SECTON 5: Quantifying Plant Community Interactions

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5 QUANTIFYING PLANT COMMUNITY INTERACTIONS

Understanding the interactions between individual plants and among plant species is fundamental to managing plant communities. Management regimes and treatments based on a quantitative approach to understanding interactions are more defensible and repeatable than regimes that rely on subjective application of principles. Quantifying interactions in plant communities is generally undertaken by integrating direct measures of numbers, size and sometimes vigor of individual plants, and interactions between individuals or species with some form of "competition" model.

The best competition models link the response of key species to the environment and mechanisms of competition. While numerous competition models for white spruce exist, there are no explicit early age competition models for aspen, or for mixtures of aspen and white spruce, where aspen is treated as a crop rather than as a competitor. (The Mixedwood Growth Model[1] is a quantitative model that addresses performance of aspen, white spruce and mixtures of aspen and white spruce. The website for the model cautions against using the model before early, stochastic influences on plant community development have "settled down".) **While this manual attempts to address this deficiency, silviculturists should be aware of the inherent biases present in the models discussed and recommended.** It is suggested the practitioner refer to Section 4.3 (Aspen White Spruce Facilitation & Competition) when considering competition model selection.

5.1 ASSESSING AND INTERPRETING PLANT COMMUNITY INTERACTIONS

Forest renewal is the most dynamic time in the life history of the forest plant community. It is characterized by an abundance of plant species and rapid changes in species and community dominance. To understand this time of community flux, the silviculturist is best served by an array of assessment and interpretation tools. Reasons for choosing specific competition indices (interpretation tools) are given in each section. However, the overarching rationale is described here.

This manual divides stand renewal into discrete phases (T3, T6, and T7) described by the time units outlined in (Section 1) and recapped here with a specific focus on plant community development. The Aspen White Spruce Facilitation & Competition Table is linked to the temporal intervals to assist in considering the complex facilitative and competitive relationship of these species. Temporal phases are provided to simplify development of silvicultural processes - they are not biologically discrete. The temporal phases used are:

T3 – *Harvest phase process*– while not strictly silvicultural this phase can have a substantial impact on the development of the plant community. Practitioners are referred to the Section 3 – Making Pre-treatment Silviculture Prescriptions (Section 3) for more discussion of harvest regime implications on reforestation.

[1] http://mgm.ales.ualberta.ca/

T5 – *Treatment phase process* – marks initial action around implementing the reforestation plan. It includes site preparation, propagule deployment (planting, artificial seeding or leave for natural (LFN)). The Guide assumes prompt (within two years of harvest) initiation of the reforestation plan.

T6 – The *Establishment phase process* (treatment to 4 years old) – is the most dynamic time in plant community development when the successional trajectory is most amenable to being "nudged". It is during this phase that the silviculturist may have the most lasting and effective influence on both the composition and structure of the developing plant community. This is also the period when the effects of aspen on white spruce are likely to be more facilitative than competitive.

T7 – *Post-establishment to performance phase process* (treatment at 5-14 years old) – is a time when the silviculturist must ensure that community composition does not shift in an undesired direction. During this phase of plant community assembly, aspen interaction with white spruce is likely shifting toward a more competitive condition whilst facilitative value is declining.

Note that this manual does not recommend assessments of community interactions at all the times listed above. Rather, the silviculturist should choose among these timings based on local knowledge, overall forest management strategies and other considerations. **It is suggested that the critical times for plant community assessment are T2 (Pre-Harvest) and T6 (Establishment phase).**

5.1.1 INTERPRETATION AND APPLICATION OF PLANT COMMUNITY ASSESSMENTS

The following sections offer assistance in interpreting the results of plant community assessments and provide suggestions and comments on making vegetation management prescriptions to direct plant community assembly toward desired outcomes. To this end, it is imperative that the silviculturist has a clear understanding of objectives for both white spruce and aspen.

SETTING COMPOSITIONAL OBJECTIVES

The first step in developing and applying a vegetation assessment is to have clear, quantitative objectives. Objectives guide the practitioner in interpreting whether the current community status is likely to lead to longer-term success, or, failing that, whether treatment or re-thinking of objectives are appropriate to ensure the current community development trajectory is consistent with desired outcomes. Clarity in objectives is best obtained by quantitative description of composition by species. For example, "pure" or single leading tree species communities are better described by species with an associated minimum proportion of density, rather than by species alone (or conversely by defining a maximum "acceptable" proportion of density of other tree species). In addition, in single species communities a maximum density of "incidental" or non-leading species might be included in the compositional objective. Similarly, in mixed species communities desired densities for all desirable species should be set, rather than simply indicating dominance. For example, a deciduous leading mixedwood might be described as aspen leading white spruce with a desired density of at least 5000 stems per ha with 500 stems per ha of white spruce.

Practitioners are cautioned that uniformity in site occupancy is an important component of reforestation success that is not addressed by density. Therefore, a measure of site occupancy (i.e. stocking) should be included in management objectives.

In managing plant communities to mixedwood objectives, clarity in density alone will not suffice. The silviculturist must clarify distribution objectives as well as density and stocking objectives. In mixedwood communities, the silviculturist must decide on how primary crop tree species' distributions interact. The following phrases and definitions are the lexicon used in this manual to describe the three most common forms of crop species admixtures employed in managing mixedwood forest community reforestation:

- ***Intimate*** - a mixture where spatial separation of species is on the scale of a few meters or less (Kabzems *et al*. 2007)
- ***Aggregated*** - a discrete mixture of species where some influence of each species on the other is maintained. A minimum width of discrete patches of 30 m and a maximum patch size of 0.25 ha (Comeau 2007 *pers. Comm.).*
- ***Segregated*** - a discrete mixture of species wherein influence of species on each other is primarily, or only, expressed at the interface between them. This is generally only applied to openings.

5.1.2 ASSESSING THE PLANT COMMUNITY AT T1 – REMOTE ASSESSMENT, T2 – PRE-HARVEST ASSESSMENT, T3 - HARVEST ASSESSMENT AND T4 – POST HARVEST ASSESSMENT

At these timings (T1-4), assessments are predictive as the plant community to be managed has not yet begun to develop. The predictive nature of assessments at these times allows the silviculturist access to a wider array of treatments than at any other time. Assessments at these timings focus on either presence of species likely to rapidly colonize the area, or on site suitability to key species that either rapidly colonize or compete vigorously with crop tree species. Treatments arising from these assessments can be made at, or prior to, stand establishment (T6); because coniferous seedlings will not be present, they will be immune to treatment. However, treatment effects on deciduous crop components should be considered prior to deployment.

Assessing the potential direction of plant community development at these early stages is vital because the ability to deploy site preparation and propagules at the treatment phase (T5) is critical to silvicultural success. Site preparation and propagule deployment (Section 7, Section 8) set the direction of stand development. Most of the treatments in the site adjustment section (Section 7) of the manual impact plant community development. Potential impact of these treatments on plant community development is given in Section 7. Further, Site Adjustment Treatments are essential components in an integrated approach to silvicultural practice. Hence, the importance of accurate assessment, interpretation, and prediction of plant community development at time T1 through T4 cannot be overemphasized.

5.2 PRE-HARVEST (T2) ASSESSMENTS – VEGETATION ONLY

This section (5.2) guides the assessment of vegetation parameters of critical importance in predicting plant community assembly after harvest. Site factors as summarized by edatopic position (Figure 5.1) are linked to potential competing vegetation in edatopes 20-31 (Appendix 2); these edatopes show fundamental site suitability ranges for key species.

Predicting post-harvest establishment, growth, and risk of competition, depends on knowing site conditions (i.e. moisture and nutrient regime), and species pre-harvest extent and coverage. Risk of competition is assessed by integrating site conditions and the autecology of the species. Generally, competition risk is highest on sub-hygric to mesic sites that are rich to very rich in nutrients; risk increases with proximity to the "ideal" edatope for the potentially competitive species identified prior to harvest. Edatope 31 (Reedgrass) is shown below in Figure 5.2.

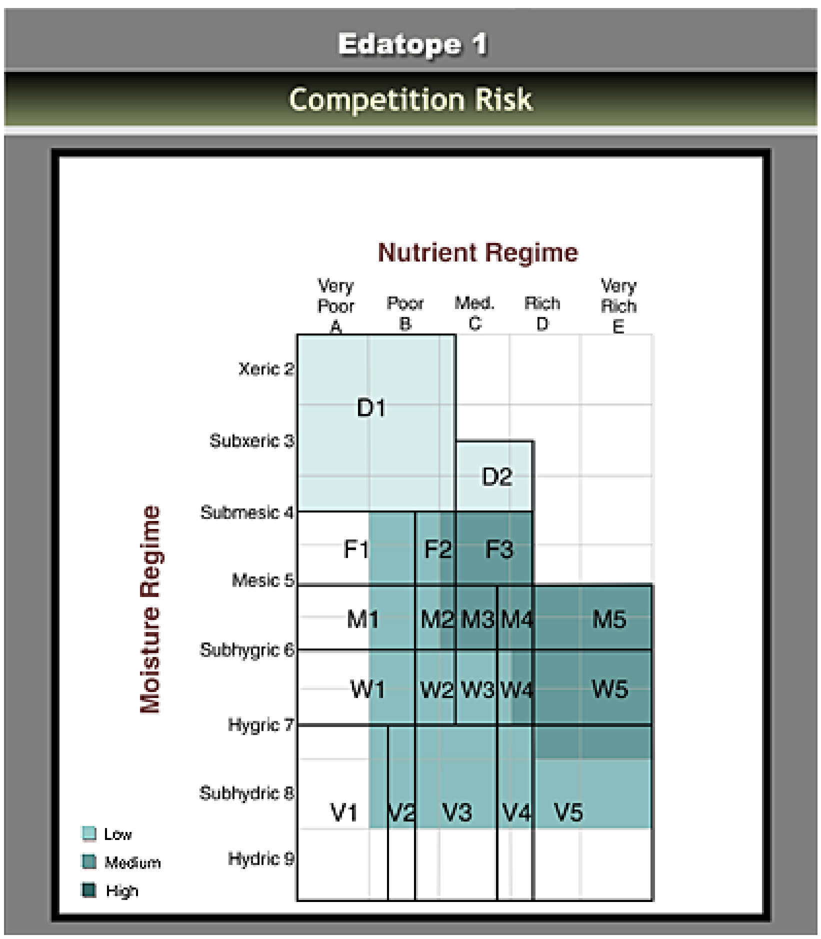

Figure 5.1 Competition risk generalized by edatopic position.

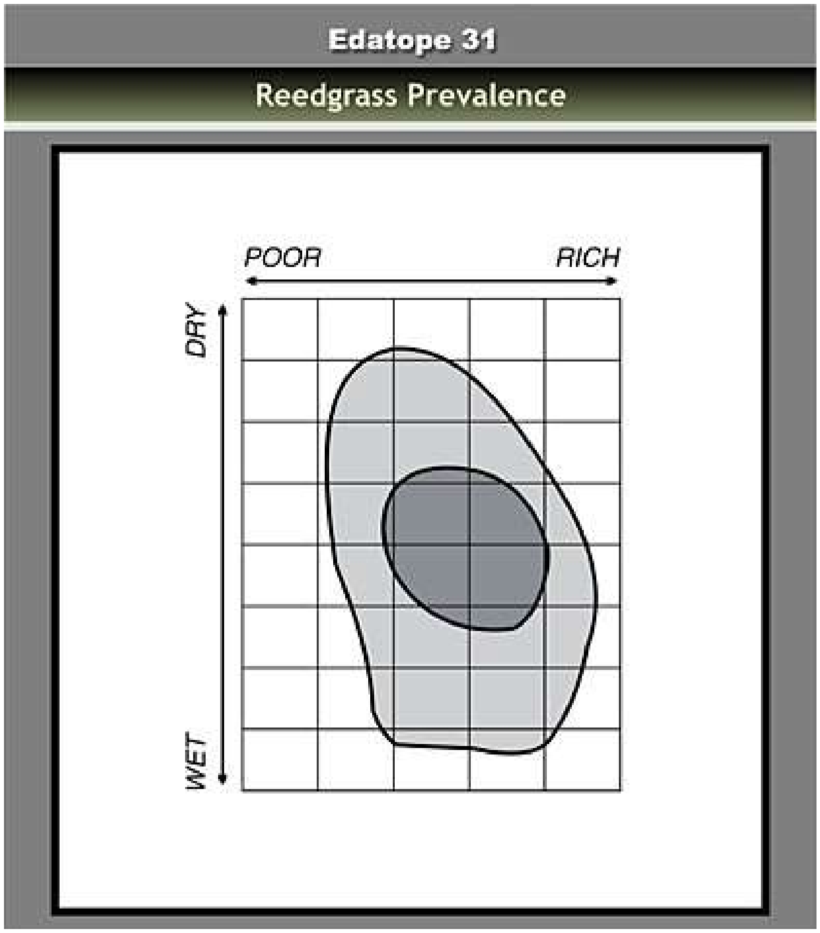

Figure 5.2. Edatopic occurrences of reedgrass.

Typically, pre-har ... lot per ha). Sampling pre-harvest vegetation condition at this low intensity may result in sampling error and relatively low confidence in results (see Section 6 for discussion on sampling).

It is particularly important that the pre-harvest assessment capture all variability in site across the planned opening. By capturing this variability, the pre-harvest assessment establishes the reforestation units which are each discrete site units within the planned opening.

In addition, the pre-harvest assessment provides the silviculturist the opportunity for input on how to and even whether to harvest. This is particularly important when either site severity or lack of deciduous propagule potential is likely to prevent reforestation success.

5.2.1 REEDGRASS

The most competitive species encountered in early seral mixedwood species management in the boreal forest is bluejoint reedgrass (*Calamagrostis canadensis*) (Bell *et al*. 1999). Reedgrass thrives on sites wetter than modal (Lieffers *et al*. 1993). These sites include all sites where the moisture regime may be classified as sub-hygric, hygric, sub-hydric and hydric (MR 6-9). In addition, reedgrass can be successful on mesic and submesic sites with medium to rich nutrient regimes.

Pitt *et al* 2015 quantitatively describe the effect of reedgrass on development of an intimate white spruce–aspen mixedwood and how interaction between reedgrass and aspen results in very different outcomes for the white spruce compared to white spruce interacting with aspen or reedgrass independently. In particular, they quantitatively demonstrate the facilitative role of aspen in supporting white spruce survival and growth in the presence of reedgrass competition.

Reedgrass will opportunistically take advantage of any competition control strategy which does not include controlling it (Man *et* al 2008) largely due to its aggressive rooting habit resulting in reedgrass more efficiently scavenging nutrients than other plant species. Furthermore, reedgrass reduces soil temperature below levels optimal for other species. Based on the invasive nature of this species, its potential for impacting reforestation success, and its wide distribution in the western boreal forest, pre-harvest assessments should identify presence and abundance (culms/m^2) in pre-harvest assessment plots. Further, pre-harvest assessment surveyors should note presence and location of any reedgrass seen within the boundaries of the surveyed block area.

5.2.2 ASPEN

As a crop species and as both a facilitator of and competitor with white spruce, aspen merits careful attention; its performance potential is important in setting the stand management objective as well as in identifying potential vegetation management strategies. Assessment at this phase needs to consider several factors relating to regeneration potential of aspen:

- Presence – determine whether or not aspen is present in the stand and conforms to the AVI descriptor. In effect, the pre-harvest assessment must confirm the mixedwood character of the stand.
- Density – if aspen is present, its density in stems per hectare must be determined. A minimum plot size of 0.01 ha (5.64 m radius circle) centered on pre-harvest assessment plots should be used to determine aspen density. As variability in aspen density or distribution increases, the number of plots should be increased to reduce risk of sampling error (see Section 5).
- Distribution – determine whether aspen is distributed evenly throughout the stand, is found in clumps, or the stand is somewhat segregated into hardwood and softwood components. An even distribution can be inferred if aspen occurs in all pre-harvest assessment plots. If aspen does not occur in all pre-harvest assessment plots, the occurrence and density of aspen in each plot should be mapped.
- Vigour – determine the age and general thrift of the aspen component of the stand. Age of aspen at breast height should be determined using an overstory tree of median diameter. Aspen thrift can be assessed using a categorical assessment scale – the first portion of the Deciduous Propagule

Potential Tool is an example. Aspen thrift and the following constraining factors have been incorporated into the Deciduous Propagule Potential Tool.

Constraints to aspen performance include:

- Site moisture regime – sites drier than mesic and wetter than sub-hygric limit aspen growth.
- Site nutrient regime – aspen grows best on medium to slightly rich nutrient regimes. Aspen growth is more constrained by poor nutrient regimes than it is by rich nutrient regimes.
- Multi-generational diseases (e.g. *Armillaria ostoyea*) that infest aspen suckers from parent root systems.
- High elevation (in Alberta, elevations above 1225 m) can be limiting to aspen growth (However, aspen can do well at higher elevations on south facing slopes if on well- drained soils).

A discussion on using pre-harvest aspen presence, abundance, and vigor data to formulate mixedwood management objectives and establishment regimes appears in Sections 2 and 4.

5.2.3 OTHER SPECIES

Many species present in an unharvested stand have potential to interact competitively with both primary boreal mixedwood crop species (Arnup *et al.* 1996, Bell *et al.* 1999). These species include:

- Herbaceous species including fireweed (*Chamerion angustifolium*), aster species (*Aster macrophyllus* and others) and lungwort (*Mertensia paniculata*).
- Woody species including alder (*Alnus crispa* and *Alnus tenufolia*), willow (*Salix* spp.), white birch (*Betula papyrifera*), balsam poplar (*Populus balsamifera*), lodgepole pine (*Pinus contorta* var. *latifolia*), beaked hazelnut (*Corylus cornuta*), honeysuckles (*Lonicera* spp.), low-bush cranberry (*Viburnum edule*) and raspberry (*Rubus ideaus*).

Presence and abundance of these species in the pre-harvest assessment plot should be recorded. Abundance of woody species should be recorded as density per hectare. Herbaceous and *Rubus* species should be recorded as percent cover in pre-harvest assessment plots.

While other species, alone, will rarely result in a competitive burden limiting to white spruce or aspen they frequently contribute substantially to overall competitive effect. Therefore competition assessments must include all potential competitors to provide a complete assessment of competition for desired tree species.

5.3 INTERPRETING PRE-HARVEST (T2) ASSESSMENTS

This section provides only a synopsis of how to predict the development of the plant community over the first 14 years after forest harvesting. Several references provide detailed reviews of both the autecology of key species and offer guidance on how they are likely to interact with tree species. These references include Arnup *et al*. (1995), Haeussler *et al.* (1990), and Peterson and Peterson (1995). British Columbia Ministry of Forests has produced a series of monographs to assist practitioners in managing competing vegetation. They are referenced by competing species complex and are available on-line at the BC Ministry of Forests website (URL is shown in References). It is recommended that these references be consulted as part of reading and using this section of the Guide.

5.3.1 REEDGRASS

A critical factor in reedgrass population dynamics is the presence of small openings in the mature (or over-mature) forest caused by windblown white spruce. Reedgrass seed often invades these spots, as they are generally moist, frequently medium to rich in nutrients and the blow down event has exposed mineral soil, a necessity for reedgrass seed success (Lieffers *et al.* 1993).

Collins (2001) describes the reedgrass disclimax phenomenon, demonstrating how invasion after harvest from pre-existing rhizomes results in site dominance by reedgrass within a season or two. Risk of a disclimax condition can be inferred from Lieffers *et al*. (1993):

> *If the grass is found in every square meter of the understory prior to logging, there will be rapid spread when the stand is clear-cut unless clones are killed using herbicides or a deep burn.*

Comeau (2007, *pers Comm.*) suggests that when cover of reedgrass prior to harvest exceeds 25%, abundant reedgrass can be expected post-harvest. Clearly, reedgrass presence in the pre-harvest stand flags a high risk of reedgrass competition in the reforesting stand. Therefore, reedgrass merits special attention in developing community management strategies. In particular, site adjustment regimes (Section 7), propagule selections (Section 8) and anticipated deployment of vegetation management treatments, especially foliar herbicide treatments (Section 6.2), may be driven entirely by reedgrass competition. Section 2 discusses developing mixedwood and deciduous management strategies in the face of reedgrass competition.

5.3.2 MIXEDWOOD MANAGEMENT WITH REEDGRASS COMPETITION

Reedgrass is a particularly challenging problem to mixedwood and deciduous management as most silvicultural treatments for reedgrass management impact aspen success. Therefore reedgrass, particularly on wetter, richer sites may limit the ability to manage for pure deciduous or deciduous leading mixedwood stands. Note that some operational evaluation of pre-harvest reedgrass control has been undertaken with limited success (Kent 2006 *pers. Comm.*).

The extent of reedgrass emergence can be checked by the presence of a vigorous aspen canopy post-harvest (Pitt *et al*. 2015, Man *et al*. 2008, Pitt *et al*. 2005, Comeau *et al.* 2005, and Pitt *et al*. 2004). Thus, choosing a mixedwood objective may be a primary means of managing reedgrass. However, reedgrass competition may limit aspen emergence particularly on sub-hygric and wetter sites (see Edatopes 1, 21 and 31; Appendix 2). In this case, or when a "pure" conifer objective is being pursued, it is important that reedgrass management treatments be anticipated in developing the silvicultural regimes as <u>timing is a critical component of most mixedwood establishment regimes</u>.

Silviculturists are referred to Dunbar *et al*. 2011[2] who provide an excellent reedgrass decision tool for use in stand establishment.

In particular, if foliar herbicide treatment is likely to be used for reedgrass control, impact on aspen can be somewhat ameliorated by ensuring treatment occurs within two (2) years after harvest. Both operational experience (Formaniuk 2006 *pers. Comm.*, Pike 2006 *pers. Comm.*) and several papers addressing either herbicide impacts on biodiversity (Sullivan *et al.* 1998) or longer term mixedwood effects of stand tending with herbicides (Pitt *et al.* 2004), suggest that earlier use of herbicides causes less long-term reduction of aspen density. **Care is warranted when applying this approach as deciduous response to broadcast herbicide use varies with timing, application rate, conditions prior to and after treatment, site factors such as moisture regime and forest floor depth, and presence of herbaceous forb species such as fireweed.**

Therefore, use of broadcast herbicide treatment to control reedgrass may or may not benefit aspen, with significant impact on meeting deciduous management objectives should aspen fail to recover.

5.3.3 ASPEN

In mixedwood silviculture, understanding the dynamics of aspen establishment is critical to success. Aspen is necessary to successful regeneration of mixedwood and deciduous stands and plays an equivocal role in the regeneration of white spruce, acting as both a commensal facilitator and a competitor. Thus, the aspen regeneration potential gathered in the pre-harvest assessment is critical, both for setting objectives and determining establishment silvicultural regimes.

Aspen reproductive potential is driven by a combination of biotic, site, and abiotic factors. Potential for this species as a crop or competitive species is directly linked to its reproductive potential. Figure 5.3 offers a conceptual approach to identifying the factors that control aspen reproductive potential and the main causal agents underlying them.

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2 https://www.google.ca/url?sa=t&rct=j&q=&esrc=s&source=web&cd=4&cad=rja&uact=8&ved=0ahUKEwjT3LqCyMfTAhWa8oMKHaHACGoQFgg4MAM&url=http%3A%2F%2Fjem.forrex.org%2Findex.php%2Fjem%2Farticle%2Fdownload%2F78%2F37&usg=AFQjCNE0S0iO8zafILCiImCQ3kxWlnjKIQ&sig2=UGMzsANF6UzjwKNQw1OJAw

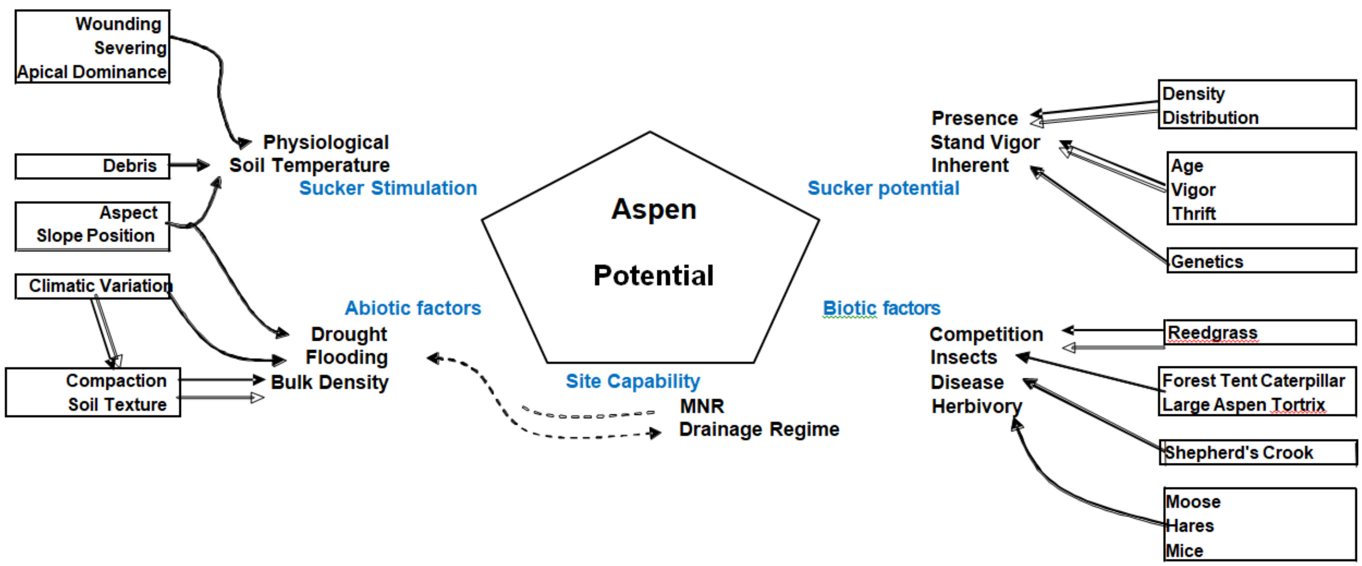

Figure 5.3. Aspen regeneration potential and causal factors (from Frey et al. 2003).

The following are some suggested thresholds for adequate establishment of aspen as a crop:

- A minimum density of 35 to 80 stems per hectare in the unharvested stand (Greene *et al*. 1999). This density is based on several papers which found aspen suckering occurred within 10 m of parent trees. Thus, a single parent tree is capable of establishing aspen on approximately 300 m^2. Therefore under "best case conditions" approximately 35 parent trees per hectare are required. Others suggest at least 50 (see also Peterson and Peterson 1995, Frey *et al*. 2003) and as many as 80 stems per hectare (Kabzems, *pers. Comm.* 2007).
- Even distribution of the stems across the proposed cutblock.
- If using the Aspen Thrift Tool (incorporated into Deciduous Propagule Potential Tool), a minimum thrift rating of moderate.
- If using the Deciduous Propagule Potential Tool, a minimum rating of "Likely".

Alexandruk (2003 *pers. Comm.*) adds the stipulation that stand age be less than 120 years.

If an aspen stand (or the aspen component of a mixedwood stand) meets the foregoing criteria, aspen regeneration potential is sufficient to meet mixedwood and possibly pure deciduous composition objective via a leave-for-natural reforestation strategy. Note that site adjustment treatments may help overcome some of the reductions in aspen sucker potential associated with older stands (Fraser *et al.* 2003).

If a pure deciduous stand is desired after harvest, the silviculturist must pay particular attention to aspen vigor and distribution, as root suckers are the only reliable aspen propagule, at present. Thus, sufficient propagules, with abundant suckering potential, are critical to successful establishment of deciduous stands (Frey *et al*. 2003, DesRochers and Lieffers 2001).

If a mixedwood condition is the objective, aspen distribution is less critical than for pure deciduous stands, but a clumped distribution of ramets may lead to clumping of clones after harvest. For mixedwood objectives, the vigor conditions outlined above remain critical.

Frey *et al.* (2003) provide an excellent review of the many external factors affecting aspen sucker regeneration. They summarize current understanding of how the physiological phenomenon of suckering interacts with several environmental and operational factors. Silviculturists are advised to read this review as it provides a clear understanding of how operational practices and overall plant community status can impact aspen establishment.

Several other factors affect aspen sucker regeneration. Identification of these factors in the pre- harvest assessment provides the opportunity to prevent some of them, and to anticipate the need to address others via site adjustment. These factors include:

- Slope position and aspect. A mid-slope position and a southerly aspect are the most favourable for aspen, while toe of slope and northerly aspects are least favourable. Frey *et al.* (2003) suggest this phenomenon may be related to temperature regime.
- Presence of reedgrass competition in the developing stand. Reedgrass competes with aspen on several levels:
    - For nutrients – reedgrass is a highly efficient scavenger for nitrogen (Hangs *et al*. 2003, Landhäusser and Lieffers 1998, Man *et al* 2008).
    - Reedgrass thatch cools soil below the range (>12°C) best suited to aspen sucker development (Landhäusser and Lieffers 1998).
    - Reedgrass root and rhizome mass may physically impede root development of other species (Comeau 2006, *pers. Comm.*).
- Water logging and soil compaction. Waterlogging of aspen roots post-harvest can substantially reduce sucker number and vigour. At the pre-harvest assessment, potential for both waterlogging and compaction (which exacerbates waterlogging) can be identified. Potential for waterlogging is driven by available moisture (moisture sub-hygric or wetter) and fine textured soils (clay or clay loam). Traffic on such sites when they are wet and the soil is not frozen (i.e. summer harvesting when soils are wet) can result in compaction of soil macropores (McNabb *et al.* 2001), which in turn can cause waterlogging and create physical barriers to aspen root penetration. Good management practice can prevent compacted soil through adjustment of harvesting practice, see Section 5.4 for guidance.
- In-block chipping. In-block chipping poses unique challenges to aspen regeneration. Hog fuel and chipper debris can insulate soil and prevent suckering (Mihajlovich, *personal observation*), and chipping activities result in greater compaction of roads and landings than whole tree logging. Conlin (2001) found aspen log decks and chip piles exuded a dark leachate that appeared to have an allelopathic effect on aspen suckering.

Silviculturists should be alert for the risk factors identified above and address harvesting activities to ensure these risks do not eventuate, especially if a deciduous or mixedwood objective is desired.

5.3.4 HORIZONTAL STRUCTURE OF MIXEDWOOD STANDS

While not an assessment consideration, the desired horizontal structure of mixedwood plant communities is critical to community establishment and adjustment decisions. Unharvested mixedwoods occur in a wide array of horizontal assemblages from intimate tree on tree mixtures (“salt and pepper”) and complex blends of three and four tree species through larger patches of aspen and white spruce. To simplify management decisions and treatment regimes, this manual uses a coarse separation of mixedwood structures into three categories – ***Intimate, Aggregated*** or ***Segregated***.

A mosaic of intimate and aggregated patches of varying sizes and shapes can be found in some areas.

Aggregated stands with sharply defined patches of aspen, or segregated stands, tend to maintain the patchy or segregated pattern after harvest provided the sucker potential is maintained. Attempts to increase aspen extent with stimulation of suckering post-harvest will be limited by the extent of preharvest aspen root penetration beyond the aggregated or segregated portion of the opening.

5.4 AT-HARVEST (T3) ASSESSMENTS

5.4.1 INTERPRETING AT-HARVEST (T3) ASSESSMENTS

Assessments at harvest focus on harvest related impacts on site conditions or on vegetation that will influence subsequent plant community development. At-harvest assessments focus on ensuring that harvest activities do not compromise silvicultural objectives. Harvesting activities can impact plant community development by impacting site quality or availability of propagules, either directly or indirectly.

5.4.2 IMPACT OF HARVESTING

The most critical impact harvesting can have on site condition is soil compaction. This is of particular importance as compaction substantially limits aspen sucker emergence. Because deciduous regeneration depends in large part on suckers as a leave for natural reforestation strategy, anything that reduces sucker emergence compromises deciduous or mixedwood reforestation objectives.

Compaction is most likely if summer harvesting occurs on loamy and finer textured soils when they are moist or wet. McNabb *et al*. (2001) identified medium to fine textured soils at or above field capacity as being most at risk of compaction by multiple passes of harvest equipment during “summer” logging.

The solution is prevention; ensure harvesting activity is stopped on areas of medium (clay loam) or finer soil texture if soil moisture is at or above field capacity. Most forest companies have developed guidelines and/or best practice manuals to deal with compaction and other site impacts from harvesting activities. Compliance with these guidelines, combined with equipment operator training, is the best way to ensure harvest activities do not jeopardize reforestation opportunities. Rude (2003 *pers. Comm.*) suggested that a quick test for compaction risk is to toss a handful of wet soil at the side a skidder or forwarder tire. If the soil sticks to the tire, conditions are too wet and harvesting activity should be stopped.

A second important harvest related effect on vegetation development is distribution of slash across the soil surface. Debris distributed across the soil surface can act as insulation. This is of particular importance on sites where aspen regeneration is desired and which are on aspects less than entirely favorable to aspen suckering (generally northerly and/or easterly aspects). By acting as insulation on these less than favorable sites, debris will hold soil temperatures below levels favorable to aspen suckering in a patchy fashion across the harvested unit. Landhäusser *et al.* (2001) found aspen growth potential (measured as assimilate production) was directly correlated with soil temperature, falling to negligible levels at soil temperatures of 5°C. Baxter (2004) recommends that logging slash be spread no deeper than 15 cm to prevent inhibition of suckering. This condition may be exacerbated by the presence of reedgrass on sites with an easterly or northerly aspect. Silviculturists may wish to consider some form of slash abatement and/or reedgrass management on northerly and easterly aspect sites with abundant debris loads. If slash abatement treatments are planned when the soil is not frozen, they should be implemented when soil is not wet to ensure that they do not cause compaction.

Optimal aspen suckering occurs at warmer (>12°C) soil temperatures (Frey et al. 2003, Baxter 2004, Fraser et al. 2002). Therefore, heavy slash loading after harvest may inhibit aspen suckering (Baxter 2004, MB Conservation 2005). Slash loading is likely to result in patchy emergence of aspen propagules due to areas of heavy slash burden more completely limiting aspen emergence than areas with little or no slash burden. Baxter (2004) and Manitoba Conservation (2005) agree that slash depths in excess of 15 cm are likely to reduce aspen sucker emergence.

Wan et al. (2006) discuss a number of factors that influence the success of aspen sucker regeneration. They make the case that root damage and exposure at harvest can substantially reduce the number of propagules. No quantitative guidance or damage thresholds are given.

Conlin (2001) found over-wintered aspen log decks and in-block chipping residues exuded a dark leachate that seemed to have an allelopathic effect on aspen suckering. This suggests a need for prompt and thorough clean-up of chipping residues and hauling of aspen prior to spring thaw.

Harvesting may also cause the water table to rise due to the removal of vegetation that acted to control water levels through transpiration. If a raised water table results in the site moisture regime becoming sub-hygric or wetter, use of mechanical site preparation to create elevated microsites may be warranted for conifer establishment. Furthermore, deciduous or mixedwood cropping objectives may be compromised.

Raised water tables are rarely apparent at time of harvest, but if conditions favorable to a rise in water table are present then further monitoring (at T4) is warranted. Conditions that can indicate a likely rise in water table post-harvest include, in order:

1. Slope position and local topography – i.e. depressional and toe slopes are most susceptible to a post-harvest rise in water table.

2. Fine soil texture – silty clay loam or finer.
3. Poor drainage regime – imperfectly drained or poorer.
4. Moisture regime sub-hygric or wetter prior to harvest.

Furthermore, the practitioner should be aware of the potential impact of other operations within the same local watershed, as the compound effect of many smaller canopy removals may cause a general rise in water table as both transpiration and interception of precipitation are reduced.

5.5 POST-HARVEST (T4) ASSESSMENTS

The post-harvest assessment serves three purposes:

1. It confirms presence of plant species likely to compete with crop species.
2. It links seasonal and longer-term climatic variation to vegetation predictions.
3. Finally, and possibly most importantly, post-harvest assessment ensures harvesting operations have not negatively impacted deciduous regeneration potential or coniferous reforestation chance.

Confirming the presence of key plant species is straightforward - abundance (density or cover) of key plants should not be assessed due to disruption of the site caused by harvesting,. Instead, the post-harvest assessment should focus strictly on confirming the presence and general distribution (clumped, dispersed patches, even) of these species on the site. If post-harvest vegetation assessments are made after there has been sufficient plant community development to demonstrate composition and the likely rate and extent of community expansion, the same methods discussed in Section 5.6 Establishment Phase Community Assessments, should be employed.

Seasonal or longer-term climatic variation can be addressed at the post-harvest vegetation assessment. The most frequently encountered influential climatic variation is sustained drought. Drought is likely to inhibit development of some species more than others; therefore, treatments to influence plant community development may be adjusted in the presence of on-going drought. The plant species by edatope charts (edatopes 20-31) may be used to infer susceptibility to drought. That is, plant species that perform well on dry (sub-mesic to xeric) sites are likely better able to tolerate seasonal or more sustained droughty conditions. As a caution, silviculturists should temper decisions to reduce treatment intensity or change treatment type with the awareness that site adjustment treatments cannot be changed or intensified once crop trees are established on site.

5.5.1 POST-HARVEST SITE IMPACT ASSESSMENTS

Post-harvest assessments are primarily useful for confirming high risk conditions identified in the pre-harvest assessment. Specifically, post-harvest assessments can confirm whether soil compaction has occurred during logging activities. If compaction has occurred little can be done to alleviate it once it occurs. While compaction can be alleviated through use of sub-soil mechanical site preparation treatments, these treatments are likely to substantially reduce sucker regeneration potential. Thus, compaction may be reduced but aspen sucker potential is not greatly improved by the amelioration treatment.

Post-harvest assessment can determine if slash loads pose a threat to aspen emergence or attainment of conifer density/stocking. Slash loading can be reduced using either piling rakes or shear blades on crawler tractors. If slash abatement is undertaken, silviculturists should ensure that treatments do not unduly expose or damage aspen roots (Section 5.3). During slash abatement treatments, care, similar to that used in harvest operations, should be taken to prevent soil compaction.

A post-harvest assessment will also provide an opportunity to assess how overstory removal has affected water table level. Conditions that indicate a likely rise in water table post-harvest include:

1. Fine soil texture – silty clay loam or finer.
2. Poor drainage regime – imperfectly drained or poorer.
3. Moisture regime sub-hygric or wetter prior to harvest.
4. Most importantly slope position and local topography – i.e. depressional and toe slopes are most susceptible to a post-harvest rise in water table.

5.6 ESTABLISHMENT PHASE (T6) ASSESSMENTS

Plant community assessments during the establishment phase are critical to success. During this stage of plant community development, herbaceous competition (including reedgrass, fireweed, , and aster species) and raspberry develops more quickly than larger woody species. Therefore, herbaceous species exert the greatest competitive constraint on crop tree species (Bell *et al*. 2000, Wagner 2000). Landhäusser and Lieffers (1998) and Man *et al* 2008 found reedgrass competition significantly reduced aspen growth. Similarly, herbaceous competition has been found to significantly slow the growth of white spruce (Eis 1981, Cole *et al.* 1999, Man *et al* 2008). Balandier *et al*. (2006) discuss competition based on the life form of competing species. They describe early competition as primarily between roots; life forms with high specific root length (i.e. root length per unit weight) and erectile foliage (like reedgrass) compete best for soil resources, not light. Man *et* al 2008, Comeau *et al*. (2005) and Pitt *et al*. (2004, 2005) found aspen suckers reduced cover of reedgrass during and after the establishment phase.

The establishment phase is the most dynamic stage in plant community development. Harvesting causes an increase in soil temperature, increased availability of water and a flush of soil nutrients (Titus *et al*. 2006). This flush of available nutrients contributes to dynamic forest plant community development. The overarching influence of herbaceous competition at this stage of plant community development is driven by the rapid emergence and growth of herbaceous species immediately after harvest disturbance. In much of Alberta's boreal mixedwood forest the rapid onset of herbaceous vegetation is magnified by the disclimax nature of reedgrass – its presence in the understory prior to harvest facilitates its rapid colonization of harvested areas via both rhizome and seed reproduction.

An especially critical aspect of plant community management in this phase of community development is the impact of herbicide treatments on deciduous tree species in the community. Herbicide treatments made within two (2) growing seasons after harvest greatly reduce the abundance of deciduous trees in the plant community and change species composition within the deciduous stand component but do not eliminate deciduous trees from the eventual forest stand (Pitt *et al*. 2004 and Greenway *unpub*). Herbicide treatments made at this stage of community development are likely to shift dominance among deciduous trees from aspen to balsam poplar or birch. Broadcast foliar herbicide treatments made more than two (2) growing seasons after harvest may jeopardize the ability to maintain a deciduous crop tree component in the new community unless application methods or treatment areas are adjusted to ensure maintenance of a deciduous crop (see Section 4).

Size and height relationships between crop trees and competing vegetation are important considerations when assessing the plant community at this stage of development. Height relationships translate fairly directly into an understanding of competition for available light. However, size relationships can also offer some insight into competition for nutrients and water. Thus an assessment method that integrates cover adjacent to subject trees and the relative size of crop tree seedlings (or suckers) and competing plants may better integrate all aspects of competition into an approachable management interpretation.

See Section 6 for guidance in developing sampling regimes. The first step in accurately assessing community development is to stratify the community (each opening or cutblock) into homogeneous units based on composition and size of the plants making up the community.

Stratification can be done by ocular assessment; however, with inexperienced assessors or when trying to stratify to relatively high precision it is advised that quantitative methods of stratification be used (see Section 5.6). Each vegetative stratum identified should be treated as a separate plant community for assessment and interpretation purposes.

Once the opening has been stratified, data should be collected via crop tree centered sampling points. Sampling intensity and plot locations should be based on the size of area sampled and the estimated variability in vegetation across the area (see Section 6). Ensure sampling intensity is adequate to describe the community being assessed with reasonable certainty and without bias. Both are important as they ensure prescriptions and management actions are repeatable and defensible.

5.6.1 DECIDUOUS CROP STATUS

The most crucial establishment phase assessment for communities with a deciduous or mixedwood composition objective is the status of the deciduous crop. Deciduous condition during this phase is the critical determinant of likelihood that deciduous objectives will be met. Said plainly, ***if deciduous condition appears inadequate to meet long-term objectives, then objectives should be adjusted***. Adequacy of the deciduous crop depends on the desired crop species population and the management objective. The following factors should be considered in assessing adequacy of deciduous crop population:

- **Deciduous objective.** Density should be high enough that self-thinning and other stressors (see Section 4) are unlikely to reduce density below desirable levels. Estimates of aspen densities assuring success as a crop range from 30,000 stems per hectare (Kabzems 2007 *pers. Comm.*) through 75 000 (Greenway 2003 *pers. Comm.*) to 100 000 stems per hectare (Lieffers 2002 *pers. Comm.*). If full stocking is desired, distribution should be uniform across the reforestation site; that is, deciduous saplings must be present across the entire site by year two after harvest. In effect, the aspen crop should be approaching full site occupancy within two or three years of harvest.

- **Deciduous leading objective.** Deciduous density should be similar to that necessary to meet a pure deciduous objective. However, distribution is somewhat less critical as open or void areas in the deciduous crop tree distribution may be filled with coniferous seedlings to ensure site occupancy objectives are met.
- **Coniferous leading or coniferous objective.** Deciduous distribution requirements are less stringent as deciduous distribution can be variable with coniferous seedlings eventually occupying areas that do not contain deciduous saplings. Deciding on an acceptable or optimal deciduous density in these circumstances presents a challenge. Deciduous saplings pose substantial competition to coniferous seedlings while offering nurse benefits to those same seedlings. Further, deciduous saplings in mixed species communities are subject to many of the same density reduction pressures that act to "self-thin" aspen in more pure aspen stands. Therefore, when planning desired aspen density in these communities, the silviculturist should consider:
    - Risk of frost or winter injury damage to conifers – if this risk is substantial, higher deciduous densities might be desirable. (Section 9)
    - Risk of browsing or other damage to crop trees – if this risk is substantial (for example, it is the "high" phase of the moose population cycle); higher deciduous densities might be considered. However if the snowshoe hare population cycle is high, lower deciduous densities might be preferred as there is some evidence to suggest that higher deciduous densities will provide hares and other browsers better cover and they will therefore move further into openings attacking both deciduous and coniferous seedlings.
    - The broader array of facilitative and competitive interactions between coniferous and deciduous seedlings; see Section 4 for discussion and summary of aspen-white spruce interactions.

5.6.2 ASSESSING DECIDUOUS CROP STATUS

Assessments of deciduous crop status should combine density and distribution. Both of these are readily drawn from a grid survey (e.g. survival survey, early regeneration survey, etc.) provided the survey uses fixed area plots and deciduous stem counts are made. If a grid survey is not undertaken a combination of a visual overview (preferably from above) that describes distribution and allows stratification with a density assessment will suffice. Density assessments should use either fixed area plots and stem counts or, if made visually, should be frequently checked against stem counts to ensure accuracy and repeatability of results.

5.6.3 LIGHT-BASED COMPETITION INDEX

This sampling method is premised on use of a light-based competition index (Comeau 1993) to integrate conifer crop tree status and community condition (see Section 5.8). This method was chosen for T6 – Establishment Phase assessments because it emphasizes herbaceous competition. In fact, this competition index tends to underestimate the competitive influence of woody plants on conifer crop trees (Comeau

1999 *pers. Comm.*). This index is easy to apply in the field as it utilizes visual estimations of cover on crop tree centered plots. Ter-Mikaelian *et al*. (1999) compared the repeatability and accuracy of visual cover estimates to quantitative evaluation of Photosynthetically Active Radiation (PAR) demonstrating that visual estimates of cover – provided they are done by the same assessor (or presumably if multiple assessors maintain calibration with each other) – are just as accurate and repeatable as quantitative assessments of PAR. Wang et al. (2000) found similar results comparing visual estimation of competition to three different quantitative measurements. Details of how to apply a competition index that interprets plant community interactions to a competitive status can be found in Comeau and Braumandl (1991).

To apply the competition index, the assessor needs to quantitatively describe the plant community in a 1.26 m radius circle centered on the conifer crop tree. The following steps outline how to do this. A sample tally card for collecting this information is found in the Comeau Competition Index Tool. The tally card is based on an Excel spreadsheet so it can be readily converted for use in handheld computers, tablets or personal data assistants (PDAs). Data collection steps are as follows:

1. Locate the conifer crop tree seedling closest to the plot location determined by the sampling regime used (i.e. grid point or sequential survey location spot).
2. Record the species of the conifer seedling and measure its total height to the nearest centimeter.
3. Assess the hardwood component of the emerging community in the 1.26 m radius plot as follows:
    - Record deciduous species in order of dominance.
    - Measure the modal height of the deciduous community to the nearest centimeter.
    - Estimate the total ground cover of the deciduous layer. For covers less than 5% estimate to the nearest one (1) percent. For covers between 5 and 100% estimate cover to the nearest 5 %.

The plant community, excluding the dominant deciduous tree species, surrounding the seedling should be broken into layers based on height; a minimum of one layer and a maximum of three layers are suggested. Note that layers are not based on species so a single layer can have multiple species in it and a single species can occur in multiple layers. For each layer identified record the following:

- Deciduous layer containing deciduous crop trees only, as per Step 3.
- Dominant plant species (one or two species).
- Modal height of the layer to the nearest centimeter.
- Ground cover of each layer expressed as percent, with 100% equaling total cover. For covers less than 5% estimate cover to the nearest one (1) percent. For covers between 5 and 100% estimate cover to the nearest 5 %. Cover is best estimated using relatively small assessment units; split the circular assessment plot into four discrete wedge-shaped pieces each representing ¼ of the assessment plot. Then use one of the following two methods to estimate cover:
    1. Estimate total cover, by layer, in each wedge and average the result to get cover of that layer across the entire plot.

2. Estimate the proportion of 25% cover, by layer, in each wedge (i.e. a layer that fully covers a wedge gets 25% cover) and total the results to get cover or that layer across the entire plot.

Note that total covers (i.e. cover of all layers combined) somewhat in excess of 100% are not uncommon at this stage of plant community development.

Plant community assessment and interpretation at T6 is the first-time individual crop trees are present and subject to assessment. The presence of conifer crop trees drives the quantitative assessment. With quantitative assessment, there is an opportunity to set pre-determined limits to competitive interactions above which vegetation management treatments will be deployed. Called thresholds, these triggers to treatment are discussed prior to developing interpretive methods for T6 assessments (Section 5.7). Note that thresholds drive T7 - Composition and Performance community assessments, as well.

5.6.4 STAND LEVEL ESTABLISHMENT ASSESSMENTS

Remedial adjustments to prevent or offset silvicultural failures are more likely to succeed the earlier in the community development process that they are deployed. Promptness ensures remedial or re-treatments are less burdened by being behind the general thrust of community development. Therefore, establishment vegetation assessments might be linked, in time, implementation, or both, to a broader assessment of community development and silvicultural success. For example, competition assessments might be linked to survival assessments.

Deciduous crop trajectory is generally evident within three or four years of harvest unless impaired by catastrophic factors like insect or disease outbreaks, untoward weather events, or similar stochastic influences. Therefore, stand level assessments at establishment provide timely insight into the likelihood of deciduous success. There are few interventions available to enhance deciduous success after stand initiation treatments are complete; so remedial treatment is unlikely to be feasible. However, if the probability of failure in the deciduous crop is unacceptably high, remedial treatments designed to bolster stand density or occupancy with coniferous plantings may be deployed. Prior to deploying coniferous remedial treatments, silviculturists should re-define stand level objectives based on density and spatial distribution of deciduous crop trees, site type, and need for/feasibility of remedial vegetation management or site adjustment treatments.

For example, if gaps or voids in deciduous crop tree distribution are found in a community slated for a deciduous leading mixedwood stand on slightly wetter than modal sites (i.e. sub-hygric site), the silviculturist should diagnose the cause of gaps and may choose to revisit the compositional objective for the community before making remedial treatment prescriptions. If the gaps in deciduous density are due primarily to an overabundance of soil moisture, the silviculturist might choose to revise the objective to conifer leading condition and employ remedial site adjustment treatment to create raised microsites. However, if the primary cause of gaps was diagnosed as reedgrass competition the silviculturist might choose to integrate fill planting of coniferous seedlings with pre- or post-planting reedgrass control treatment using herbicides, after changing the stand objective to reflect a more conifer dominated outcome.

Silviculturists should determine what proportion of area not containing deciduous saplings would mean the deciduous objective is compromised. For example, a threshold of 50% would infer that reedgrass dominating half or more of the opening area would likely be cause for revisiting a deciduous-leading objective, as there are no operational treatments suitable for releasing deciduous species from reedgrass competition.

Stand level vegetation assessments should assess the variability of the developing community using the following criteria:

- Uniformity of species composition and presence of areas where composition is dramatically different. In particular, silviculturists should be on the lookout for pockets or clumps where reedgrass is beginning to dominate the plant community.
- Deciduous crop tree density and distribution should be assessed for uniformity with particular emphasis on the desired compositional outcome.
- Coniferous crop tree density and distribution should be assessed with emphasis on compositional objective(s) and survivability. Conifer survivability and growth potential can be more finely assessed using the herbaceous competition index assessment described in Sections 5.6 and 5.8.

The Vegetation Management Process Tools for T6 – Establishment and T7 – Composition require the practitioner to input minimum densities and extent of deciduous needed to achieve the longer-term composition objective (and regeneration standards). Practitioners should set these minima prior to assessing vegetation and likely should set these standards with assistance from the management planning forester responsible for their long-term, strategic forest management plan.

5.7 THRESHOLDS

Thresholds are defined as “the point at which a physiological or psychological effect begins to be produced” (Merriam-Webster 2005). As used in this context, thresholds are pre-determined quantitative hurdles used to determine when to intervene in plant community development.

Thresholds are generally based on biological parameters, either parameters measured directly or arising from a tool which integrates biological parameters.

Thresholds are not independent of management. Thresholds are quantitative representations of a silviculturist’s acceptance of plant competition to crop species (that is, levels of competition below the threshold are tolerated whilst levels of competition at, or above the threshold trigger intervention). In this setting, thresholds do not meet the definition given for two reasons:

- Silviculturists generally accept some level of competition in the plant community being managed as the financial and, in the case of white spruce and aspen, biological cost of complete removal of competition below “true” thresholds is too high.
- Mixed species stands must, almost by definition, accept some level of inter-specific competition as part of attaining their mixedwood status.

Another key factor in managing plant communities is recognizing the existence of critical periods of competitive interaction. Wagner *et al.* (1999) discuss critical periods in the context of vegetation management to reduce competition. That is, the time period within community development when competition between desired (or crop) species and other species is most influential in determining the longer-term performance trajectory of crop species.

Wagner (2000) offers guidance in setting thresholds for young conifers – this guidance may be generalized to address tolerant (or intermediate) and intolerant tree species. Figure 5.4 generalizes individual tree response to competition. It shows three “biological thresholds”, the precise location of which will be related to the tolerance of the tree species considered. Figure 5.5 illustrates critical periods for some eastern boreal species including intolerant (jack pine and red pine), intermediate (black spruce) and tolerant (white pine) species.

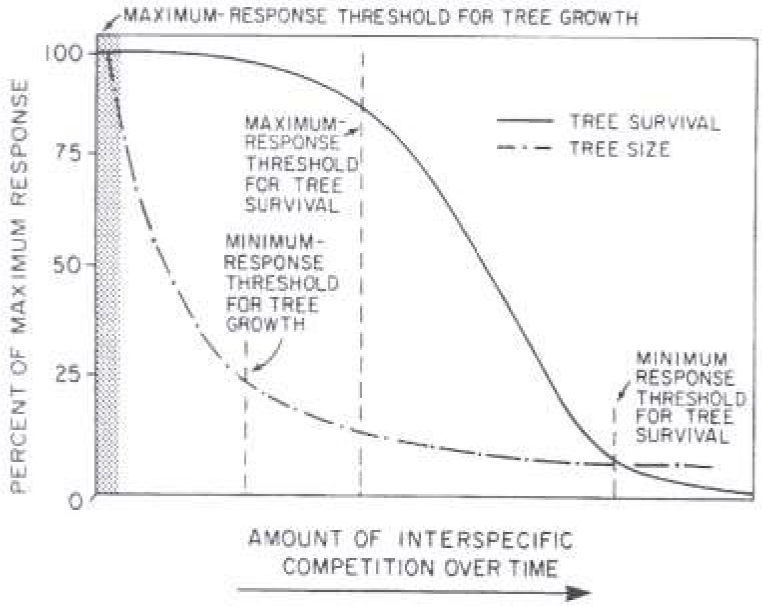

Figure 5.4. Hypothetical relationship between inter-specific competition, tree survival and volume growth. The maximum- and minimum-response levels for tree survival and growth occur at different levels of interspecific competition. The maximum-response threshold for tree growth occurs in the shaded region under nearly vegetation-free conditions (From Wagner 2000).

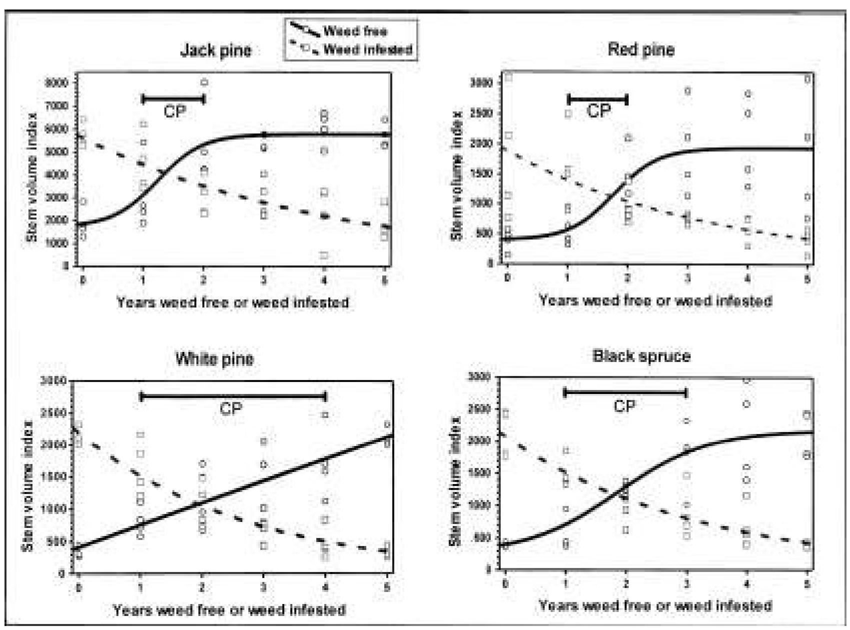

Figure 5.5. Critical periods for four eastern boreal conifer species (From Wagner et al. 1999, Wagner 2000).

5.7.1 SETTING THRESHOLDS

Silviculturists should set thresholds for white spruce competition at establishment (T6 – T7) with the facilitative commensal and competitive nature of spruce-aspen interaction in mind (Section 4). The competition assessment models provided in the Guide (Comeau Competition Index Tool, Lorimer's Competition Index Tool, and Light Threshold Tool) give practitioners the ability to ***estimate*** the idealized biological "cost" of competition in white spruce plantations.

Practitioners must understand that competition models estimate impacts of competition as if it were the only factor limiting crop tree success (survival and growth). That is not the case as numerous other factors act to limit crop tree success. Therefore response to operational treatments is unlikely to be as "large" or as clearly defined as shown in the models. In particular, growth responses are likely to be less dramatic than suggested by the models as many factors act to limit growth. These factors include:

- Less than complete treatment success. Herbicide treatment efficacy can be impaired by climatic conditions (D'Anieri *et al*. 1985) and motor manual treatments may require repetitive treatment to give "full" control (Biring *et al*. 1996).
- Climatic factors such as drought or very wet years can result in less crop tree growth than optimal.
- Competition rebound from treatment may be dramatic if seedbanking species are present prior to treatment (Dewey 1994).
- Crop tree growth may be impaired by other stress factors including: insect attack, disease, herbivory, and mechanical damage associated with climatic events like wind or ice storms.
- There is considerable evidence that soil nutrient levels are limiting to tree growth – in the absence of competition (Pitt *et al*. 2005 and 2004, Titus *et al*. 2006, Hangs *et al*. 2003 and 2002).

Thresholds can be readily set during the early phases of the reforestation cycle as there is substantial short to medium term data to support the predictions of the various competition indices recommended with this Guide. Generally the shorter the term of the projection the more likely it is to be quantitatively correct. As the term of a projection lengthens, silviculturists should treat competition indices and associated thresholds as offering relative or comparative predictions of outcomes. Figure 5.6 (Wagner 2000) offers the silviculturist a conceptual model for setting thresholds based on growth responses.

It is best to set thresholds prior to collecting field data as this reduces the likelihood of bias in setting the threshold. Silviculturists are advised to read the referenced material cited in this and other related sections to better understand the biological principles underlying the community assessment and competition integration models presented here.

Clearly the risk amelioration afforded white spruce seedlings by aspen is an important consideration in determining the need for, type, and timing of competition management interventions. Further, silviculturists ignore the influence of herbaceous competition on early community development at their peril. Unfortunately, quantifying the "benefits" of the facilitative aspect of the aspen–white spruce relationship is more difficult for a number of reasons:

- The risks ameliorated vary in frequency, likelihood of occurrence, and severity from place to place and may also be changing with climate change.
- Susceptibility to risk factors, both in extent and severity, vary with growing conditions and other silvicultural treatments.
- Competition models do not quantify the separate impacts of woody and herbaceous competition.

Thus, practitioners must, at present, set thresholds based on both quantitative effects data and an understanding of the risks faced in their area of operation.

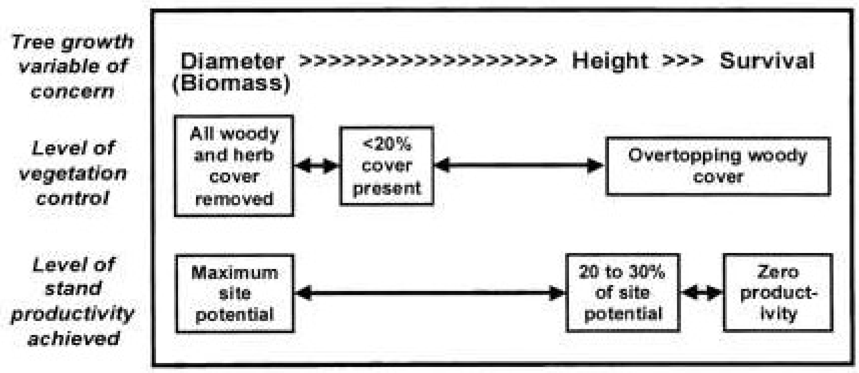

Figure 5.6. Schematic representation of the relationship between tree growth objective, target level of competition control, and level of stand productivity achieved (From Wagner 2000).

Risk assessment can be further refined in the case of frost damage, as topography, microsite, and seedling size all contribute to summer frost damage. A more detailed discussion of risk of summer frost damage appears in Section 10. Consult this section if this discussion suggests a risk of summer frost damage exists. Regions with a high risk of summer frost injury can be found on the Environment Canada Risk of Late Spring Frost Map found at: http://www.nrcan.gc.ca/earth-sciences/geography/atlas-canada

If most of the active buds of seedlings in an area are below the projected frost line, the risk of injury may outweigh the benefit of competition reduction. Location of the projected frost line can be estimated by looking for areas without air drainage (Figure 5.7). The frost line is the vertical point in these areas where frost will find a way out and no longer be trapped.

A significant challenge in setting thresholds in mixedwoods is that most crop tree response assessments focus on coniferous crop tree species (at least in the boreal environment) to the exclusion of deciduous crop species, and that longer-term response data is lacking. Thus, there is a clear need for data demonstrating trade-offs in crop volumes between deciduous and coniferous components of mixedwood stands under a variety of woody and woody-herbaceous competition conditions. These data would provide a more quantitative basis for evaluating the trade-offs inherent to managing the complex facilitative–competitive relationship between white spruce and aspen.

There is also a dearth of data allowing prediction of the longest-term effects of competition – that is, we have little ability to predict competition effects to rotation age from the end of the reforestation period. Two factors drive this lack of data. First, most of the mature North American boreal forest is still of "natural" origin and most of the northern European boreal forest is managed on a much smaller scale. Second, there is considerable time for stochastic factors to influence the final outcome when projecting yields (or any other outcome) at age 60 to 120 years based on conditions at age 15 or less. Therefore, caution should be used in giving credence to quantifying predictions of final harvest volumes based on end of reforestation phase stand conditions.

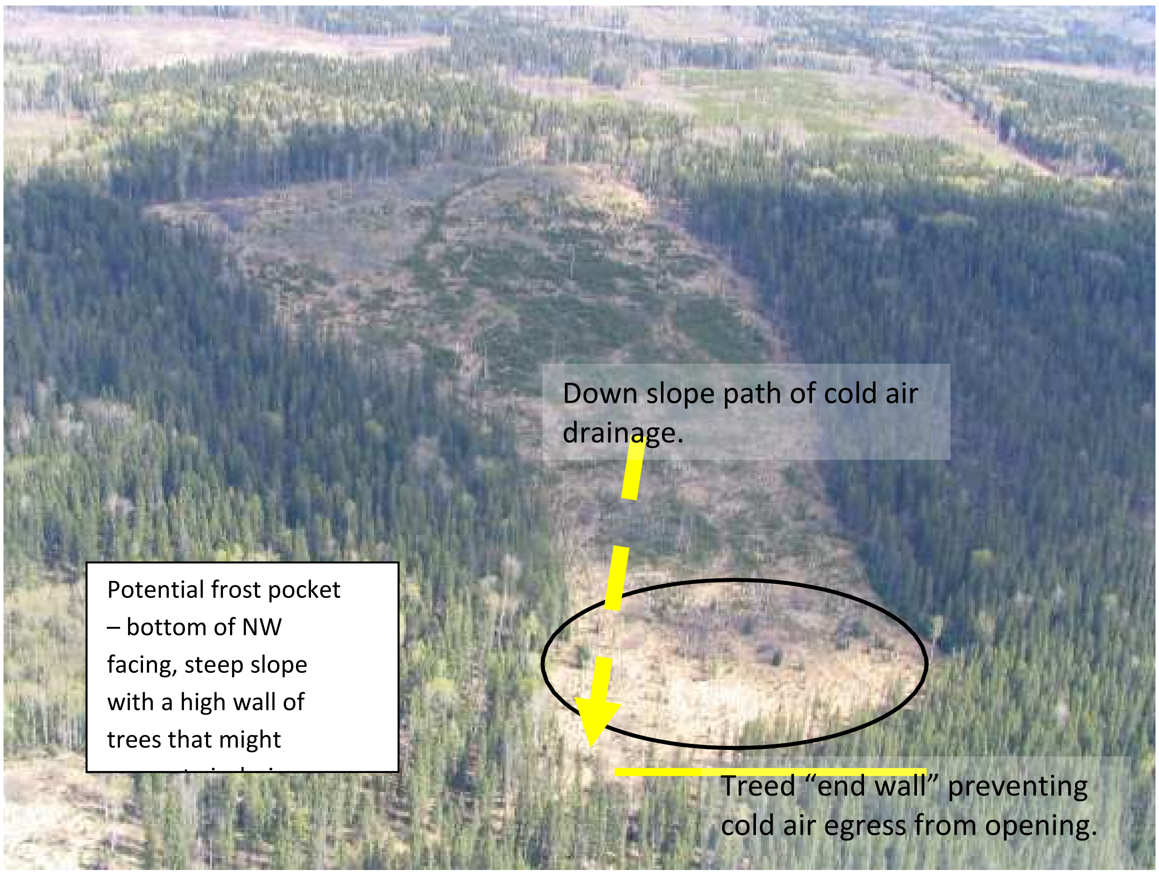

Figure 5.7. Potential frost pocket location (©Incremental Forest Technologies Ltd. 2005)

5.8 INTERPRETING ESTABLISHMENT (T6) ASSESSMENTS

Establishment is the phase of community development where the broadest array of composition possibilities exists. Compositional options are broadest if sufficient coniferous propagules have been deployed and aspen suckering is abundant.

This is also the phase where the facilitation value of aspen to white spruce is highest. White spruce is most susceptible to winter injury during the first three years after planting (McDonald 2004 *pers. Comm.*, Formaniuk 2004 *pers. Comm.*) and will remain susceptible to frost injury until the majority of active meristems are above the frost line. Also, there may be a nutrient cycling benefit associated with aspen leaf litter. However, Hangs *et al*. (2002) demonstrate that aspen competition interferes with nitrogen uptake by white spruce seedlings. It is important to note that the facilitation of white spruce by aspen comes with a price in white spruce growth reduction due to competitive interactions between these species (Coopersmith and Hall 1998).

Given the complexity of plant community interactions at this reforestation phase and the equivocal relationship of aspen-white spruce interactions, quantifying community interactions with aspen-spruce interactions addressed separately and within the overall assessment is prudent. Therefore careful interpretation of the data collected is essential to understanding this complex interaction. The competition index used at this stage of community development is driven by light. In effect, the competition index value acts as a surrogate for photosynthetically active radiation (PAR) reaching the white spruce seedling. By understanding the response of spruce seedlings to light the impact of competing species on white spruce growth can be interpolated from the competition index value. Note that the competition index provides a means of interpolating reduction in white spruce seedling growth from optimum conditions. In forest settings, a number of factors (competition, climate, site quality) drive seedling growth.

Therefore, the competition index should not be treated as an absolute predictor of growth but rather as an aid in understanding the relative competitive status of seedlings.

To interpret and assemble the data, use the Comeau Competition Index Tool. To use the calculator, data from each plot are inserted in the appropriate sections of the calculator, as shown in Figure 5.8.

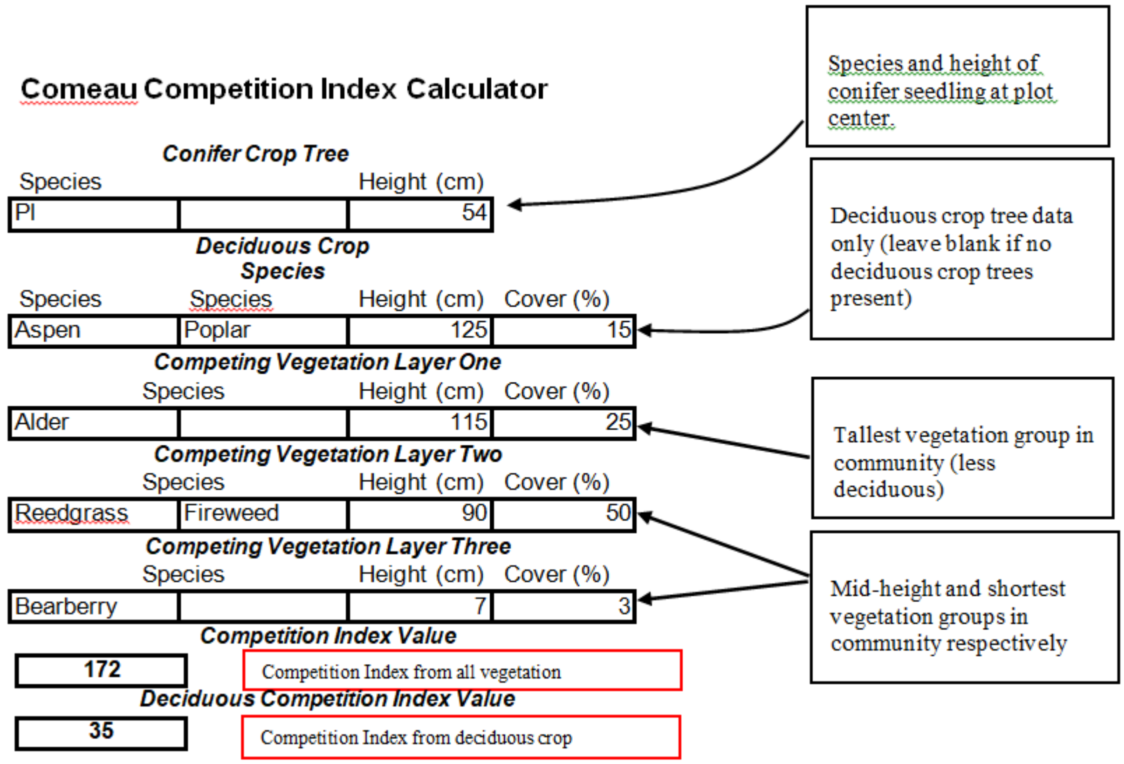

Figure 5.8. Comeau Competition Index Calculator (derived from Comeau 1991).

For each plot, competition index is calculated from cover and height data. The average values of total and deciduous competition are then tabulated, by stratum. The following stepwise approach to interpretation of competition index values is drawn from Comeau and Braumandl (1991) and treats all competition the same – essentially as herbaceous competition.

By locating competition index values on Figure 5.9, the practitioner can estimate maximum impact of competition on white spruce seedlings. It is suggested that practitioners set a threshold value for competition index based on this chart, the compositional objective for the plant community being managed, and the practitioner's perception of the need for aspen nurse crop values. Note that aspen facilitation diminishes with time; Section 4.3 (Tables 4.2a and 4.2b) summarizes facilitative and competitive interactions. It is important to note that survival on the chart below does not consider the facilitation value of deciduous trees, instead it is an idealized survival based entirely on seedling response to competition. Similarly, growth is a percent of optimum; practitioners should recognize that trees in a "wild" environment seldom attain optimal growth rates as other limiting factors (e.g. drought, moisture stress, herbivory, and nutrient deficiency.) act to reduce growth below optimal levels, even in the absence of competition.

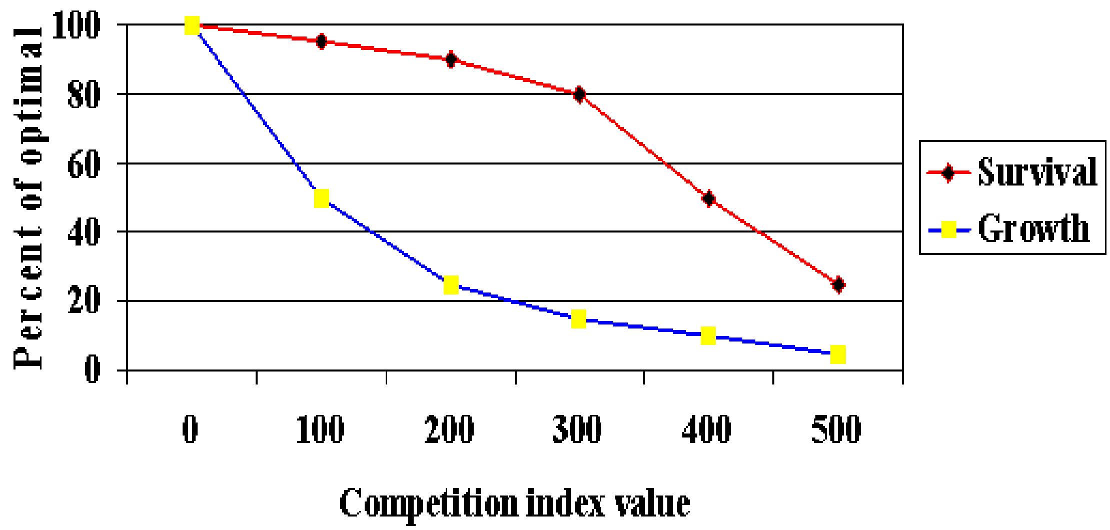

Figure 5.9. Relationship of competition index values to optimal growth (after Comeau 1992).

For communities where the management objective is a “pure” conifer condition, using the average Total Competition Index value will provide a clear understanding of the cost of competition to seedling performance.

For mixed communities, the practitioner should consider both Total and Deciduous Competition Index values; the difference between these values shows the impact of competition that is not part of either crop. Thresholds for managing mixed species objective stands should consider the balance in composition desired. For example, one might tolerate less competition in a conifer- leading stand than in a deciduous-leading stand. Thresholds should also consider the age of the community, as there is often more deciduous recovery following broadcast glyphosate herbicide treatments made within two years of harvest.

The T6 Establishment Phase – Vegetation Management Decision Process provides a platform for integrating thresholds, Comeau Competition Index values, deciduous crop objectives, and treatment methods. For detailed guidance in how to use the process see the T6 Establishment Phase – Vegetation Management Decision Process Fact Sheet.

5.9 TREATMENTS AT ESTABLISHMENT (T6)

Competition in the Establishment phase may be primarily herbaceous species or may be mixtures of deciduous tree, shrub and herbaceous species. Treatments at this phase generally pose a significant risk to deciduous crop species. Additional considerations at the establishment phase include facilitative influence of aspen on spruce and on limiting expansion and spread of reedgrass. Where the regenerating stand is less than three years old, the potential for aspen recovery is greater following treatment. After three years, there is increased risk to aspen from treatment particularly for intimate mixedwood objectives where there is less opportunity to stratify an opening to target aggregated patches. Careful integration of objective and likely future competition is thus required at the establishment phase.

Figure 5.10 provides a generalized decision flowchart for treatment at establishment phase. Application of the decision flowchart assumes use of competition measurement tools and thresholds described in this guide for establishment phase assessments. Additional flexibility on treatment options, such as broadcast herbicide, is available for conifer and conifer leading objectives for stands less than three years old. The silviculturist, then, may be confronted by a choice between maintaining the facilitative benefit of aspen to white spruce and not compromising the long-term availability of aspen for mixedwood compositional objectives.

It is recommended that practitioners also become familiar with the post-establishment phase (T7) options as treatments are largely limited to spot or patch herbicide treatments if a mixedwood composition is desired.

As described for the post-establishment phase, if herbaceous competition is substantial it may be necessary to change objectives. For example, if a combination of reedgrass and deciduous tree competition is limiting white spruce survival and growth below acceptable limits, it might be appropriate to change objectives to a more deciduous oriented outcome. Another example is a situation where heavy reedgrass is limiting success of all tree species and a mixedwood composition is desired. In this situation changing objectives to a conifer condition would facilitate herbicide tending and fill-planting with coniferous seedlings.

Establishment

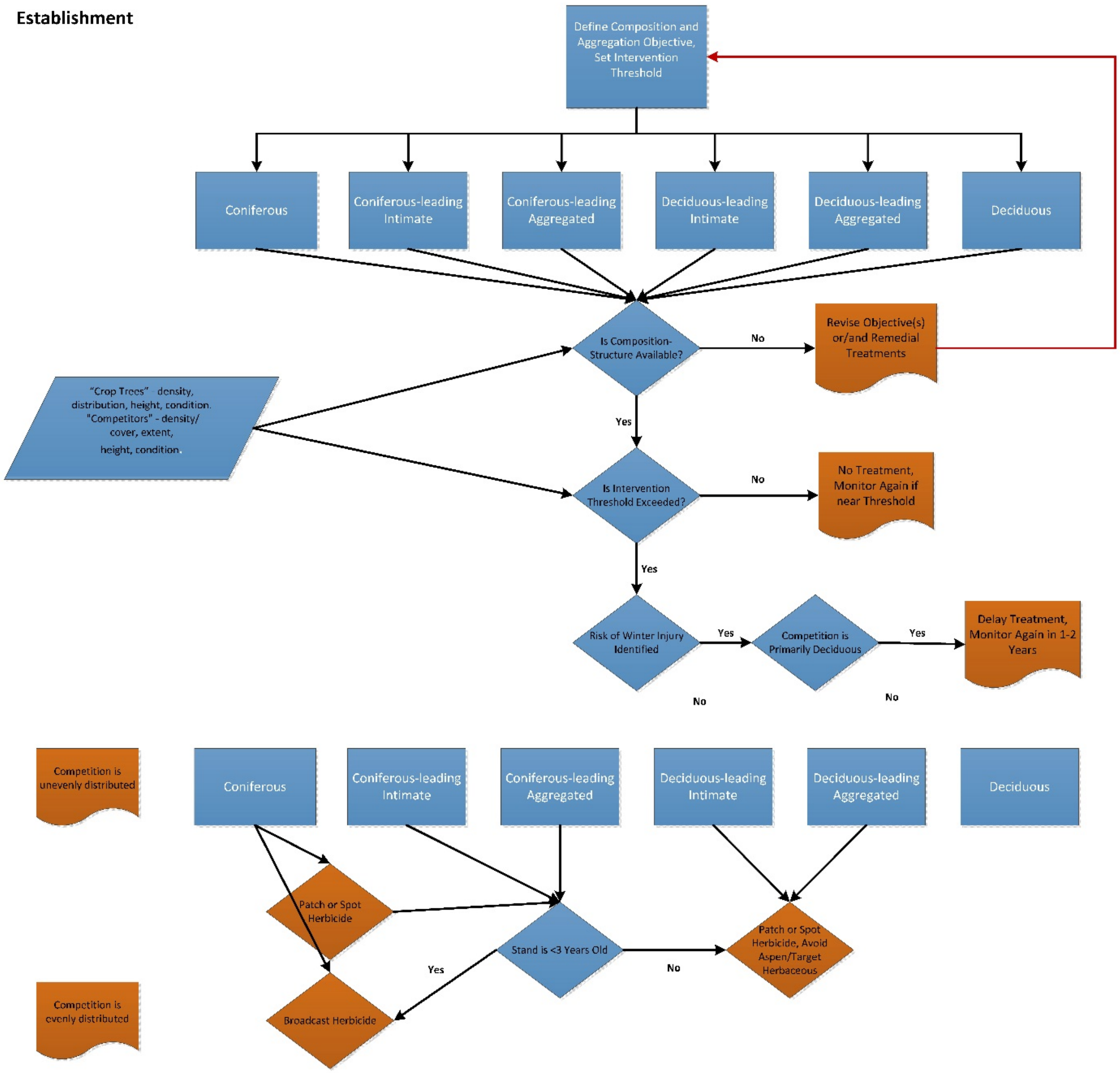

Figure 5.10. Generalized decision flowchart for treatment at establishment phase.

5.10 POST-ESTABLISHMENT (T7) ASSESSMENTS

Development of the plant community stabilizes and moves toward a condition reflective of the mature forest in the Post-establishment (5 to 12 years old) phase of development. The impact of opening the forest canopy is diminished and trends in longer-term community assembly become apparent. Silvicultural intervention can adjust but not set composition. Conversely, treatment at this phase can have a substantial impact on white spruce growth potential – a function of white spruce being an intermediate tolerant species.

Over time community composition and trajectory are clearly evident. Treatments can reinforce an existing trajectory or somewhat alter a compositional objective but they are not able to produce the massive alterations in the assembly of the plant community induced by treatments in the Establishment (T6) phase.

Focus on management objectives is important for several reasons. First, treatments made later in the community assembly process have a more lasting impact on composition (Greenway *unpub.*, Pitt *et al.* 2004). Second, herbaceous vegetation is no longer dominant and competitive interactions are more complex, i.e. woody plant species are competing with each other as well as with herbaceous vegetation. Third, management objectives must guide species extent and compositional complexity of mixedwoods. Fourth, relationships between white spruce and aspen are moving toward a more competitive and less facilitative state.

At this phase of plant community development, treatments will focus on shifting composition toward management objectives. Therefore, community assessments need to determine if interactions between crop species (i.e. spruce and aspen) are competitive, facilitative, or both. Early on woody species competition may contribute substantially to overall competition burden while herbaceous competition (particularly from reedgrass) continues to limit crop tree growth. Therefore, both woody and herbaceous competition must be addressed. Later reedgrass may compete with both tree species but the community is moving toward a state where reedgrass will be excluded so herbaceous competition is unlikely to drive vegetation management decisions.

Choice of competition assessment method in this phase is dictated by the nature of competition. If the competition is comprised of a mixture of woody and herbaceous species Comeau's Competition Index Tool is likely the best choice; if competition is largely between woody species Lorimer's Competition Index Tool is likely the better choice.

5.10.1 HERBACEOUS VEGETATION ASSESSMENT

Competition from herbaceous or/and younger woody species should be assessed using the light-based Comeau Competition Index Tool discussed in Section 5.8.

5.10.2 WOODY VEGETATION ASSESSMENT

If aspen and spruce dominate the plant community herbaceous competition can be ignored. In these circumstances a simpler approach to assessing the white spruce–aspen interaction can be employed.

Two methods of assessing white spruce–aspen interactions are available in this Guide. The nature of the interaction between white spruce and aspen determines which tool to use. If aspen consistently overtops the white spruce and clearly dominates the site, the Light Threshold Tool should be used. If the white spruce and aspen form a more co-dominant mixture, Lorimer's Competition Index Tool should be used. The tools are differentiated into the foregoing uses because the Light Threshold Tool is derived from an aspen density by diameter table developed by Comeau (2003) to estimate understory light. It uses aspen size and diameter to calculate light availability to white spruce seedlings or saplings found within or below an aspen canopy. Lorimer's Competition Index Tool is a more generic tool designed to compare site occupancy (assess dominance) between woody species.

5.10.3 LIGHT THRESHOLD TOOL

This tool allows flexibility in plot size; however, a plot radius at least equal to the height of a modal spruce seedling is suggested as a minimum. For example, if white spruce saplings are approximately 1m tall, a mil-ha plot (1.78m radius) can be used; conversely if white spruce saplings are approximately 2.5m tall a 50m^2 (3.99 m radius) plot is suggested.

To employ this tool, plots should be located as recommended in Section 6. Plot centers for this tool fall where the sampling design places them as the tool focuses strictly on aspen; it does not rely on presence of a white spruce seedling to calculate the competition value. Sample tally cards for this tool are found with the Tool. Data collected in the sample plot are:

1. Tally all aspen (and balsam poplar) saplings in the plot by diameter in 1cm diameter classes. Measure diameter at 30 cm above ground (D30).
2. Record the diameter tally in the Light Threshold Tool Calculator.

Note: Recent work in northeastern British Columbia suggests that quantifying absolute light values with this tool requires local calibration of the tool (Comeau et al. 2006). This has not yet occurred for Alberta conditions. Therefore, results obtained with this tool should be used as relative predictors (i.e. compared with each other), not as absolute predictors of light values.

5.10.4 LORIMER'S COMPETITION INDEX

Several competition indices for woody species interaction have been developed. Most relate either diameter or basal area of the subject species. That is, the competition index is the result of dividing the cumulative diameter or basal area of one species by the cumulative diameter or basal area of a second species or group of species. Quantitative assessment of interspecific competition between woody plants seems to hinge on site occupancy; the competition indices attempt to quantify this relationship. Site occupancy is a function of three disparate factors: density of each competing species, distribution of each competing species, and size of competing species. This might be generalized as:

Site Occupancy = ₣ (density, distribution, size).

Therefore, using cumulative diameter or basal area addresses two of the key variables: density and size.

Some competition indices are distance independent using the basic calculation described above. Others are distance dependent using some measure of distance between the trees forming the competition index to more finely quantify competition. The following theoretical equations describe woody species competition indices (CI):

$$CI_{\text{Distance Independent}} = \sum \text{Basal Area Species 1} \div \sum \text{Basal Area Species 2}$$

$$CI_{\text{Distance Dependent}} = (\sum (\text{Basal Area Species 1} \div \text{Basal Area Species 2}) \div \text{Distance between Individuals}$$

Choice of competition index is somewhat equivocal as the literature does not give a clear sense of whether distance-dependent or distance-independent competition indices are more quantitatively reliable in assessing competition. Comeau (2006 *pers. Comm.*), Stadt *et al.* (2002), De Luis (1998), and Clinton *et al.* (1997) all assert that distance independent competition indices accurately predict impacts of competition on crop trees. Conversely, MacIssac and Navratil (1996), Ferment *et al.* (2001), Mailly *et al.* (2001), and Canham *et al.* (2004) all suggest distance-dependent competition indices are more predictive of competitive interactions.

Careful reading of the literature suggests that distance dependent indices are more explanatory when assessing inter-specific competition between intolerant species. Comeau (2006 *pers.*

Comm.) proposes that in the boreal environment, quantifying these parameters suffices because aspen is usually distributed across reforested areas uniformly enough to ignore distribution effects on competition. Distance independent indices adequately explain competition between an intolerant and tolerant species. Therefore Lorimer's Competition Index (Lorimer 1983) is recommended for ease of implementation.

Lorimer's Competition Index provides a distance independent assessment of interspecific competition. It relates relative abundance of conifer and deciduous stems (via accumulated diameter) to create a numeric index using the following formula:

$$\sum (D_i)/D_c = CI_{Lorimer}$$

Where D_i = basal diameter of the i^{th} woody competitor, and D_c = basal diameter of the subject coniferous seedling.

Plots should be located as recommended in Section 5. A plot radius of 2.99 m is suggested. Sample tally cards for this competition index are found with the Tool. The white spruce nearest the nominal plot centre becomes the crop tree. Based on this tree the following measurements are made:

1. Basal (15 cm above ground level) diameter of the white spruce crop seedling.
2. Basal diameter of all aspen in the 2.99m radius circle.

A compiler for assembling these data and an interpretive guide to Lorimer's Competition Index are found in the Lorimer Competition Index Tool and the included Lorimer Competition Index Tool Fact Sheet.

5.11 INTERPRETING POST-ESTABLISHMENT (T7) ASSESSMENTS

The Post-establishment phase may be a time of transition or it may be a time when transition is well advanced. If the community is transitioning from an herbaceous state to a woody species dominated condition, the silviculturist will likely have employed both the herbaceous competition index assessment and the light threshold tool. As discussed in Section 5.9 the herbaceous competition index should not be used alone at this phase. Results of the Comeau's Competition Index assessment should be compiled and interpreted as shown in Section 5.8. Thresholds should be set as described in Section 5.7.

The following provides guidance in interpreting woody competition indices.

5.11.1 INTERPRETING THE LIGHT THRESHOLD TOOL

The light threshold tool integrates aspen diameter and density to estimate light availability within and under the developing aspen canopy. While the tool is not calibrated for Alberta, Comeau (2006 *pers. Comm.*) considers the tool sufficiently accurate for operational assessment purposes. Comeau (2003) discusses the light levels and aspen data on which the tool is based. The tool simply compiles and translates aspen diameters into quadratic mean diameter, and aspen numbers into density. It then indicates where this places the stand on a chart of light availability to white spruce, with some measure of statistical reliability. The chart also shows some nominal boundaries of white spruce behavior at higher and lower levels of aspen competition. (Quadratic mean diameter is a calculated value that represents the diameter of the tree with mean basal area). Again, the practitioner is cautioned that these values do not represent an absolute growth function; instead they represent site growth potential in the absence of other constraints.

The following is one approach to applying the Light Threshold Tool; practitioners may choose to develop a different approach to meet their specific needs.

It is recommended that individual vegetation assessment plots be compiled and placed on the figure that shows the impact of the aspen community structure on white spruce growth potential. The practitioner should then record dispersion of individual plots across the range of interaction. The frequency of occurrence at a specific level of competition could then be used to set thresholds and determine if treatment is required. Broad categories of competition are:

- Light levels are below those necessary for white spruce survival. Aspen density by quadratic mean diameter is plotted above the upper **red** line on the graphic output of the tool.
- Light levels are between those necessary for white spruce survival and those giving 66% of optimal spruce diameter growth. Aspen density by quadratic mean diameter is plotted between the upper **red** line and the lower **blue** line on the graphic output of the tool.
- Light levels are above those giving 66% of optimal spruce diameter growth. Aspen density by quadratic mean diameter is plotted below the lower **blue** line on the graphic output of the tool.

While the light availability to survival relationship used above is essentially a physiological phenomenon, the light availability to 66 percent of optimal diameter growth is an arbitrary relationship. This level was arrived at through discussion with Comeau (2006) to identify a light level, and by inference a level of competition, that would likely be attainable at reasonable cost.

5.11.2 CALCULATING AND INTERPRETING LORIMER'S COMPETITION INDEX

Lorimer's Competition Index is a simple ratio of cumulative deciduous diameter to subject conifer diameter and thus provides a distance-independent assessment of interspecific woody plant competition. To compile data and calculate this competition index use the calculator provided in the Lorimer Competition Index Tool as described in the included fact sheet. The tool output is a summary of Lorimer's Competition Index values.

Delaney (1995) suggests that a ratio of 1.0 or greater of competition to white spruce using a diameter or basal area based competition index will jeopardize white spruce performance. MacIssac and Navratil (1996) suggest the threshold is between 0.75 and 1.0. Practitioners are advised to set thresholds based on composition objectives as well as white spruce performance criteria. Attention should be given to the range and distribution of competition index values as a range of competition index values is likely acceptable in managing communities to mixedwood objectives.

5.12 TREATMENTS AT POST-ESTABLISHMENT (T7) PHASE

Competition in this phase is transitioning from herbaceous species to interspecific and intraspecific woody competition. Early in this phase herbaceous competition may still exert considerable impact on coniferous seedlings (and possibly aspen suckers). Therefore, treatments for herbaceous competition management may be necessary. Such treatments pose significant risk to deciduous crop trees. Conversely, facilitative influences of aspen on white spruce have become substantially lower. Therefore, broadcast herbicide treatments for herbaceous competition management may be useful for managing to a "pure" conifer condition. If a mixedwood condition is desired, spot or patch herbicide treatments are likely the only practical herbaceous competition management options available. Even these choices are likely to damage aspen sufficiently, presenting a challenge to attaining a deciduous dominated condition.

Therefore, if herbaceous competition is substantial it may be necessary to change objectives. For example, if a combination of reedgrass and deciduous tree competition is limiting white spruce survival and growth below acceptable limits, it might be appropriate to change objectives to a more deciduous oriented outcome. Another example is a situation where heavy reedgrass is limiting success of all tree species and a mixedwood composition is desired. In this situation changing objectives to a “pure” conifer condition would facilitate broadcast herbicide tending and fill planting with coniferous seedlings.

A number of treatments are available to manage woody competition around individual conifer crop trees. Motor manual control using brushsaws to cut competing individuals down is the most common method of treatment. A modification of this treatment that is gaining favor is including a cut surface herbicide treatment to increase durability of control when treating root suckering and/or basal sprouting species. Basal bark application of triclopyr herbicide has been used for this purpose as well.

Figure 5.12 shows a schematic approach to making vegetation management treatment prescriptions.

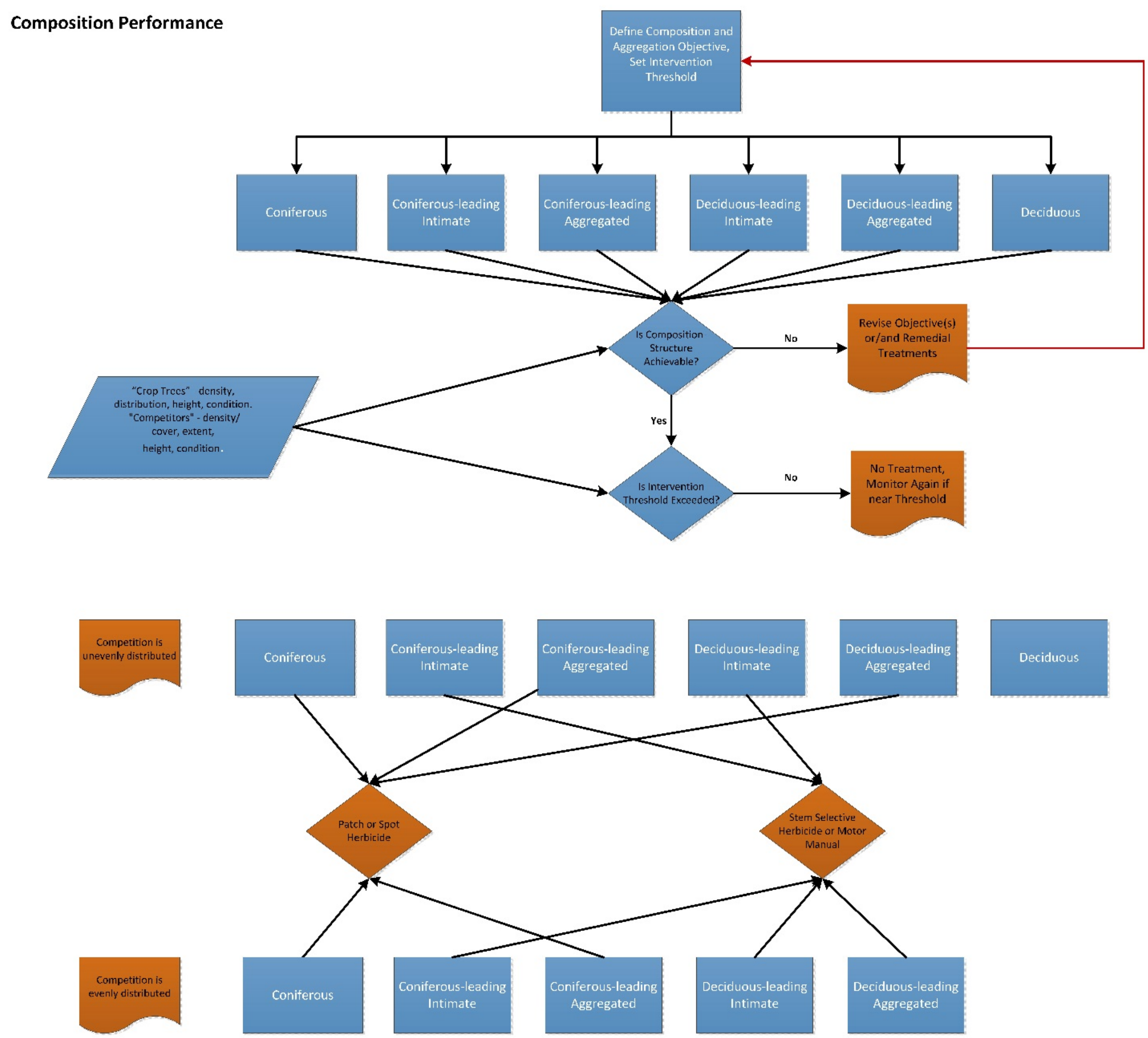

Figure 5.12. Generalized decision flowchart for treatment at composition or performance phase.

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