse loamy soils and occasionally on shallow soils.



Associated Forest Cover

Black spruce is often associated with jack pine in coniferous stands. Black spruce, trembling aspen and white birch are frquent overstory associates of jack pine in mixedwood stands. Balsam fir and white spruce occur less commonly.

Associated Ecosites

Jack pine is the dominant or co-dominant species in the following ecosties: 11, 12, 24, 33-35, 37, 49, 50, 65, 82, 83, 85, 92, 114

REPRODUCTION

Sexual Reproduction Class	Monoecious
Seed Bearing Age (yrs)	5 - 10
Seed Type	Winged Seed
Frequency of Seed Crop (yrs)	3 - 7
Max. Dispersal Distance (m)	40 - 60
Time of Dispersal	All Year
Seed Bank	

Some seed is produced every year and accumulates in the crown in serotinous cones. Cones require high temperatures to open usually provided by fire or hot, dry temperatures of at least 27°C. Seeds remain viable in closed cones for years.

Preferred Seedbed*	MS, BD
Vegetative Reproduction	Nil

Reproduction Comments

Cones are serotinous. Closed cone habit of jack pine prevents adjacent uncut stands from providing much seed, however, high temperatures (50 degrees C) near the ground promote the release of seed from cones in logging slash.

GROWTH

Average/Max. Height (m)	21/25
Average/Max. DBH (cm)	30/70
Rooting Habit	

Frequently develops a taproot as a seedling and maintains it until maturity. On deep, well-drained soils the roots may penetrate below 2.7 m.

Early Growth	During the first 20 years, jack pine is one of the fastest growing conifers in its native range. Early growth ranges from 30 to 140 cm per year.

Avg./Max. Longevity (yrs)	120/200+
Successional Status	Early to mid-successional species that in the absence of further disturbance, is succeeded by black spruce, white spruce, balsam fir, and white birch

FACTSHEET

Jack Pine

DAMAGING AGENTS

Insects
Jack pine budworm is a major pest that can cause considerable mortality in mature stands. Swaine jack pine sawfly, eastern pine shoot borer, white pine weevil and white spotted sawyer beetle are also common damaging agents.

Jack pine budworm
www.nrcan.gc.ca

Diseases
Relatively resistant to disease. Minor diseases include scleroderris canker, sweetfern blister rust, armillaria, and western gall rust.

Wildlife
Young jack pine may be heavily browsed where deer and hare populations are high.

Other
Resistant to windthrow.

GENETICS

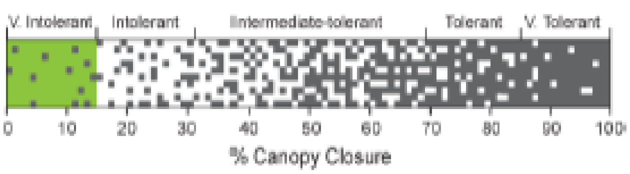
Races, Varieties, Hybridization
Differences in growth between provenances are clinal. Provenance test results have been applied to the establishment of seed zones and tree improvement programs. Jack pine x lodgepole pine is the only verified interspecific jack pine hybrid.

Genetic Resource Management
First generation programs in NE and NW ON. Seed orchards producing improved seed with emphasis on faster height growth. Second generation programs in various stages of development and establishment across the north.

Seed Transfer Considerations
Genetically improved seed for superior growth is available by breeding zones across northern Ontario. Seed from natural populations shows a weak latitudinal cline of growth variation. Transferring seed northward within 2° (latitude) can be safe and promote growth.

TOLERANCES

Light
Once established, seedlings require close to full sunlight for optimum growth and survival.



Temperature
Tolerant of air temperature extremes from -40°C to +35°C. Resistant to frost damage in spring due to delayed flushing.

Moisture
Highly tolerant of droughts in excess of 30 days. Moderately tolerant of short-term flooding with decreasing tolerance to prolonged flooding.

Low Nutrient Conditions
High tolerance to low nutrient conditions

RESPONSE TO DISTURBANCE

Overstory Removal
Advance regeneration does not develop due to inadequate light levels under overstories. Requires nearly complete overstory removal to regenerate successfully.

Fire
Jack pine is well adapted to fire and develops as even aged stands on dry, burned over areas. Young stands on flammable dry sites are vulnerable to fire.

Competition
Very intolerant of vegetative competition from broadleaved trees, shrubs, grasses and other herbaceuous vegetation. Should be released from competition within 1 - 2 years of establishment.

Management
Responds well to pre-commercial thinning. Herbicide application with glyphosate should be avoided during late season growth.

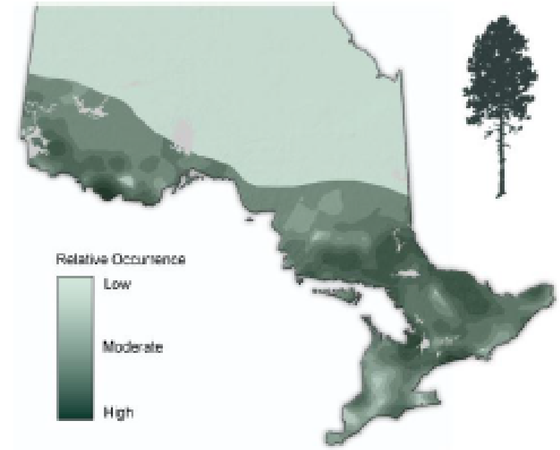
FACTSHEET

Red Pine

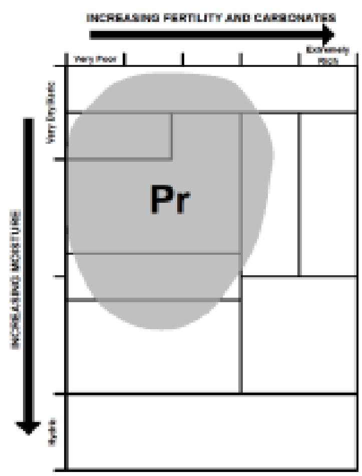
Pinus resinosa

Laurie Thompson

RANGE



HABITAT



Soil and Site Relations

Occurs mainly on dry to fresh, rapidly drained, sandy or coarse loamy soils and infrequently on finer textured or poorly drained soils. Red pine also grows on rock outcrops.

Associated Forest Cover

Red pine can form pure stands, however it usually mixed with other species including white pine, trembling aspen, white birch, balsam fir, black spruce, and jack pine.

Associated Ecosites

Red pine is a dominant or co-dominant species (with white pine) in the following ecosites: 11, 15, 23, 27, 33, 35, 39, 48, 50, 54, 64, 69, 97, 103

REPRODUCTION

Sexual Reproduction Class	Monoecious
Seed Bearing Age (yrs)	15 - 25
Seed Type	Winged Seed
Frequency of Seed Crop (yrs)	3 - 7
Max. Dispersal Distance (m)	20 - 40
Time of Dispersal	Oct. - Nov.
Seed Bank	

Cones open best on hot, still autumn days when there is little wind to carry the seeds far. If rainfall is deficient, the seeds can lie over for 1 to 3 years before germinating.

Preferred Seedbed*	MS, BD, PM
Vegetative Reproduction	Nil

Reproduction Comments

Good seed crops are infrequent and irregular which limits the regeneration of this species by natural seeding. Red pine does not reproduce vegetatively.

GROWTH

Average/Max. Height (m)	24/37
Average/Max. DBH (cm)	90/113
Rooting Habit	

Usually a well-developed root system that is wide spreading and moderately deep.

Early Growth	Usually takes 4 - 10 years to reach breast height with an average annual height increment of 30 cm between 5 and 50 years if unimpeded by competing species.
Avg./Max. Longevity (yrs)	150/200+
Successional Status	Red pine is an early to late successional species. It becomes established in early successional stages after disturbance and is capable of persisting in the overstory into late successional stages due to its longevity and large size.

Red Pine

DAMAGING AGENTS

Insects

Relatively resistant to insect damage. The red pine cone beetle consumes seed. Sawflies (red-headed pine and European pine) cause growth losses or mortality in young stands. The European pine shoot moth and the pine false webworm also cause damage.

Pine false webworm
Mike Francis

Diseases

Scleroderris canker infects needles and buds and spreads to branches and stems. Armillaria root rot and fomes root rot cause rooting of the roots.

Wildlife

Deer and hare may feed on young seedlings where alternate preferred browse is scarce. Mice and voles can girdle small seedlings where grass and herb vegetation provide cover. Porcupines may girdle branches and stems causing reduced

Other

Relatively windfirm species.

GENETICS

Races, Varieties, Hybridization

No red pine hybrids exist. Attempts at artificial hybridization have failed.

Genetic Resource Management

No tree improvement program

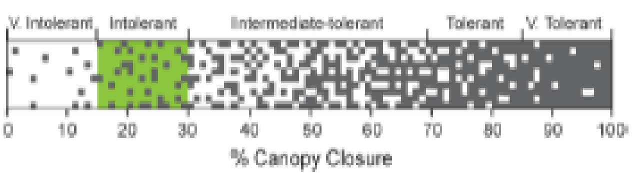
Seed Transfer Considerations

Trees are exceptionally uniform as genetic diversity is overly low within red pine. Seed sources generally do not show large growth variation. A northern Ontario provenance trial indicates that seed from the Lake States and western Ontario performs better than those from Maritime Provinces.

TOLERANCES

Light

Seedlings require at least 45% full sunlight during first 5 years and best growth after 5 years occurs between 65-100% full sunlight.



Temperature

Newly flushed growth and flowers are susceptible frost damage. Above normal temperatures in April, July, August, and September may also favor cone and seed production 2 years later.

Moisture

Drought resistant. Does not tolerate short term (<20 days) flooding or lack of soil aeration. Susceptible to frost dessication/winter drying of foliage.

Low Nutrient Conditions

High tolerance to low nutrient conditions

RESPONSE TO DISTURBANCE

Overstory Removal

Relatively elastic and capable of responding to release from long term suppression of dense overstory cover. However, early release is recommended in plantations to maximize height and volume growth benefits.

Fire

Red pine is well adapted to fire - mature trees have thick bark and high crowns to survive ground fires. Young stands on flammable dry sites are vulnerable to fire. Burned over areas provide excellent seedbed for red pine seeds.

Competition

Dense grass, shrubs (raspberry and hazel), and hardwoods (aspen) can greatly suppress young seedlings.

Management

Red pine is an ideal plantation species with the potential to produce high yields. Responds well to moderate pre-commercial thinning with a spacing of one half the height of dominant and co-dominant trees. Root grafts are common in red pine stands.

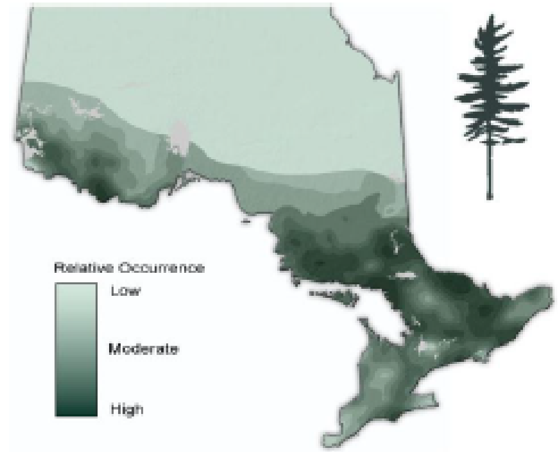
FACTSHEET

White Pine

Pinus strobus

Erik Wainio

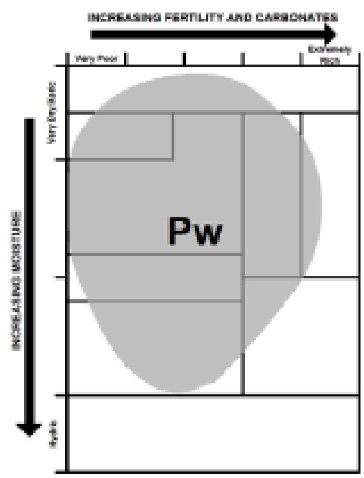
RANGE



HABITAT

Soil and Site Relations

White pine grows on a variety of soils and moisture conditions but is most successful on medium-textured, well-drained sands or sandy loams of low to medium site quality. White pine also grows on rock outcrops.



Associated Forest Cover

White pine can form pure stands, however it is usually mixed with other species including red pine, balsam fir, white spruce, cedar, black spruce, white birch, red maple, hemlock, trembling aspen, and jack pine.

Associated Ecosites

White pine is a dominant or co-dominant species (with red pine) in the following ecosites: 11, 15, 23, 27, 33, 39, 48, 50, 54, 64, 69, 81, 87, 97, 103, 113, 118

REPRODUCTION

Sexual Reproduction Class	Monoecious
Seed Bearing Age (yrs)	15
Seed Type	Winged Seed
Frequency of Seed Crop (yrs)	3 - 5
Max. Dispersal Distance (m)	80 - 200 (in open)
Time of Dispersal	September
Seed Bank	

White pine seed is best the first year after seedfall and shows very limited delayed emergence the second year and none the third year.

Preferred Seedbed*	MS, PM, BD
Vegetative Reproduction	Nil

Reproduction Comments

Best cone production comes from large diameter, widely spaced dominant trees with full crowns. Exposure to full sunlight during seed germination can create lethal seedbed temperatures. White pine does not reproduce vegetatively.

GROWTH

Average/Max. Height (m)	26/45
Average/Max. DBH (cm)	100/172
Rooting Habit	

Usually 3-5 large roots spread outward and downward in the soil, giving the tree a firm anchor.

Early Growth

Growth is initially slow, however, after reaching breast height, annual height growth averages 30 - 60 cm and up to 100 cm in good conditions.

Avg./Max. Longevity (yrs)	200/450+
Successional Status	White pine is a both mid-successional and late successional species due to its longevity and large size. Stand disturbance, often by fire, is essential to natural white pine regeneration.

White Pine

DAMAGING AGENTS

Insects

White pine weevil damage trees often between 2-6 m in height by girdling the leader. Other insects of concern include jack pine budworm, introduced pine sawfly and whitespotted sawyer beetle.

White pine blister rust
MNR

Diseases

White pine blister rust can cause severe growth loss and mortality in white pine stands by attacking live bark and cambium. High risk sites include low-lying, north facing slopes with cool, moist conditions.

Wildlife

Preferred browse species of deer and hare during fall and winter. Mice and voles can girdle small seedlings where grass and herb vegetation provide cover.

Other

Relatively windfirm species.

GENETICS

Races, Varieties, Hybridization

White pine can hybridize with a variety of non-native to Ontario pine species

Genetic Resource Management

First generation clonal seed orchards established across much of south-central Ontario. Progeny tests established in the northern breeding zone.

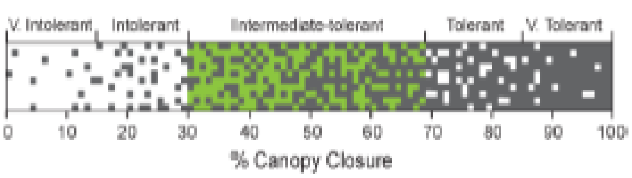
Seed Transfer Considerations

Geographic populations exhibit considerable growth variation along a latitudinal cline. Seed from southern populations generally grows faster, but less cold hardy, than seed from northern populations. A northward seed transfer within 2° (latitude) may increase forest productivity at low risk of frost damage.

TOLERANCES

Light

Requires 20-25% full sunlight for establishment and 55-100% full sunlight for future growth.



Temperature

Intolerant of air and soil temperature extremes. Newly flushed growth susceptible frost damage. Planting of white pine should be avoided in low lying areas to minimize frost damage.

Moisture

Seedlings intolerant of prolonged drought and flooding. Susceptible to frost dessication/winter drying of foliage.

Low Nutrient Conditions

High tolerance to low nutrient conditions

RESPONSE TO DISTURBANCE

Overstory Removal

Elastic; can respond to release after long term suppression, however, response decreases with increasing age and decreasing crown length. Improved height growth, as a response to release, requires 2 - 3 years to take effect.

Fire

White pine is well adapted to fire - mature trees have thick bark and high crowns to survive ground fires. Young stands on flammable dry sites are vulnerable to fire. Burned over areas provide excellent seedbed for white pine seeds.

Competition

Underplanted seedlings cannot tolerate heavy overtopping from shrubs (raspberry, hazel). Does not compete well with vigourous hardwoods (aspen, oaks, and maples).

Management

Application of herbicides may suppress or kill white pine during periods of active growth. White pine's susceptibility to blister rust and weevil limits it as a planting species and requires management to avoid high risk sites.

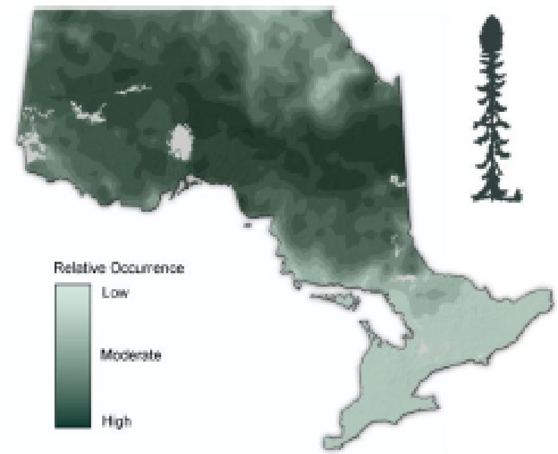
FACTSHEET

Black Spruce

Picea mariana

John Stevens

RANGE



HABITAT

Soil and Site Relations

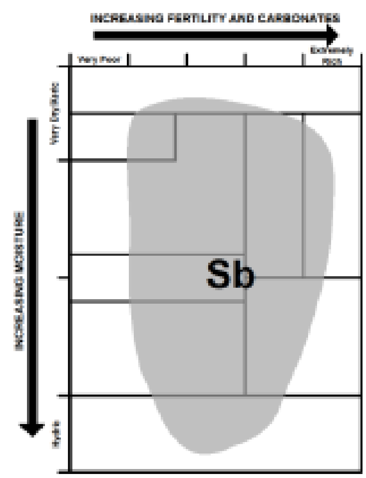
Grows on a very wide range of sites and soils from dry, shallow, mineral soils to wet, very poorly drained organic soils.

Associated Forest Cover

On upland sites, jack pine is the most common associate, along with balsam fir, trembling aspen, white birch and white spruce. Black spruce commonly forms pure stands on lowland sites where tamarack and cedar are minor associates

Associated Ecosites

Black spruce is a dominant or co-dominant species in the following ecosites: 24, 34, 35, 38, 49, 50, 53, 65, 67, 68, 82, 83, 86, 98, 99, 101, 102, 114, 117,



REPRODUCTION

Sexual Reproduction Class	Monoecious
Seed Bearing Age (yrs)	10 - 15
Seed Type	Winged Seed
Frequency of Seed Crop (yrs)	1 - 4
Max. Dispersal Distance (m)	80 - 200 (in open)
Time of Dispersal	Sept. - Apr.
Seed Bank	

Cones remain partially closed and disperse seed for several years; number and viability decline rapidly but some remain in cones for up to 25 years, opening during fires.

Preferred Seedbed*	MS, SM, PM, BO, BD
Vegetative Reproduction	Layering

Reproduction Comments

Cones are semi-serotinous. Most seed is shed from cones within 4 years. Seed is viable up to 5 years in cones and 10 - 16 years on ground. Layering may be the primary method of natural regeneration in sphagnum bogs and shallow soils over bedrock.

GROWTH

Average/Max. Height (m)	17/21
Average/Max. DBH (cm)	30/41
Rooting Habit	

Although some black spruce roots may penetrate to 60 cm, most spread laterally at the moss-humus interface.

Early Growth	Under favourable conditions, juvenile black spruce up to 10 years old experience indeterminate growth. Average annual height growth is 3 cm in first year, 5-13 cm in second year and 20-38 cm in third year.
Avg./Max. Longevity (yrs)	150/250
Successional Status	Black spruce is an early successional species on upland and lowland sites and also a mid-successional species in mixed upland stands. Even-aged stands readily develop after disturbance but in the absence of fire, can be succeeded by balsam fir and cedar.

Black Spruce

DAMAGING AGENTS

Insects

Relatively resistant to insect damage. Spruce budworm may defoliate trees when mixed with balsam fir and white spruce. Successive years of attack may lead to moderate to severe mortality.

Spruce budworm
MNR

Diseases

Various butt and root rots including tomentosus root rot, shoestring root rot) and armillaria root rot, cause windthrow and breakage in older stands. Spruce needle rust and eastern dwarf mistletoe are also damaging agents.

Wildlife

Not a preferred browse species of moose deer, or hare.

Other

Older stands susceptible to windthrow on both lowland and upland sites due to shallow rooting habit. Dwarf mistletoe is a parasitic plant species that causes witch's broom which may reduce growth and lead to death.

GENETICS

Races, Varieties, Hybridization

Hybrids between black and red spruce are common. Rosendahl spruce is a very rare natural hybrid between white and black spruce reported in northern Minnesota.

Genetic Resource Management

First generation programs in NE and NW ON. Seed orchards producing improved seed with emphasis on faster height growth. Second generation programs in various stages of development and establishment in the north.

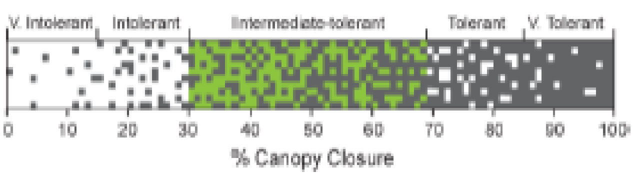
Seed Transfer Considerations

Genetically improved seed for superior growth is available by breeding zones across northern Ontario. The performance of seed from natural populations is often negatively correlated with the latitude of seed origin. Moving seed northward a short distance may promote growth.

TOLERANCES

Light

Grows best in full sunlight but is capable of surviving in low light levels (down to 10% of fullsunlight) for long periods.



Temperature

Resistant to frost damage in spring due to delayed flushing.

Moisture

Very tolerant of short to medium duration flooding. Prolonged flooding lasting over 48 days may result in mortality in young and mature stands. Capable of developing advetituous roots to adapt to long term changes in the water table.

Low Nutrient Conditions

High tolerance to low nutrient conditions

RESPONSE TO DISTURBANCE

Overstory Removal

More elastic than jack pine. Severely suppressed seedlings do not respond quickly to release. Seedlings should be released prior to showing signs of suppression. Complete and sudden overstory removal may result in increased grasses and sunscald damage.

Fire

Well adapted to fire and readily develops as even aged stands on burned over areas. Post-fire release of seed from semi-serotinous cones occurs over 2 - 4 years. Vulnerable to crown and surface fires.

Competition

Sphagnum and labrador tea may outcompete germinants and smother them on lowland sites. Small seedlings are susceptible to crushing from grass and snow press. Partial shade from an aspen overstory may benefit early establishment of seedlings.

Management

Resistant to most herbicides if applied after buds have set. Responds well to release and thinning between 10 and 50 years of age.

FACTSHEET

Red Spruce

Picea rubens

Martin Streit

RANGE

HABITAT

Soil and Site Relations

In Ontario and Quebec red spruce is found on cool moist site such as north-facing slopes and lake shores. It is very shade tolerant and can survive as an understory tree for many years.

Associated Forest Cover

Typically a component of mature forests mixed with eastern white pine, balsam fir, eastern hemlock, yellow birch and sugar maple.

Associated Ecosites

insufficient data

REPRODUCTION

Sexual Reproduction Class	Monoecious
Seed Bearing Age (yrs)	35-40
Seed Type	Seed
Frequency of Seed Crop (yrs)	3-8
Max. Dispersal Distance (m)	within 100 m
Time of Dispersal	October - March
Seed Bank	

Little if any viable seeds remain in the forest floor beyond 1 year.

Preferred Seedbed*	mineral, humus, rotting wo
Vegetative Reproduction	Rarely layers

Reproduction Comments

Red spruce reproduces almost exclusively by seed. Where the ranges of red and black spruce overlap, hybrids are common, with features intermediate between the parents.

GROWTH

Average/Max. Height (m)	18/23
Average/Max. DBH (cm)	61/83
Rooting Habit	

Shallow rooting with average depth 33 cm and maximum depth 56 cm.

Early Growth	Shade is required during early growth. Heavy mortality of seedlings grown in the open if temperatures reach 46 degrees Celsisus, even briefly.

Avg./Max. Longevity (yrs)	200/400
Successional Status	On shallow, acidic, glacial till soils, red spruce is considered a late successional species. It is usually mid-successional on fertile, well-drained slopes,and on abandoned fields and pastures where it is replaced by shade-tolerant hardwoods.

FACTSHEET

Red Spruce

DAMAGING AGENTS

Insects
The most important insect enemy is spruce budworm, although red spruce is much less vulnerable than balsam fir or white spruce. Other insects include eastern spruce beetle, European spruce sawfly and yellowheaded spruce sawfly.

Spruce budworm
www.nrcan.gc.ca

Diseases
Red spruce has few diseases. Needle cast caused by Lirula macrospora may result in severe defoliation of the lower crown and a subsequent reduction of growth.

Wildlife
Seeds are preferred over balsam fir by deer mice and voles. Birds have been noted to damage terminal buds of young spruce.

Other
Mice and voles have been found to consume and store significant amounts of spruce seeds in preference to those of balsam, suggesting one reason for the low ratio of spruce to fir seedlings in naturally regenerated stands.

GENETICS

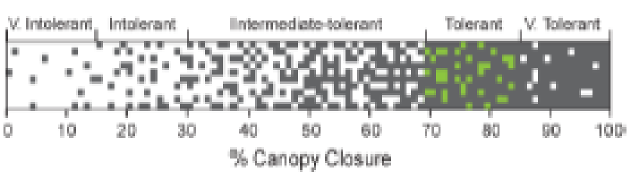
Races, Varieties, Hybridization
Commonly hybridizes with black spruce when their ranges overlap. Features are intermediate between the parents.

Genetic Resource Management
No tree improvement program

Seed Transfer Considerations
Small remnant stands in Ontario still produce quality seed, but seed production may decrease in the future due to reducing level of pollination and inbreeding depression. Growth performance is more influenced by introgressive hybridization index with black spruce than by seed sources.

TOLERANCES

Light
Shade tolerant with best germination at 10% light. Requires 50% light for optimal growth of established seedlings.



Temperature
Seeds require 20°-30°C to germinate. Heavy mortality occurs in seedlings if the temperature reaches 46°C, even briefly.

Moisture
Occurs on dry to moist upland site and wet organic sites, overal requires moisture and cool climate. Sufficient moisture is necessary for germination.

Low Nutrient Conditions
Low tolerance to low nutrient conditions

RESPONSE TO DISTURBANCE

Overstory Removal
Responds to release even after 145 years of suppression. Requires partial cutting system to maintain moisture and shade conditions to out-compete other species and black/red hybrids.

Fire
The shallow root system, thin bark, and flammable needles of red spruce make trees of all ages very susceptible to fire damage.

Competition
Main competition from balsam fir and hardwoods that produce heavy shade, like beech and sugar maple. Competition from aspen, birch, and other thin-crowned species is less. Hybrids out-compete red spruce when harvesting practices create open conditions.

Management
Shalow rooted species and subject to windthrow following harvest. Partial harvest is recommended to prevent excessive windthrow damage.

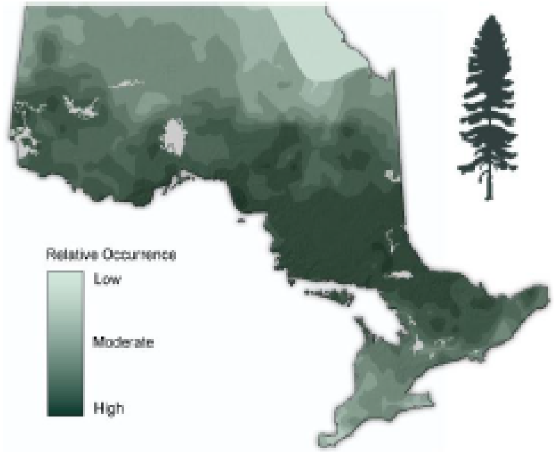
FACTSHEET

White Spruce

Picea glauca

Erik Wainio

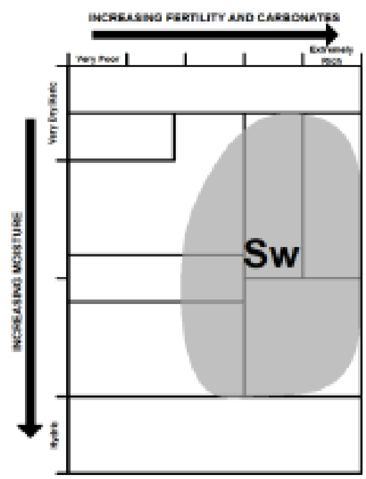
RANGE



HABITAT

Soil and Site Relations

Grows on a wide range of sites and soils but prefers well-aerated, deep, fresh sites with soils of moderate to rich fertility. Not commonly found on organic or very shallow soils.



Associated Forest Cover

Commonly occurs in mixed, even and uneven aged stands. Boreal associates include balsam fir, trembling aspen, black spruce, and white birch. GLSL associates include yellow birch, hemlock, white pine, and sugar maple.

Associated Ecosites

White spruce is a dominant or co-dominant species (with balsam fir) in the following ecosites: 26, 37, 52, 67, 68, 85, 86, 101, 102, 116, 224

REPRODUCTION

Sexual Reproduction Class	Monoecious
Seed Bearing Age (yrs)	10 - 20
Seed Type	Winged Seed
Frequency of Seed Crop (yrs)	2 - 6
Max. Dispersal Distance (m)	40 - 60
Time of Dispersal	Sept. - Jan.
Seed Bank	

White spruce seeds remain viable for only about 1 to 2 years.

Preferred Seedbed*	MS, HM, DW, BD, PM
Vegetative Reproduction	Nil

Reproduction Comments

Seed is viable for one year (up to two years if conditions remain extremely dry).

GROWTH

Average/Max. Height (m)	19/39
Average/Max. DBH (cm)	45/79
Rooting Habit	

Frequently characterized as shallow rooted but where soil conditions don't limit rooting taproots and sinker roots can descend to a depth of 3 m.

Early Growth	Under favourable conditions, white spruce up to 10 years old experience indeterminate growth. Usually requires 6 -12 years to reach breast height.

Avg./Max. Longevity (yrs)	150/250
Successional Status	White spruce is a late successional species that gradually replaces pine, aspen, birch, and/or poplar on well-drained sites. Less frequently it occurs as an early successional species, forming pure stands or mixing with hardwoods immediately after fire.

White Spruce

DAMAGING AGENTS

Insects

Spruce budworm feeds on emerging foliage causing root starvation and mortality. White spotted sawyer beetle and other bark beetles can follow budworm infestation. Yellowheaded spruce sawfly can also be a problem on young open grown trees.

White spotted sawyer
www.nrcan.gc.ca

Diseases

Stressed and/or overmature trees and stands susceptible to shoestring root rot, armillaria root rot and trunk and butt rot. Seedlings are susceptible to snow blight. Spruce needle rust causes rust on the current year's needles.

Wildlife

In protected areas, hare browse leaders in winter which later affects stem form. Mice and voles can girdle small seedlings where grass and herbaceous vegetation provide cover.

Other

Planted seedlings are susceptible to frost heaving on wet, fine-textured soils. Damage from whipping/abrasion can occur when leaders come into contact with hardwood canopy.

GENETICS

Races, Varieties, Hybridization

Hybrids between black spruce and white spruce are relatively rare although hybrids with other spruce in western Canada are common.

Genetic Resource Management

First generation clonal seed orchards established across much of north-western Ontario. Progeny tests established in the Red Lake and Dryden breeding zones.

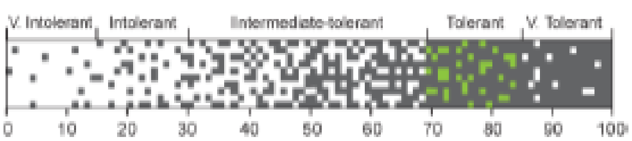
Seed Transfer Considerations

Geographic populations perform variably in field trials, showing a latitudinal cline of growth variation. Seed from south-central Ontario often out-performs local seeds at northerly sites. A northward seed transfer within 2-3° (latitude) may increase forest productivity at low risk of maladaptation.

TOLERANCES

Light

Seedlings grow well in 45% of full sunlight during first 5 years. Best growth after 5 years occurs at full sunlight.



Temperature

Seedlings have low tolerance to spring frost (compared to black spruce) when growing in the open due to early flushing habit. Can withstand severe winter temperatures.

Moisture

Moderately tolerant of short-term flooding and intolerant to more prolonged flooding. Seedling and tree vigour and survival are reduced after prolonged flooding. Less tolerant of flooding than black spruce.

Low Nutrient Conditions

Moderate tolerance to low nutrient conditions

RESPONSE TO DISTURBANCE

Overstory Removal

Elastic at all ages, however, early release of seedlings is recommended to maximize growth benefits. Where growing with hardwoods established at same time, usually overtopped and remains in understory for long periods of time until released.

Fire

Commonly exists in mixedwood stands that are not highly susceptible to fire. Budworm killed stands on dry soils are most susceptible to fire. Young plantations are susceptible to scorching due to extensive crowns and thin bark.

Competition

Heavy raspberry, grass, beaked hazel, mountain maple, and/or alder cover can significantly reduce vigour, growth, and survival of newly planted seedlings. Grass and hardwood litter can smother germinants.

Management

Natural regeneration is often inconsistent and planting is usually required if white spruce is desired in the future stand. Planted seedlings may exhibit a prolonged period of minimal height growth during establishment.

Appendix 4 - Best Practices for Commercial Thinning Even-aged Stands of Jack Pine, White Spruce, Black Spruce, Red Pine and White Pine.

This silviculture guide limits commercial thinning to a stand tending treatment, consistent with its classification in the *Forest Management Planning Manual for Ontario's Crown Forests* (OMNR, 2009). Commercial thinning can be described after Kayahara *et al*. (2006) as *a stand tending treatment in well stocked, vigorous, immature stands, where some portion of the trees removed have reached a merchantable size and where the sale of timber harvested will potentially earn a positive financial return. The primary objective of the treatment is to accelerate the diameter increment of residual trees (relative to no thinning), but the treatment should also, by suitable selection, improve the form, quality and/or value of the residual trees. Commercial thinning is differentiated from a two-stage harvest in that the former is a tending treatment, the primary purpose of which is to enhance the growth of residual stems without reducing total stand volume growth.*

The following best management practices apply to the planning and implementation of commercial thinning operations in even-aged stands of jack pine, white spruce, black spruce, red pine, or white pine. For jack pine, white spruce, and black spruce, they are largely based on the specifications outlined in Kayahara *et al*. (2006), which were derived from a thorough and comprehensive literature review (McKinnon *et al*. 2006) and are supported by recent experience (e.g., Pelletier and Pitt 2008). The best practices for red pine and white pine are based on a more extensive history of field experience and related publications (e.g., Smith and Woods 1997; Woods and Penner 2000).

Based on current knowledge, these best management practices represent "best bets" for conducting commercial thinning in Ontario. New research and operational trials and long term growth and yield information is needed to support future development of this treatment. Further development and refinement of decision support tools (e.g. DMDs) are also required. As additional data becomes available, commercial thinning under additional site, stand and/or treatment conditions may be supported.

1. Site Conditions

a) ***Site productivity.*** Commercial thinning should be concentrated on the more productive (higher site index) sites to maximize individual tree growth response and minimize the risk of a reduction in stand volume growth through rapid re-occupancy of post-thinning canopy gaps. The well drained, deep soils often associated with these sites may also reduce the risk of windthrow of residual stems.

2. Stand Conditions

a) ***Species Composition***. Priority should be placed on commercially thinning stands composed of pine species over spruce species due to the faster growth of the pines. Due to the more limited availability of studies of black spruce growth response to commercial thinning white spruce should be favoured over black. It is less clear how well black spruce, which has slower growth and a narrower and less plastic crown, responds.

b) ***Stand Development Stage.*** Candidate stands should have achieved full site occupancy (full use of the growing space available), which occurs at the stem exclusion stage of stand development when few, if any, stems are added to the main canopy. Some of the trees to be removed must also have reached merchantable size.

c) ***Stand History.*** Candidate stands will ideally have a history of density regulation (i.e., planting and/or pre-commercial thinning), because such stands develop evenly and are otherwise most likely to maintain conditions that support good growth responses in residual stems (see Point 2c).

d) ***Stand Vigour, Stability, and Health.***

i**)** ***Live Crown Ratio.*** Commercially thin stands only if residual trees will have minimum live crown ratios of 35%, because conifer trees with small crowns and suppressed diameter growth will respond poorly to increased light and growing space and may suffer “thinning shock”.

ii) ***Height/Diameter Ratio.*** Trees with height/diameter ratios greater than 100% are especially unstable and at high risk for wind damage. Commercially thin stands only if the H/D ratio of residual trees does not exceed 70%-90%.

iii) ***Stand Health.*** Select stands that are generally free of existing insect and disease infestations, otherwise volume and investments may be lost to damaging agents. For example, stands with jack pine budworm, spruce budworm, or significant occurrence of tomentosus, annosus, or *Armillaria* root rots should be avoided. Signs and symptoms of these and other insect and disease infestations are detailed in various publications (OMNR, 1991, Whitney 2000, Davis and Myer 2004) and online databases (e.g., Natural Resources Canada 2013).

3. Thinning Treatment and Operations

a) ***Timing of Thinning.*** The timing of commercial thinning operations should occur sufficiently before the culmination of mean annual volume increment (MAI) and during the period of active height growth, after which the opportunity for good crown expansion and growth response is lost. This means that for the boreal tree species, where only one commercial thinning is to take place (see Point #3b, below), commercial thinning on high productivity sites should generally not occur later than (values assume a 15 year post-thinning response period):

- 35 years for jack pine
- 40 years for white spruce
- 50 years for black spruce
- 25-30 years for red pine
- 30-35 years for white pine

Early density regulation can, however, be used to extend culmination of MAI by several years or, in some cases, decades. For red and white pine, the latest age for thinning therefore depends on the number and timing of each treatment. Some of the older plantations in Ontario that have been periodically thinned are still being thinned beyond the age of 70 years. An upper age limit for thinning is therefore only speculative for red pine and white pine, at this time.

Within the window for biologically feasible thinning defined above, the *ideal* time to commercially thin depends on site quality (or site index) and stand density. The tools described in Point #4 can be used to estimate this timing.

b) ***Thinning Type and Intensity.*** Only single-entry thinning from below (i.e., selective thinning that emulates natural competitive processes and avoids high grading) should be used for jack pine, white spruce, and black spruce. Remove overtopped, intermediate, some co-dominant, and poorer quality trees to favour larger, more vigorous, quality trees in the upper (dominant and co-dominant) crown classes. The thinning intensity using this method should not exceed one-third (30-35%) basal area removal, but for operational purposes an additional 10-12% of stand basal area is permitted to be removed for main machine trails (see Point #3c) (Kayahara *et al*. 2006; Pelletier and Pitt 2008). Although multiple thinnings from below are also ecologically appropriate, and multiple light thinnings in particular may yield more merchantable stand volume, they are often not operationally or financially feasible for these three boreal tree species.

Multiple thinnings are more feasible for red pine and white pine and can produce appreciable volumes and value (Woods and Penner 2000). An initial thinning treatment for red pine or white pine plantations should consist of non-selective row thinning (removing every fourth of fifth row, or roughly 20-25% basal area) combined with light (10-15%) thinning from below within the intervening rows (up to a maximum 40% *total* basal area removal). In this case, the removed rows, which are part of the prescribed thinning treatment, also function as machine trails both during the initial thinning and in any subsequent thinnings. Subsequent selective thinnings or thinning from below can then occur periodically and should not exceed a total of *one-third* basal area removal. In addition to spacing and stem quality, selective thinnings for both red and white pine should also target the removal of suppressed trees.

In order to support the above thinning intensities, ideal candidate stands should have minimum initial basal areas of (for red pine and white pine, these values apply to first thinnings):

- 25 m^2/ha for jack pine,
- 35 m^2/ha (14 m height) - 40 m^2/ha (15 m height) for red pine (Smith and Woods 1997, Gilmore and Pallik 2005),
- 32 m^2/ha for white pine (P. Nitschke 2013),
- 28 m^2/ha white spruce, and
- 25 m^2/ha black spruce.

Where a regime of multiple thinnings is used for red pine or white pine, pre-thin basal areas at later stages of stand development will be higher.

c) ***Extent of Main Trails.*** Where main trails[13] are used, their size and extent should not compromise full site occupancy (lead to a divergent post-thinning yield curve). Thus, main trails should not individually exceed the inter-tree spacing required for rapid re-closure of canopy gaps and collectively should not elevate total stand basal area removal to unacceptably high levels.

For prescriptions of uniform thinning from below of moderate intensity (30-35% basal area removal), in jack pine, white spruce, or black spruce stands, no more than an additional 10-12% basal area should be removed in main trails. Individual main trails should not result in canopy openings more than 3 m wide (Kayahara *et al*. 2006; Pelletier and Pitt 2008). Small, lightweight forwarding equipment and purpose-built commercial thinning harvesters are most suited to achieve these objectives.

Main trails (and associated limits on them) are not applicable to row thinning applications with red pine and white pine, because the removed rows are part of a biologically acceptable thinning prescription for these species, even if the removed rows additionally function as access trails.

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[13] A "main trail" is a machine travel corridor in a thinned stand, which is created to allow forwarding equipment access to extract felled logs and, in the selection and spacing criteria of a thinning prescription. Main trails are typically used to operationalize uniform thinnings from below (e.g., Pelletier and Pitt 2008).

d) ***Size of Operating Area.*** The location, market price, proximity of equipment, and many other factors will influence the minimum operable size of a thinning project. Work in red pine in central Ontario suggests a minimum size of 8-10 acres (3-4 ha).

e) ***Careful Logging.*** Site and tree damage should be minimized during thinning. Commercial thinning operations must conform to the direction for site disturbance (compaction, rutting and erosion) provided in the *Forest Management Guide for the Conservation of Biodiversity at the Stand and Site Scales* (OMNR, 2010).Damage to the boles, crowns and roots of residual trees should be minimized through appropriate selection of harvesting equipment and the use of trained equipment operators.

4. Decision Support Tools

a) Density Management Diagrams. The use of density management diagrams (DMDs) is advised when developing commercial thinning prescriptions to evaluate alternative thinning strategies for achieving stand management objectives, plan the timing and intensity of thinnings, and estimate the average extracted product dimensions (tree size). DMDs graphically show the trajectory of stand development, or more specifically how average tree size (stem diameter, basal area, or volume), stand density, and stand volume (yield) change over time for even-aged stands (diagrams sometimes also include dominant tree height and other parameters). DMDs are based on the -3/2 power law of self-thinning and apply to thinning from below operations; they cannot be used for row or crown thinnings, which do not similarly emulate natural density-dependent mortality processes. Refer to Archibald and Bowling (1995), Smith and Woods (1997), and Newton (2009) for more discussion and detail on thinning with DMDs. Refer to the following publications for species-specific DMDs:

- Jack pine (Archibald and Bowling 1995, Sharma and Zhang 2007, Newton 2009);
- White spruce (Saunders and Peuttmann 2000);
- Black spruce (Newton 2012);
- Red pine (Smith and Woods 1997); and
- White pine (Smith and Woods 1997).

b) ***Pre-Harvest Field Assessments.*** Pre-harvest field assessments (e.g., Bidwell *et al*. 1996) should be used to verify site and stand conditions in the field prior to thinning, given that the success of commercial thinning is highly dependent on appropriate site and stand conditions. As a component of this assessment, pre-treatment sampling provides initial empirical data if future monitoring is planned.

Basal Area Guidelines. The following tables provide a translation from the SDI approach in the Density Management Diagrams discussed above to basal area ranges by DBH.

Red Pine:

DBH		SDI Fully Stocked		SDI Target Residual BA			Minimum Residual BA (33% Removal)	
Cm	Inches	M2/ Ha	Ft2/ Acre	M2/ Ha	Ft2/ Acre	% Removal	M2/ Ha	Ft2/ acre
15	6	37.1	162	28.3	123	24%	24.7	108
17.5	7	38.5	168	30.1	131	22%	25.6	112
20	8	40.8	178	31.4	137	23%	27.2	118
22.5	9	42.1	183	31.8	139	24%	28.0	122
25	10	44.2	193	33.4	145	24%	29.4	128
27.5	11	44.5	194	34.4	150	23%	29.6	129
30	12	45.9	200	34.6	151	25%	30.6	133
35	14	47.1	205	36.5	159	23%	31.4	137
40	16	48.4	211	37.7	164	22%	32.2	140

White Pine:

DBH		SDI Fully Stocked		SDI Target Residual BA			Minimum Residual BA (33% Removal)	
Cm	Inches	M2/ Ha	Ft2/ Acre	M2/ Ha	Ft2/ Acre	% Removal	M2/ Ha	Ft2/ acre
15	6	24.7	108	18.5	81	25%	16.5	72
17.5	7	27.6	120	20.4	89	26%	18.4	80
20	8	30.8	134	22.6	98	27%	20.5	89
22.5	9	33.0	144	23.8	104	28%	22.0	96
25	10	35.6	155	25.8	112	28%	23.7	103
27.5	11	37.4	163	27.6	120	26%	24.9	109
30	12	40.6	177	29.0	126	29%	27.0	118
35	14	44.2	193	31.7	138	28%	29.4	128
40	16	47.7	208	35.2	153	26%	31.8	138
45	18	50.9	222	37.4	163	27%	33.9	148

White Spruce:

DBH		SDI Fully Stocked		SDI Target Residual BA			Minimum Residual BA (33% Removal)	
Cm	Inches	M2/ Ha	Ft2/ Acre	M2/ Ha	Ft2/ Acre	% Removal	M2/ Ha	Ft2/ acre
15	6	34.3	149	25.1	109	27%	22.8	100
17.5	7	36.7	160	26.4	115	28%	24.4	106
20	8	39.3	171	28.3	123	28%	26.2	114
22.5	9	40.7	177	29.8	130	27%	27.1	118
25	10	42.9	187	31.2	136	27%	28.6	124
27.5	11	43.6	190	32.7	142	25%	29.0	126
30	12	45.9	200	33.9	148	26%	30.6	133

Literature Cited

Archibald, D.J. and C. Bowling. 1995. Jack pine density management diagram for boreal Ontario. Ontario Ministry of Natural Resources, Northeast Science and Technology, Timmins, ON and Northwest Science and Technology, Thunder Bay, ON. NEST Technical Note TN-005 and NWST Technical Note TN-031. 20 pp.

Bidwell, P.K., Turner, B., Archibald, D.J. and N. Maurer. 1996. An approach to pre-harvest silviculture prescriptions in boreal Ontario. Ontario Ministry of Natural Resources, Northeast Science and Technology, Timmins, ON and Northwest Science and Technology, Thunder Bay, ON. NEST Technical Note TN-014 and NWST Technical Note TN-034. 12 pp.

Davis, C. and T. Meyer. 2004. Field guide to tree diseases of Ontario. Revised edition.NODA/NFP Technical Report TR-46.Natural Resources Canada, Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, ON.137 pp.

Gilmore, D.W., T.C. O'Brien and H.M. Hoganson. 2005. Thinning red pine plantations and the Langsaeter hypothesis: a northern Minnesota case study. North. J. Appl. For. 22:19-26.

Gilmore, D.W. and B. J. Palik, eds. 2005. A revised managers handbook for red pine for the north central region. USDA For. Serv., North Central Research Stn, St. Paul, MN.General Technical Report NC-264.

Kayahara, G.J., McKinnon, L.M. and R.G. White. 2006. Commercial Thinning Specifications and Exceptions Monitoring Protocol for Jack Pine, White Spruce and Black Spruce in Ontario's Boreal Forest.Ontario Ministry of Natural Resources, Northeast Science and Information, Timmins, ON.NESI Technical Note TN-022. 8pp.

McKinnon, L.M., Kayahara, G.J. and R.G. White. 2006, Biological framework for commercial thinning even-aged single species stands of jack pine, white spruce, and black spruce in Ontario. Ontario Ministry of Natural Resources, Northeast Science and Information, Timmins, ON.NESI Technical Report TR-046.129 pp.

Natural Resources Canada. 2013. Trees, insects and diseases of Canada's forests. Online database: http://tidcf.nrcan.gc.ca/.

Newton, P.F. 2009.Development of an integrated decision-support model for density management within jack pine stand types. Ecological Modelling 220: 3301-3324.

Newton, P.F. 2012.A decision support system for forest density management within upland black spruce stand-types. Environ. Monitoring & Software 35:171-187.

Nitschke, P. 2013. Bancroft-Minden Forest Company, in personal communication with J. Hall.

OMNR, (Ontario Ministry of Natural Resources). 1991. Common pests of trees in Ontario. Queen's Printer for Ontario, Toronto, ON. 84 pp.

OMNR, (Ontario Ministry of Natural Resources). 2009. Forest Management Planning Manual for Ontario's Crown Forests. Queen's Printer for Ontario, Toronto, ON. 447 pp.

OMNR, (Ontario Ministry of Natural Resources). 2010. Forest management guide for conserving biodiversity at the stand and site scales. Queen's Printer for Ontario, Toronto, ON. 211 pp.

Pelletier, G. and D.G. Pitt. 2008. Silvicultural responses of two spruce plantations to mid rotation commercial thinning in New Brunswick. CJFR 38:851-867.

Saunders, M.R. and K.J. Puettmann. 2000. A preliminary white spruce density management diagram for the Lake States. Department of Forest Resources, University of Minnesota, St. Paul, MN.Staff Paper Series No. 145.13 p.

Sharma, M. and S.Y. Zhang. 2007. Stand density management diagram for jack pine stands grown in eastern Canada. North. J. Appl. For. 24:22-29.

Smith, D.J. and M.E. Woods. 1997. Red Pine and White Pine Density Management Diagrams for Ontario. OMNR, Southcentral Sciences Section, North Bay, ON.SCSS Technical Report TR-048. 31pp.

Smith, D.M. 2003.Effect of method of thinning on wood production in a red pine plantation.North. J. Appl. For 20:39-42.

Whitney, R.D. 2000. Forest management guide for Tomentosus root disease. Ontario Ministry of Natural Resources, Sault St. Marie, ON.20 p.

Woods, M.E. and M. Penner. 2000. Growth and yield response of red pine plantations to thinning. Ontario Ministry of Natural Resources, Southcentral Sciences Section, North Bay, ON.SCSS Technical Note #06.36 pp.

Appendix 5 –The Use of Prescribed Burning as a Silviculture Tool

Prepared by Nicole Galambos and Dan Johnson

Introduction

Prescribed burning as defined by MNRF, (2008a) *is the deliberate and knowledgeable application of fire by authorized personnel to a specific land area to accomplish predetermined forest management or other land use objectives.*

The use of prescribed burns (PB) in a safe and cost effective manner can help balance the needs of silviculture, hazard reduction and ecological management practices across Ontario. Forest managers may plan for and deliver a PB to achieve various silvicultural objectives. PBs can:

- Prepare a site for regeneration (artificial or natural) through suitable microsite creation by reducing litter layer (duff) thickness and harvesting debris (slash) and increasing soil temperatures and nutrient availability (MacRae *et al*. 2001).
- Temporarily reduce density and growth of competing vegetation to allow crop species to establish. Achieving vegetation management objectives depends on the autecology, fire adaptive traits, and response to different fire severities of competing and crop species (Luke *et al*. 2000, MacRae *et al*. 2001).
- Be an alternative vegetation management treatment where the use of herbicides is controversial or prohibited.
- Reset forest units that are poorly stocked or regenerating or moving towards an undesirable state to help achieve forest management planning and sustainability objectives. Large areas damaged by insects or weather events can be renewed using prescribed burning.
- Burn slash piles at roadside from full tree harvesting, with subsequent regeneration treatments, to recover the productive land from these areas.

Policy Context

The MNRF prescribed burn policies apply to prescribed burns on Crown land administered by the MNRF, private land that is managed by the MNRF or any burn regardless of land ownership that involves MNRF personnel in operational, support, or approval roles. Ontario's Prescribed Burning Operations Policy (OMNR, 2008a), associated Prescribed Burn Manual (OMNR, 2008b) and Prescribed Burn (PB) Toolbox (OMNR, 2008c) provide guidance for application submission, planning, and implementation of PBs.

Prescribed burns in Ontario are classified as either *high* or *low* complexity (OMNR, 2008a). Complexity is determined based on a number of factors including, but not limited to: risk of escape, ignition method, burn size and the potential impact of the burn. The level of burn complexity determines the planning detail required, as well as the training and qualification requirements of the personnel involved.

Prescribed burn proponents are responsible for preparing an application, accompanying complexity assessment and a PB plan, in accordance to the PB Operations Policy (2008a) and the PB Manual (OMNR, 2008b). The PB plan includes information on fire intelligence, behaviour, communications, ignition, suppression and safety.

MNRF and AFFES are responsible for the review and approval of applications and plans for PBs. The plan review assesses all planned actions and associated risks to ensure the PB will meet the objectives of the burn proponent. MNRF also provides PB training to non-AFFES staff and specialists who may assist in the development of the PB plan.

Examples of Recent Prescribed Burns

A recently completed project, through the Forest Ecosystem Science Co-operative Inc. (Forest Co-op), collected a digital record of all the historical prescribed burns in Ontario. Paper records of plans and post burn reports were scanned and linked to spatial locations of the burns. Collecting this historical record has allowed for additional research and study of the post-fire effects and longer-term silvicultural results of prescribed burning.

Table xx. summarizes various examples of recent prescribed burns in Ontario. These examples provide a general overview of PB objectives and conditions to consider moving forward. It is hoped that the information and knowledge gained on fire behaviour and the effects on forest vegetation communities from these recent PBs through the associated ongoing research projects will renew our interest and improve our comfort level in using prescribed burning as an important tool in our silviculture toolbox.

Best Management Practices

The following are recommended best management practices when planning and conducting prescribed burns:

- Select timing of burn (season) to minimize risk of escape and to meet burn severity objectives.
- The size, shape, access, fuel type, natural and human-made boundaries and nearby values can affect final cost and degree of success of a PB.
- Proponents and operators should discuss the objectives of the burn to ensure they are realistic and attainable.
- Careful assessment and selection of indices is required when setting prescriptions, all parties should discuss prescription to keep costs down and/or to achieve results.
- Select timing of burn when indices are not too high (fire burns too hot and removes entire duff layer) or too low (fire is slow moving with variable coverage).
- Consider multiple burns where competing vegetation is abundant.
- Avoid burning during time periods when forests are used frequently by anglers, hunters, recreationalists, and Aboriginal communities.

- Mitigate smoke from entering sensitive areas (i.e. communities) by burning under conditions that drive smoke column upwards or away from sensitive areas.
- If regenerating burnt areas with natural seeding, ensure seed trees will survive and withstand any damage from the heat of the burn (adequate height, age, bark thickness).
- Ensure timing of PB coincides with a good seed year and season of seed dispersal if regenerating burnt areas with natural seeding.
- When creating slash piles, ensure piles are engineered ("fluffed") to maximize air circulation and drying of debris and minimize mineral soil mixing.
- Burn slash piles within 3 years of completed harvest operations.
- Practice good public relations, notification, and education.

Table xx. Examples of recent prescribed burns in Ontario.

Complexity	Location	Proponent	Time of Burn	Objective	Pre-burn Site Conditions	Result	Comments
Low	Northeast Region	SFL holder	Late fall /winter (annually)	Prescribed burning of slash piles to prepare area for regeneration to recover lost productive land and achieve forest renewal and sustainability objectives.	Post full tree harvest piled and engineered ("fluffed") slash piles	Private contractors ignite and monitor the burning of slash piles (un-merchantable wood and debris left at roadside from harvesting). Piles self extinguish over winter. Burnt areas are recovered to productive land through regeneration (i.e. tree planting).	Comfort level with all industry, contract and MNR staff involved in slash pile burning has increased under the MNR's Low-Complexity Slash Pile Burning prescriptions and requirements.
Low	Northeast Region	MNR (Science and Information)	Started fall 2008 (multi-year project)	1) To promote the growth of planted and natural red oak regeneration by using prescribed burning as a tending method, and to compare results with herbicide tending, brush saw tending and no tending. 2) To determine the timeframe (time since harvest) for the effective use of prescribed burning as a tending tool.	Harvested red oak stands	Top kill of hardwood brush and sufficient plot coverage achieved on all plots burnt to date (1-3 plots burnt in each 2008, 2010, 2011, and 2012). Preliminary results show that PB at the intensities used appears to be most effective at top-killing competition (pin cherry, polar, red maple) <8 cm DBH, or within 8 years of the shelterwood harvest (residual canopy of 40% crown closure).	All hardwood stems that are top-killed will re-sprout and a second burn may be required to allow red oak to achieve dominance.
Low	Northeast Region	MNR (Ontario Parks)	2011 fire season	Ecosystem restoration, fire behaviour research, fire hazard reduction with an interest in re-establishing historic white pine stands to the area with presence of mature white pine on site.	Jack pine dominated stands with super-canopy white pine	2 of 3 identified areas ignited with CFS researchers onsite. Sufficient intensity to remove competing vegetation, permitting seedling establishment.	Successful partnership with the Canadian Forest Service (CFS), MNR fire and protected areas staff. Research results will benefit the fire community.
Low	Northwest Region	MNR (Parks and Protected Areas)	Started fall 2012 (multi-year project)	Ecosystem restoration: re-introduce surface fires onto islands in a conservation reserve to maintain ecological integrity of fire-dependent ecosystems.	Understory of mixedwood stands on islands	District MNR and AFFES staff worked together to develop the PB applications and plans, in consultation with local residents and First Nations groups. AFFES staff igniting 3-6 islands per year during late summer/early fall.	MNR staff established long-term monitoring plots to track post-fire vegetation changes and ensure the desired effects are being achieved.
High	Northeast Region	SFL holder	Fall 2011	Wildlife habitat renewal: create woodland caribou habitat by reducing hardwood, balsam fir, and species cover on sites.	Over-mature mixedwood stands in clay belt region	Approximately 500 ha treated with 2 pre-burn aerial herbicide sprays and one day ignition. Area planted to black and white spruce in spring of 2012.	Careful assessment and selection of indices is required, all parties should discuss to keep costs down and/or to achieve results.
High	Northwest Region	SFL holder with MNR (Science and Info., District Office, AFFES)	Started fall 2010 (multi-year project)	Multiple stakeholders and objectives: Fire hazard reduction, forest renewal, fire behaviour/silviculture research, wildlife (woodland caribou) habitat renewal.	Blowdown occurred in 2007	Approximately 1,000 ha of blowdown were ignited and burned during the fall to minimize the potential for escape.	The PB removed significant amounts of the blowdown and provided valuable fire behaviour information.
High	Northwest Region, Far North Planning Area	AFFES	Fall 2010	Fire behaviour research, fire hazard reduction.	Blowdown occurred in 2005	In consultation with local First Nations, AFFES planned and carried out a 1,000 ha PB in the fall to minimize the potential for escape. Area is planned to be aerially seeded to jack pine in 2014.	The PB removed significant amounts of the blowdown and provided valuable fire behaviour information.

Literature Cited

Luke, A.B., D.J. Archibald, R.W. Arnup, and N.L. Wood. 2000. Prescribed fire as a vegetation management tool. NWST Technical Note TN-45, in Bell, F.W., M. McLaughlan, and J. Kerley (compilers). Vegetation management Alternatives – A Guide to Opportunities. Ontario Ministry of Natural Resources, Thunder bay, ON. 12 pp.

MacRae, D.J., M.G. Weber, and P.C. Ward. 2001. Site Preparation – Prescribed Fire in R.G. Wagner and S.J. Columbo, (eds.), *Regenerating the Canadian Forest: Principles and Practice for Ontario*. Fitzhenry and Whiteside, Markham, ON. pp 201-219.

OMNR. 2008a. Prescribed Burn Operating Policy. Ministry of Natural Resources. Aviation, Forest Fire and Emergency Services. Amended July 18, 2008.

OMNR. 2008b. Prescribed Burn Manual. Ministry of Natural Resources. Aviation, Forest Fire and Emergency Services. Amended July 18, 2008.

OMNR. 2008c. Prescribed Burn Toolbox. http://www.mnr.gov.on.ca/en/Business/AFFM/2ColumnSubPage/197308.html

Appendix 6 – Overview of Management Interpretations

The following table is provided for convenience. Significant explanatory detail has been removed and the details of conditions are not included. The full management interpretation tables are available in section 5.1. In the unlikely event of a discrepancy between this overview table and the direction in section 5.1, section 5.1 will be deemed correct.

H = high probability
L = low probability
NR = not recommended
Grey shading indicates a condition applies – refer to section 5.1 for details. To avoid obscuring more specific conditions, some of the more generic conditions (e.g. apply principles from the tree marking guide) have not been shaded grey.

Partial overview of management interpretations in section 5.1 (some detail removed for clarity).

Species	Mr	Ms	By	Bw	Be	LH	Aw	Pb	Po	Cb	Or	Bd	Bf	La	Sw	Sb	Sr	Pj	Pr	Pw	Ce	He
Clearcut with standards	H	H	H	H	NR	NR	NR	H	H	L	H	NR	H	H	H	H	NR	H	H	H	H	NR
Clearcut seedtree	H	H	H	H	NR	L	NR	H	NR	L	H	NR	H	H	H	H	NR	H	H	H	H	NR
Shelterwood Uniform	H	H	H	H	H	H	H	L	L	H	H	H	H	L	H	H	H	NR	H	H	H	H
Shelterwood strip/group	H	H	H	H	H	H	H	L	L	H	H	H	H	NR	H	H	H	NR	H	H	H	H
Shelterwood irregular	H	H	H	H	H	H	H	L	L	H	H	H	H	NR	H	H	H	NR	H	H	H	H
Selection individual	H	H	NR	NR	H	H	H	NR	NR	NR	NR	H	H	NR	NR	H	H	NR	NR	NR	H	H
Selection group	H	H	H	H	H	H	H	L	L	H	H	H	H	L	H	H	H	L	L	H	H	H
Cut to length	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
Tree length	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
Full tree	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
Preharvest chemical	L	L	L	H	L	L	L	H	H	H	H	L	H	H	H	H	H	H	H	H	H	H
Preharvest prescribed burn	L	L	L	H	L	L	L	H	H	H	H	L	NR	H	H	H	H	H	H	H	L	H
Preharvest site preparation	H	H	H	H	H	L	H	NR	NR	H	H	H	H	L	H	H	H	L	H	H	H	H
Preharvest plant	H	H	H	H	H	H	H	NR	NR	H	H	H	H	H	H	H	H	L	L	H	H	H
Mechanical site preparation	H	H	H	H	H	L	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
chemical site preparation	H	H	H	H	H	L	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
Prescribed burn	H	H	H	H	L	L	H	H	H	H	H	H	NR	NR	H	H	H	H	H	H	H	H
Advance regeneration	H	H	H	H	H	H	H	H	NR	H	H	H	H	H	H	H	H	L	H	H	H	H
Natural seed	H	H	H	H	H	H	H	H	L	H	H	H	H	H	H	H	H	H	H	H	H	H
Coppice	H	NR	NR	H	H	H	H	H	H	H	H	H	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Planting	H	H	H	H	H	L	H	H	L	H	H	H	H	H	H	H	H	H	H	H	H	H
Artificial seed	H	H	H	H	H	H	H	H	L	H	H	H	H	H	H	H	H	H	H	H	H	H
Manual/Mech. Clean	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
Chemical clean	H	H	H	H	H	L	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
Midstory	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
PCT	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
Commercial thin	H	H	H	L	H	L	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H