Silviculture and Best Management Practices for the Dry-Belt Douglas-fir Area in the Cariboo Forest Region

First Approximation

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March 7, 2024

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Re: ***Dry-Belt Douglas-Fir Area in the Cariboo Forest Region***

Dear Reader,

The Dry-Belt Douglas-Fir forests of the Cariboo comprise about half of the area of the The 100 Mile House Forest District and about 25% of the Cariboo-Chilcotin Forest District. These are the environment surrounding most of our communities and infrastructure.

Historically, these environments were managed by Indigenous people using low- or mixed-severity fire. These forests now have 125 years of industrial timber harvesting and fire protection and have now grown into a condition that puts them at risk from catastrophic fires. We seek to change course and undertake a different approach to management that will make the forests more resilient to wildfire, bark beetles, and other insects. Attached is a first approximation of *Silviculture and Best Management Practices for the Dry-Belt Douglas-fir Area in the Cariboo Forest Region.* This draft guidance sets out our expectations for silviculture and management of these important forests.

Please be aware this guidance document is a draft. We welcome your thoughtful input to clarify or improve the best management practices for Dry-Belt Douglas-fir lands in the Cariboo Forest Region. If you have feedback, please email your comments to FLP.Cariboo@gov.bc.ca. Your input will be considered in the second approximation of this guidance.

Thank you very much for taking the time to review this document and provide your feedback.

Best regards,

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Acknowledgements

Thank you to the following people for their contributions and thoughtful review of this work throughout its development:

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Executive Summary

Dry-Belt Douglas-fir forests form a substantial part of the Cariboo Forest Region. They contain many of our communities and much of the key infrastructure serving British Columbia. These forests were managed by First Nations since time immemorial, particularly through the regular application of cultural burning. Through colonial settlement and industrial development that management was interrupted. This has resulted in a forest that has high densities of small trees and stand and forest health in decline due to severe competition. The forests no longer provide the abundance of values they once did and they threaten our communities with wildfire.

The Cariboo Forest Region has embarked on a process to meet these challenges by modifying our silvicultural approach to management of Dry-Belt Douglas-fir. At the centre of those changes is a strategic plan that describes the current situation and sets out principles, values, goals and objectives for the landscapes of the Dry-Belt Douglas-fir Area. A synopsis of that strategic plan is included in this document.

Management of Douglas-fir in the dry IDF subzones of the Cariboo is challenging. Because of the environmental conditions and the sensitivities of Douglas-fir, shelter is an important part of successful silviculture. The ecological and silvicultural rationale described in Chapter 3 (and in detailed extension materials appended to this report) underpins the Best Management Practices recommended. There is a strong emphasis on achieving the direction of landscape-level planning and returning Dry-Belt Douglas-fir forests to a process of thinning and regeneration in the shelter of retained trees. Grasslands, aspen, pine and spruce stands are also desirable and important components of the future landscape.

The strategic planning process has resulted in a draft amendment to the Land Use Order that is intended to create a legal requirement governing the silvicultural approach to forest management within the Dry-Belt Douglas-fir Area. A copy of the draft amendment is appended to this document. The statements in the amendment to the Land Use Order form the organization of the Best Management Practices advanced in Chapter 4.

This first approximation of Best Management Practices for Dry-Belt Douglas-fir in the Cariboo Forest Region will be amended as input is received. A consultation and input process will be undertaken during the next year to ensure that the intent and content of this document meets the needs of governments and practitioners.

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1. Introduction

The Dry-Belt Douglas-fir Area[1] spans the southern and central parts of the Cariboo Region. These forests surround most of our communities, from Clinton to ?Esdilagh, and from Lone Butte to Tsi Del Del. These forests exist in the hottest and driest climates we have in the Cariboo-Chilcotin, containing the rolling country of forests, ranches, grasslands and river valleys.

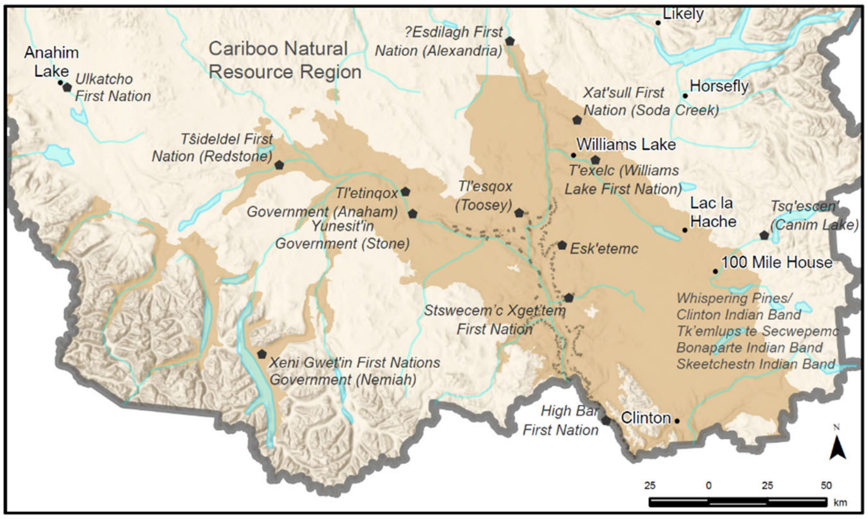

Figure 1: The Dry-Belt Douglas-fir lands (brown shade) within the Cariboo Forest Region.

Dry-Belt Douglas-fir forests have been traditionally managed by First Nations since time immemorial. The cultural use of fire was one tool that was widely applied up until 1879 when its use was outlawed, and First Nations were decimated by disease and confined to Indian Reserves. Commercial timber harvesting commenced in the mid-1900s. Cessation of burning, coupled with selective harvest of timber under various approaches, have significantly changed the current conditions of the forests and landscapes. These changed conditions, coupled with climate change impacts, have brought us to a situation where forest health and frequent high-intensity severity fire threatens our communities, while high fire severity diminishes the ecological goods and services we value in the forests.

To meet these challenges, the Cariboo Forest Region has drafted a strategic plan for the management of the Dry-Belt Douglas-fir Area (Day and Wood, 2023). The Strategy and Best Management Practices are intended to support and guide the implementation of existing and future landscape level objectives. A brief review of silvicultural and environmental considerations pertinent to the Dry-Belt Douglas-fir Area is provided in Section 0.

This document provides Best Management Practices (BMPs) for the consideration of planners, decision makers and operations supervisors. It provides supporting rationale and background information, to guide the interpretation and implementation of the Land Use Order Amendment and the strategic plan. We expect that these guidelines will inform forest professionals and require adjustments to several policies. The strategic plan has set out an Agenda for Change, which includes identifying barriers created by policy and procedures that inhibit effective implementation of the direction. That work lays ahead.

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[1] Dry and Xeric subzones of the Interior Douglas-fir Biogeoclimatic Zone, plus the Bunchgrass Biogeoclimatic Zone

This document also sets out Best Management Practices for restoration thinning (described in section 4c on page 17). Restoration thinning will be a principal activity for timber harvesting under the direction of the Land Act Order Amendment.

Finally, this document will support the Forest Landscape Planning process when that commences in the Cariboo-Chilcotin and 100 Mile House Forest Districts. As a first approximation, these Best Management Practices are subject to revision. They will be reviewed annually as part of the continuous improvement monitoring objective set out in the strategic plan.

This first approximation of Best Management Practices for Dry-Belt Douglas-fir in the Cariboo Forest Region will be amended as input is received. A consultation and input process will be undertaken during the next year to ensure that the intent and content of this document meets the needs of governments and practitioners.

2. Vision and Principles for Management of Dry-Belt Douglas-fir in the Cariboo Forest Region

a. Vision[2]

“We manage the Dry-Belt Douglas-fir ecosystems at the stand and landscape extent in a way that incorporates Indigenous knowledge and western science to emulate traditional and natural disturbance patterns. We seek to promote resilience, meet goals, and balance multiple values.”

b. Goals for Management[3]

The goals expressed in the strategic plan are listed here alphabetically.

1. Cattle will be able to graze productively in the forests and grasslands.
2. Carbon sequestration will be greater than carbon emissions.
3. Climate change impacts will be mitigated by attention to resilient and resistant (healthy) ecosystems.
4. Collaborative planning and management will support balanced outcomes for least regret.
5. Communities will co-exist with fire, safe from destructive wildfires.
6. Economic activities from sustainably managed forests will support local jobs.
7. Management activities, services and diverse manufacturing businesses provide stable employment for community members.
8. Grasslands, wetlands and forests will be in a healthy growing condition, resistant and resilient to disturbance.
9. Indigenous knowledge and cultural perspectives will be a foundation of management.
10. Invasive species will be managed.
11. Large and old trees will be retained and recruited on the landscape.
12. Logs will be regularly available to supply a vibrant and integrated forest industry in our communities.
13. Management will support conservation of biodiversity and provide habitat for a wide range of native animal and plant species, particularly including Species at Risk or species of high management interest.
14. Silvicultural systems will regenerate and grow stands dominated by Douglas-fir.
15. Sufficient clean water will be available for habitat, irrigation and consumption.
16. Treatment methods will be chosen based upon the ecosystem and objective to which they will be applied.

c. First Principles Guiding Management

As a community of practitioners, we need to provide:

A. A spatial plan of future landscapes and ecological communities – grasslands, open forests, broadleaf forests, riparian forests, uneven-aged Douglas-fir, even-aged lodgepole pine
B. Shelter for regeneration of Douglas-fir at each harvest entry
C. Reduced understory of flammable species with a high fuel strata gap and low surface fuels

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[2] Day, K. and L. Wood. 2023. A strategic plan for the collaborative management of the Dry-Belt Douglas-fir Area in the Cariboo Forest Region: 2022-2023. Draft dated May 10, 2023. Cariboo Forest Region.
[3] Ibid.

D. Coarse woody debris, large old trees, and dead trees to maintain stand-level biodiversity
E. Resilient stands throughout the landscape, growing desired ecological conditions into the future.

3. Silvicultural Review for the Dry-Belt Douglas-fir Area

a. Ecosystem Considerations Affecting Silviculture in the Dry-Belt Douglas-fir Area

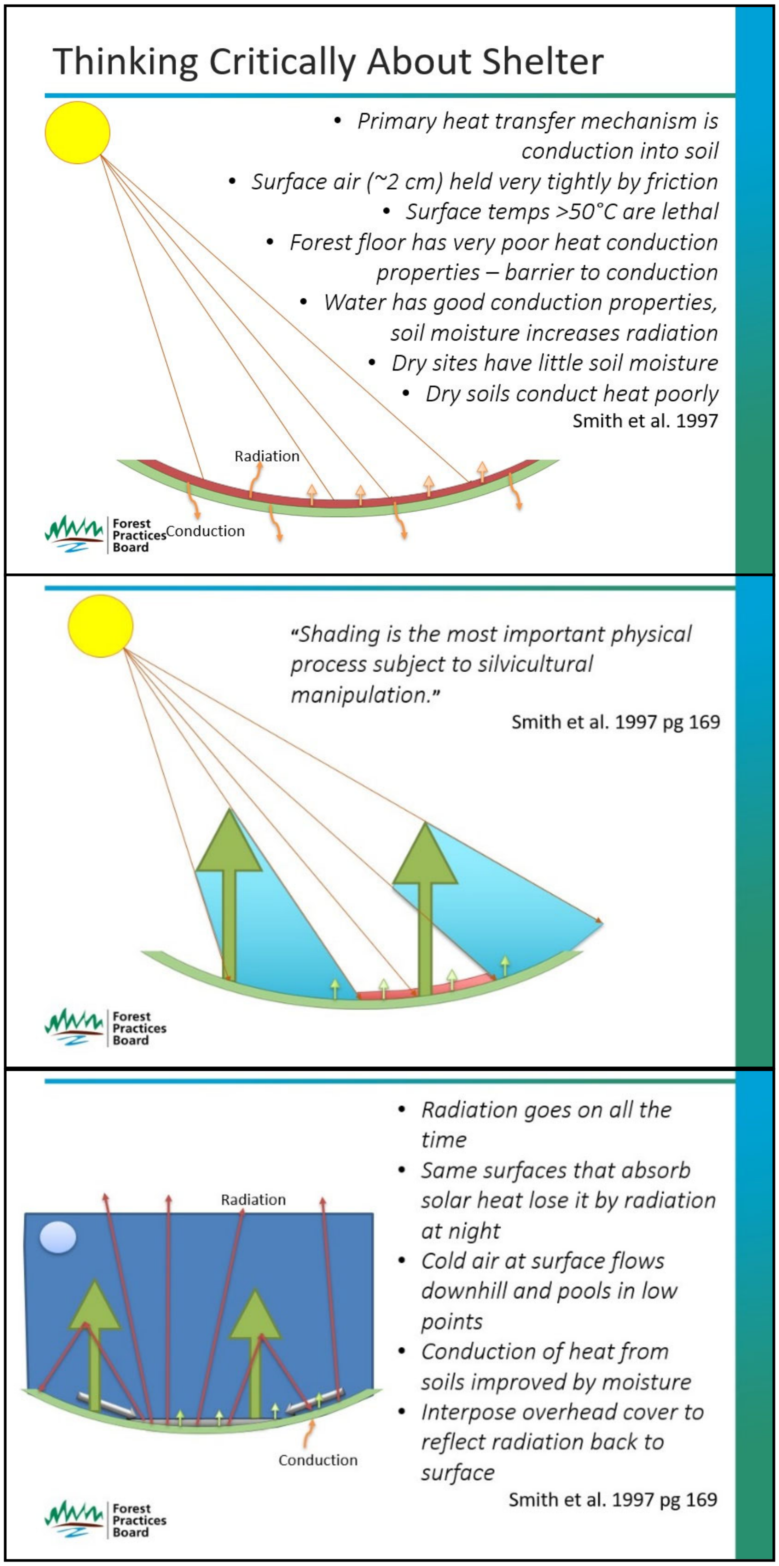
In the Dry-Belt, shelter is necessary for the regeneration (either planting or natural) and early growth of Douglas-fir (Figure 2) because of:

1. Daytime heating to lethal high temperatures causing stress, injury and mortality of regeneration; and
2. Growing season frost, caused by the accumulation of lethal cold air through radiative heat loss to the night sky.

Shelter improves the seedling environment by providing shade during the day and interrupting radiation throughout the night.

The current condition of the forest and grassland is an expression of the environmental conditions and the historical disturbances that have occurred.

The cessation of the cultural use of fire in or about 1879 resulted in rapid ingrowth of virtually all Douglas-fir stands, and gradual expansion of forests into grasslands and meadows. At present, most Douglas-fir stands are overstocked with low-vigour and poor-quality growing stock with significant repression of growth in many stands. The overstocking has led to recurrent outbreaks of



Thinking Critically About Shelter

- Primary heat transfer mechanism is conduction into soil
- Surface air (~2 cm) held very tightly by friction
- Surface temps >50°C are lethal
- Forest floor has very poor heat conduction properties – barrier to conduction
- Water has good conduction properties, soil moisture increases radiation
- Dry sites have little soil moisture
- Dry soils conduct heat poorly

Smith et al. 1997

"Shading is the most important physical process subject to silvicultural manipulation."

Smith et al. 1997 pg 169

- Radiation goes on all the time
- Same surfaces that absorb solar heat lose it by radiation at night
- Cold air at surface flows downhill and pools in low points
- Conduction of heat from soils improved by moisture
- Interpose overhead cover to reflect radiation back to surface

Smith et al. 1997 pg 169

Figure 2: Shelter is critical in the regeneration (both planting and natural) of Douglas-fir to reduce daytime heating by providing shade, and to reduce chilling due to radiation on clear summer nights. Graphics courtesy of BC Forest Practices Board.

Douglas-fir bark beetle and spruce budworm, and outbreaks of Douglas-fir tussock moth are expanding northwards.

Salvage of mountain pine beetle-affected stands and fire impacted stands have primarily been regenerated in open stand conditions with lodgepole pine predominating. Douglas-fir composition in plantations has been increasing, particularly since the Elephant Hill fire in 2017. Despite recent changes, these practices have resulted in a significant reduction in the amount and distribution of Douglas-fir forest in the Dry-Belt Douglas-fir Area. Given that Douglas-fir can withstand drought conditions better than lodgepole pine, in the face of climate change it will be desirable to shift stands back to Douglas-fir as rapidly as possible using a variety of silvicultural strategies. Thinning with retention of Douglas-fir and regeneration by shelterwoods will be the primary tools to shift species composition back towards Douglas-fir.

Timber harvesting by diameter-limit cutting (1960-80 and again recently) has affected as much as 65% of the Dry-Belt Douglas-fir area in some landscapes (Day 1998). This practice removes the productive overstory and retains the high-density sapling layer as advanced regeneration. Given that the advanced regeneration has been repressed in most stands, it is very slow to respond to available growing space, resulting in very poor growth rates.

High-density understory and long times-since-fire results in high surface fuel loading and strong vertical fuel continuity, contributing to high fire intensity and severity, frequently causing significant mortality of overstory trees after fire. Post-fire salvage creates open conditions that are challenging to regenerate to Douglas-fir.

As a result, many Dry-Belt Douglas-fir stands have low volume and poor diameter distributions and the rigid imposition of BDq regulation makes many stands inoperable because of limited availability of merchantable trees for harvest. And yet, as a community of practise we want those stands to be thinned to achieve our objectives around forest resilience, wildfire risk reduction and timber production. We need to open a discussion of alternative approaches to appropriately manage Dry-Belt Douglas-fir stands.

b. A Review of Stand Dynamics (adapted from Day 2019)

Stand dynamics is the study of changes in species composition and stand structure over time, including the effects of disturbance (Oliver and Larson, 1996). Ecosystems develop in a way that is specific to site conditions, and practitioners must be aware of the linkages between site and stand structure, silvics and stand dynamics. Silvicultural manipulations can emulate natural disturbance (Kimmins 2004).

Natural disturbances occur because of fire, wind, insects, and disease (Day et al. 2011a). Timber harvesting, fire, silvicultural treatment, livestock grazing and development-related impacts (access, livestock grazing, pollution, flooding etc.) are anthropogenic disturbances that also affect forests in the Dry-Belt Douglas-fir forests.

Stand productivity is dependent upon disturbance since disturbance controls leaf area and recycles accumulated biomass. As stands approach full site occupancy, high leaf area results in high gross production but also high respiration demands. Disturbance reduces leaf area and redistributes growing space[4] from plants (or parts) that die to those that survive or regenerate (Waring and Schlesinger, 1985). Those new or surviving plants grow more efficiently with their larger share of a reduced leaf area.

Efforts at controlling disturbance may prevent one kind of mortality but increase the risk of another type or of greater intensity (Waring and Schlesinger 1985). As an example, exclusion of stand maintaining fires has resulted in less frequent fires of much greater severity. Plant communities respond to disturbance in patterns that depend upon disturbance size, severity, frequency and type (Bazzaz 1983).

With increasing competition for growing space, trees are unable to produce enough photosynthate to meet all their requirements. Plants allocate their photosynthates in a rank order of priority described by Oliver and Larson (1996):

1. Maintenance respiration of living tissue;
2. Production of fine roots and leaves;
3. Flower and seed production;
4. Terminal and lateral branch growth and root extension;
5. Diameter growth and resistance mechanisms against insects and diseases.

Plants compete for access to growing space. In single-species stands, competition between individuals in a cohort is very even because all the individuals have much the same growth patterns. With increasing competition for growing space, trees are unable to produce enough photosynthate to meet all their requirements. It holds, therefore, that trees are unable to resist insects and diseases (e.g. bark beetles, defoliators, stem cankers), heal their wounds, or grow diameter to support their height, if competition for growing space is severe.

Following major disturbances, many species establish over a relatively short time and then dominate in turn as their environmental tolerances and growth traits allow. The resulting stand development patterns see fast-growing exposure-tolerant species dominate for a time, to then be replaced (in the absence of further disturbance) by slower-growing, shade-tolerant or longer-lived species (Oliver and Larson 1996). Examples of this “initial floristics” pattern of development would include high-severity disturbance (e.g. fire) followed by the establishment of aspen, lodgepole pine, and Douglas-fir in a relatively short period of time. Due to the low tolerance of Douglas-fir to growing season frost and the rapid early growth of aspen and pine, the stand becomes dominated by aspen and pine, which is eventually replaced by longer-lived and moderately shade-tolerant Douglas-fir. Of course, a seed source must be available for a species to become established after a severe disturbance – e.g. removal of seedbearing Douglas-fir trees will limit natural regeneration of Douglas-fir beyond about 100 m from the stand edge.

According to Oliver and Larson (1996), following intermediate or minor disturbances, some of the trees in a stand will survive and when new trees regenerate a multi-cohort (uneven-aged) stand results. Response of the overstory and the regenerating stand depends upon the type and severity of the disturbance and the vigour of the residual trees.

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[4] Growing space is the area that provides all the growth factors that give a plant the capacity to grow – sunlight, water, heat, nutrients, oxygen, and carbon dioxide (Day et al., 2011a)

- A light disturbance that kills few trees will release little growing space, which will be rapidly occupied by vigorous residual trees, and a new cohort will not be established.
- Slightly more severe disturbance may result in the establishment of a new cohort that is then suppressed by the residual stand.
- More severe disturbance allows establishment and growth of a new cohort, but their performance is still subject to the influence of the residual trees.
- Dominant and codominant trees in any stratum generally respond to increased growing space than intermediate or suppressed crown classes.
- Disturbances affecting lower strata only (e.g. light thinning from below) generally do not result in establishment of a new cohort and may not release of the overstory much growing space to dominant trees.

Oliver and Larson (1996) go on to discuss the growth after a disturbance of strata in multi-cohort stands:

- Overstory trees take up additional growing space (roots and crowns) until the new growing space is occupied.
- Dominant and co-dominant trees in lower strata also take up released growing space until they are competing and until the overhead shade and root competition from overstory trees limit their growing space.
- New stems regenerate and grow freely until they begin to compete and until the overhead strata take up available growing space.
- Light reaching lower canopy strata declines as overstory foliage increases.
- Understory cohorts can compete with overstory trees for root growing space.

Single-species stands (as are prevalent in the Dry-Belt Douglas-fir forests) can develop to a point of stagnation after a disturbance if all new trees grow at the same rate in equal growing space. When the trees have begun to compete heavily, few are able to kill their competitors because competitive advantage is small (Oliver and Larson 1996). In this condition their gross production is very close to the compensation point, and the prolonged stem exclusion stage predisposes the individuals and the stand to additional disturbance (especially snow press, spruce budworm, fire, insects and diseases). Stagnation can be averted if disturbance comes early enough to kill some of the trees and release their growing space to the survivors. In multi-cohort single-species stands such as Dry-Belt Douglas-fir, regular disturbance is likely necessary to avoid this stagnated condition, particularly in the smaller cohorts.

c. Desired Future Condition of Dry-Belt Douglas-fir Landscapes

Since the start of industrial timber harvesting in British Columbia, we have generally taken one stand at a time to harvest and regenerate. In general, there has been no plan directing tenure holders to act upon any objectives or priorities set out by the landowners. Instead, tenure-holders have had the license to identify and pursue opportunities within constraints.

Forest Landscape Plans now present an opportunity for governments (the Province and First Nations), communities and stakeholders to develop a plan and priorities for action. Clearly, we have multiple overlapping and potentially conflicting objectives that must be reconciled at the landscape and stand levels. With a landscape-level plan in place, silviculturists can continue to act on the current situation, one stand at a time, with the purpose to effect change at the landscape level.

The Forest Practices Board has issued a call to action (see sidebar) strongly urging government to act immediately on wildfire resilience at the landscape level. The strategic plan for the Dry-Belt Douglas-fir Area (Day and Wood, 2023) set out goals and objectives that are consistent with the direction of the FPB report. The objectives and indicators that speak directly to landscape planning and wildfire resilience are shown in Table 1.

> *"Bold and immediate action is required by the provincial government to align policies and programs across all levels of government with a vision of landscape resilience and human co-existence with fire. Before we can take advantage of the good work wildfire can accomplish in maintaining resilient ecosystems, we need to prepare the landscape to accept fire again. Integration of LFM [Landscape Fire Management] in BC's land management framework will enable our land and fire managers to work together and significantly increase the pace and scale of management strategies designed to restore landscape resilience."*
>
> Forest Practices Board, 2023a

Management under this complex of overlapping objectives requires collaboration, creativity, and a willingness to pursue the best outcome overall. We, as a community, need to minimize our regret when bad things happen. We must put aside the desire to maximize single objectives, or even optimize the objective set. Instead, we must work to ensure that catastrophic disturbance doesn't erase any of our values from the landscapes we live in.

The landscapes we manage are, for the most part, in poor condition to achieve our objectives. In addition, we have a limited toolset, and our tools are blunt:

- Thoughtful cutting of trees;
- Patience in waiting for regeneration; and
- Reduction of surface and ladder fuels through manual/mechanical means and through the re-introduction of fire after thinning.

Still, the recent work of First Nations and Community Forests in the Cariboo-Chilcotin demonstrates that with concerted effort and financial support for incremental costs, we can effect change that has an impact at the landscape scale.

Resistance to fire has elements at the landscape, stand and tree level. Hessburg et al. (2007) point out that the pre-contact interactions of insect outbreaks, forest diseases, fires, weather events, and intentional aboriginal burning resulted in characteristic landscape patterns. Those patterns and the variability in forest structure, species and habitats resonated with the dominant disturbance processes. Presently, however, the landscape and vegetation patterns have been altered, and these anomalous patterns support fire, insect and disease processes that are uncharacteristic in terms of duration, spatial extent and intensity (Hessburg et al. 2007).

According to Hessburg et al. (2005) and Daniels (2004) historic patterns of forest structure favored low- or mixed-severity fires. High-severity fires were uncharacteristic. At the landscape scale, there is now increased connectivity of high fuel load, increased susceptibility to insects and disease, and increased aggregation of mortality through high-severity fire, insects and diseases (Hessburg et al. 2005). Changes in stand and landscape conditions result in predominantly high-intensity fires. Large landscapes are increasingly homogeneous and regional landscapes are set up for severe and large fires and insect disturbance.

Table 1: Objectives and indicators set for landscapes within the Dry-Belt Douglas-fir Area of the Cariboo Forest Region (excerpt from Day and Wood, 2023).

Objective Concise, time specific statement[s] of measurable planned results that correspond to pre-established goals…"	**Sample DRAFT Indicators** A quantitative or qualitative variable that can be measured. Reported at the landscape or regional level
2. Maintain and restore Indigenous eco-cultural values on the landscape.	a. Landscape Level Planning and guidance documents incorporate Indigenous eco-cultural values
3. Landscapes are planned as a matrix of habitats, dominated by Douglas-fir, with grasslands, riparian areas, open stands, deciduous, pine and spruce stands forming substantial components of the landscape.	a. Proportion of Forest Landscape Plans that define a target condition for future landscape composition
	b. Proportion of Forest Landscape Plans that establish targets for maintaining biodiversity
	c. Proportion of Forest Landscape Plans that establish strategies for maintaining habitat for specified animal and plant species
	d. Proportion of desired landscape components having silvicultural systems described for implementation
	e. Percentage of area planned for Douglas-fir and disturbed in the past five years that provides effective shelter for regeneration of Douglas-fir
4. Manage ecosystems to ensure healthy, productive landscapes comprised of forests, grasslands and riparian areas that are resistant and resilient to disturbance.	a. Area of thinning (Pre-Commercial and Restoration Thinning) is completed
	b. Percentage of plans that address management strategies for forest health
	c. Area of both cultural and prescribed fire
	d. Percentage of post- harvest area that has fuel loading below potential Head Fire Intensity of 4,000 kW/m[5]
5. Manage forests and landscapes to reduce the risk of catastrophic fire affecting values.	a. Percentage of communities that have plans to address hazard reduction in the Wildland Urban Interface (WUI)
	b. Area of fuel reduction implemented annually
	c. Percentage of completed fuel treatment area (within 100 m of values) that has fuel loading below potential Head Fire Intensity of 2,000 kW/m[6]
6. Plan and operate a road system with minimum road area and effective maintenance that improves wildfire management.	a. Proportion of Landscape Units with Access management plans
	b. Percentage of access management plans that define target road density and proportion of roads beyond an access control structure
	c. Average road and landing density (including non-status roads)
	d. Proportion of road inspections documenting silt flow to waterways

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[5] Vigorous surface fire (Rank 4 fire intensity, HFI <4,000 kW/m) can be safely controlled by direct and indirect attack methods.

[6] Moderately vigorous surface fire (Rank3 fire intensity, HFI<2,000 kW/m) can be safely and reliably controlled by direct-attack methods.

According to Franklin et al. (2013), to increase resistance we need to plan and implement restoration by integrating goals at the landscape scale. Taking a landscape view allows “managers to plan for diversity of varying forest conditions to meet multiple objectives” (Franklin et al. 2013 citing others).

d. Desired Future Condition of Stands, In Summary

The strategic plan for the Dry-Belt Douglas-fir Area (Day and Wood 2023) establishes direction about the conditions of the area and sets an expectation that landscape components require descriptions of silvicultural systems.

Desired Future Condition of Grasslands and Open Forests

Areas designated to be restored to grasslands (outside the existing grassland benchmark areas) should be managed as sparsely treed open grassland conditions in accordance with the Cariboo-Chilcotin Grasslands Strategy Working Group (2007).

- Restore ingrown stands to grassland conditions through a combination of timber harvesting and prescribed or cultural fire to reduce woody debris and stimulate the growth of grassland species.
- Retain large veteran trees (>67.5 cm DBH) and up to 75 total trees/ha >12.5 cm DBH.
- Retain 5-10% of the area in patches, thinned from below to a target density > 15 m^2/ha

Desired Future Condition of Lodgepole Pine Stands

Lodgepole pine should be managed as pure stands or in mixtures with aspen. Mixtures of lodgepole pine and Douglas-fir should be managed to increase the composition of Douglas-fir over time through restoration thinning. Lodgepole pine may be managed as an overstory to provide shelter for Douglas-fir regeneration:

- As a nurse-tree shelterwood allowing a pine overstory to provide shelter for the regeneration of Douglas-fir until Douglas-fir can be released by an early thinning of the pine overstory
- By thinning the mid-aged or mature pine to create a uniform shelterwood.

Stands to be managed as lodgepole pine into the future should be managed by

- Establishing pure pine regeneration at 1800-2000 stems per hectare
- Brushing or juvenile spacing before 5 m height to retain 1800 stems/ha
- At least one commercial thinning entry before 18 m height
- Final harvest after 22 m height (about 85 years age assuming IDFdk3/01)

Desired Future Condition of Aspen Stands

Aspen stands are primarily managed for their resistance to fire in the height of the fire season. However, dense understories of grass create high head-fire intensity during the spring before green up. Clearcut or burn and regenerate aspen stands before coniferous understories overtake the aspen overstory. Regenerate by suckering to pure aspen and grow without thinning for their ecological and fire resistance benefits.

Experience with aspen silviculture is limited in the Dry-Belt Douglas-fir Area. Consider conducting research on:

- impacts of fire on regeneration success, and

- impacts of thinning on the timber production opportunity.

Desired Future Conditions of Spruce Stands

Spruce stands in the Dry-Belt Douglas-fir area are primarily confined to moisture receiving sites and riparian areas. These stands provide connectivity from low to high elevation and protect water quality and temperature. Disturbance is necessary to provide growing space and limit the accumulation of woody fuel in these stands. Incorporate their treatment into the adjacent Douglas-fir stands as a separate treatment unit.

Note that cultural and prescribed fire in these stands will have potential to cause mortality in overstory trees due to the thin bark and low crown base height of spruce.

Desired Future Condition of Douglas-fir Stands

To honour the principles and achieve the vision, goals and objectives established in the strategic plan for Dry-Belt Douglas-fir Forests (Day and Wood 2023), we envision that Douglas-fir stands a century from now, will have:

1. At least 70% Douglas-fir species composition;
2. Large old trees;
3. Presence of culturally important plants of sufficient vigour to bear fruit;
4. Presence of thickets to provide cover for animals;
5. Sheltered gaps supporting regeneration of Douglas-fir; and
6. Low surface fuel and sufficient fuel strata gap to allow the stand to survive a wildfire.

To achieve that desired future condition, at each entry we will treat stands to achieve (or pursue) the following:

Age Class Distribution

At next entry we want to retain at least three age classes and regenerate a fourth age class

- Large old trees established before the 1870s
- Trees established in the late 1800s (end of traditional cultural burning)
- Natural regeneration after harvest entries (1950-90)
- Additional planted or natural regeneration following the planned harvest

Diameter Distribution

At each entry we will retain growing stock distributed through the range of diameter classes. Traditionally in the Cariboo we have described target stand structure according to: minimum **B**asal Area, maximum **D**iameter, and the **q**uotient or ratio of trees in adjacent diameter classes. For a more detailed review of BDq math and stand structure objectives, see Appendix 2: Uneven-aged Management – Designing Target Stand Structure (Copied from Day 1996), and Appendix 3: Developing Target and Prescribed Stand Structure (From PowerPoint).

BDq targets are rote arithmetic that seeks to describe (or name) an average desired future condition of a stand. We want to be clear that BDq targets, while useful to describe a target stand structure, do not form cutting instructions. Cutting decisions are both driven by and affect the variable stand conditions present at the tree-neighbourhood level. The important part of implementation is to cut and leave appropriate trees to ensure sufficient growth and vigour of the post-treatment stand, while creating space for regeneration and growth of desirable herbs and shrubs and a new cohort of trees. BDq targets are simply a method for naming the desired future condition. Judicious tree selection in thinning and creating clumps and gaps is the craft of uneven-aged stand management.

The stand structure described below and in Figure 3 could be described (for 5 cm diameter classes) as:
B = 18 plus an old-tree reserve of 2 m^2/ha;
D = 65 cm DBH; and
q = 1.20

Immediately after harvest we want:

- 2 m^2/ha of old trees >67.5 cm DBH;
    - These trees are important for biodiversity and cultural values and should be retained and promoted in the stand;
- 11-12 m^2/ha of Mature trees 37.4 < DBH < 67.5;
    - Recognize that larger trees grow volume faster given appropriate stocking levels (Day 1998a).
    - Individual tree diameter growth and volume growth are a direct function of diameter (Day 1998b) given appropriate stocking levels and stand structures. The taller (larger) trees in a neighbourhood have the fastest growth rates because they dominate available growing space.
- 6-7 m^2/ha of Poles - trees 12.4 < DBH < 37.5.

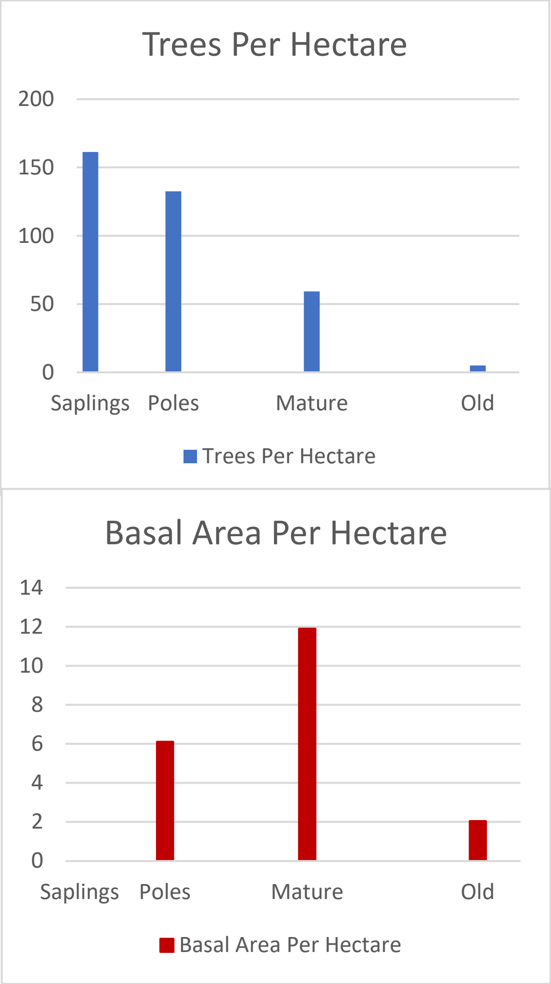

Figure 3: Desired stocking and maturity / diameter distribution (immediately after harvest) for stands in the Dry-Belt Douglas-fir area.

Desired Minimum Density

- In addition to the 20 m^2/ha (18 m^2/ha of Poles & Mature plus 2 m^2/ha of Old trees), immediately after harvest we want at least 250 Saplings/ha (<12.5 cm DBH) arranged in clumps occupying canopy gaps on about 10% of the harvest area distributed on between 500 and 1200 stems (all sizes).

Desired Maximum Density

Immediately after harvest we want not more than 1000 Saplings/ha (< 12.5 cm DBH) arranged in clumps occupying canopy gaps on about 10% of the harvest area.

Re-Entry Cycle

We expect that a harvest cycle of 20-30 years will result in a sawlog yield of about 75 m^3/ha, plus pulp logs and biomass. Modelling of the silvicultural regime is necessary to provide better estimates.

4. Practice Guidance

a. Appropriate Silvicultural Systems

Draft LAO Amendment - Direction

1) By selecting the appropriate silvicultural system, maintain or enhance the following attributes of Douglas-fir stands within dry-belt Douglas-fir ecosystems:

Maintaining Douglas-fir Stands

Choosing the correct silvicultural system should be a response to direction from land management planning. The stand structure after thinning is a response to management objectives coupled with ecosystem considerations and current condition (see section 0 page 12). Given the intention to maintain "basal area across diameter classes sufficient to achieve uneven-aged stand structure"[7], Restoration Thinning (see section 4c) should be a principal activity in any silvicultural system employed.

To achieve basal area across diameter classes sufficient to achieve uneven-aged stand structure practitioners will need to use either:

- Single Tree Selection, producing a multi-aged stand where regular thinning repeatedly opens regeneration space in the shelter of the retained growing stock and creating three or more age classes
- Small group selection with thinning in the matrix, creating a multi-aged stand where regular re-entries would open new regeneration space while again thinning in the matrix to maintain sufficient light to support growth of regeneration.
- Irregular shelterwoods which produce two- or three-aged stands where a late thinning (e.g. age 40-50?) removes older growing stock and creates regeneration space in the shelter of the younger growing stock; or

Single Tree Selection

In the Cariboo during the 1980s and 90s we have practised Single Tree Selection by BDq management as described in section 3c and Appendix 2: Uneven-aged Management – Designing Target Stand Structure (Copied from Day 1996). However, rote adherence to simple arithmetic objectives is insufficient to address the broad spectrum of stand structure and complex competition generated in single-species multi-cohort stands. Much more important is to ensure that trees are vigorous, and well-stocked stands are achieving our objectives. Comparing the outcome of a harvest to the desired stand structure disregards the pre-harvest condition of the stand and compares a stand average condition that may not in fact exist. Other authors promote more flexible stand-level objective setting, based upon stand and tree health and vigour, and landscape-level objectives (e.g., Graham et al. (2006), Graham and Jain (2005)).

Our land management objectives, when they have been clearly expressed in a Forest Landscape Planning process, will likely direct us to stand structures different from those established according to section 2.c. page 8. Our approach to Single Tree Selection will have to adapt in the future to stand structural objectives yet to be described.

While planning is carried out at the stand and landscape level, thinning is implemented by making decisions at the individual tree level. It is critical that trees we retain in the stand have better qualities

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[7] Land Act Order Amendment (Draft)

to achieve our objectives than the trees that are cut. In thinning, choose to cut trees those trees in which values are not increasing, and retain those trees in which values are increasing.

> Some observers believe that application of the selection systems requires that each stand be made into a self-contained sustained-yield unit. This condition is one that can be approached but is almost never attained in practice; even approximations of the condition are difficult to maintain. In fact, single-minded efforts to mold stands into sustained-yield units often produce results that are illogical in the light of other considerations. Nevertheless, the essentially mathematical manipulations … provide one means of monitoring programs for achieving sustained yield in whole forests.
>
> Smith et al. 1997

Small Group Selection

Small group selection is a viable silvicultural system to regenerate Douglas-fir. In the Dry-Belt Douglas-fir Area groups should not be more than one tree height (25 m) in the narrow dimension to provide sufficient shelter to limit the accumulation of growing season frost in the regenerating group. Because groups need to be small to control growing season frost, Restoration Thinning in the matrix of the stand will be important to allow more light to arrive at the regeneration.

Irregular Shelterwood

Irregular shelterwood has been practised in the Cariboo, albeit in the name of single tree selection. There is a particular stand structure, created when most of the merchantable growing stock was removed while retaining big old low-grade trees and small non-merchantable advanced regeneration. This was a relatively popular approach outside mule deer winter ranges in the 1980s and 90s, which left stands with a disrupted diameter distribution, under-stocked in poles and mature size classes and overstocked in saplings. Prescribers intended to harvest next in 50 years[8]. Recent work on the Chilcotin Military Training Area (Cariboo Aboriginal Forestry Enterprises Ltd. 2023) estimated that this condition occupies approximately 5% of the forested landbase, but we suspect it is more prevalent on Crown land. DWB Consulting Services Ltd. et al. (2010) reported that this condition occupied almost 17% of the Chimney Landscape Unit.

One example plot is shown in Figure 4. This plot had 3029 trees/ha and 14.2 m^2/ha at last measurement. Merchantable volume of the stand was only 55 m^3/ha. Periodic Annual Increment was 1.0 m^3/ha*year.

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[8] These stands fall into Stand Structure Class 13 according to Moss (2012).

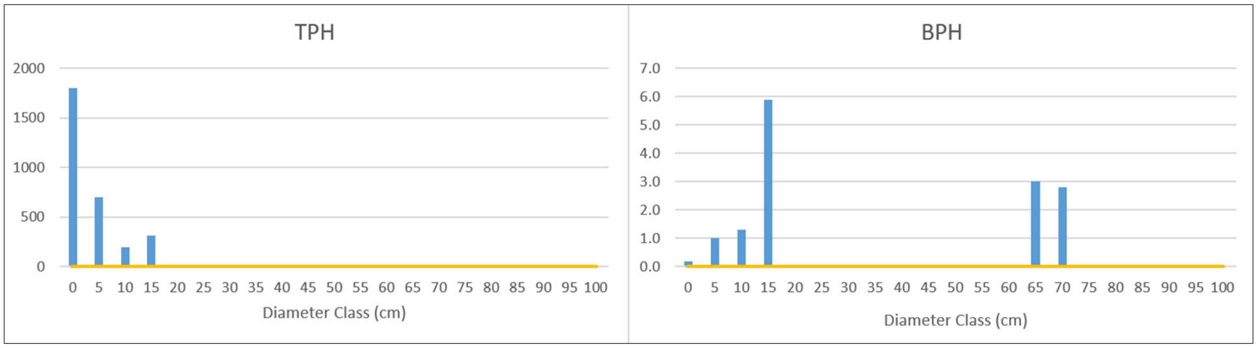


Figure 4: Graphs of stand (left) and stock table (right) for PSP 15 from Ian Moss's library of plots. The distinctly bimodal diameter distribution (typical for Stand Structure Class 13) is a legacy of harvest practices in the 1980-90s and poses a silvicultural conundrum if management is intent on pursuing the single tree selection method. Figure courtesy Cariboo Aboriginal Forestry Enterprises Ltd.

DWB Consulting Services Ltd. et al. (2010) recommended a combination of harvesting about two thirds of the remaining overstory, coupled with precommercial thinning in the understory. They estimated the volume removal at 44 m3/ha.

Cariboo Aboriginal Forestry Enterprises Ltd. (2023) has recommended that these stands should be pre-commercially thinned, and then a deferred harvest when the accumulated volume growth will support a commercial thinning entry.

BMP # 1: Appropriate Silvicultural Systems

1. Restoration Thinning (described in section 41 on page 17) will be a principal activity in any silvicultural system.
2. Pursue stand structural objectives described on page 12 as a long-term target, while recognizing the limitations imposed by current stand structure and distribution of stocking density.
3. Groups should not be larger than 25 m in the narrow dimension to provide sufficient shelter from growing-season frost.
4. Restoration Thinning in the matrix of the stand is necessary to allow sufficient light into small groups.
5. Stands previously cut as irregular shelterwoods should continue to be managed as irregular shelterwoods. Harvest by commercial thinning combined with removal of a portion of the overstory and pre-commercial thinning.
6. Undertake the next thinning entry when understory volume plus a portion of overstory volume will support a Restoration Thinning.
7. Retain 2 m^2/ha of trees DBH >67.5 cm (or the largest trees available) at each harvest entry.

b. Enhancing Characteristics of Douglas-fir Stands (Pine and Aspen Leading)

Uniform Shelterwood

Uniform shelterwoods for regeneration of Douglas-fir were used in the SBSdw1 (outside of the Dry-Belt), through a long-standing collaborative research project established by Cariboo Forest Region, UBC Alex Fraser Research Forest and Weldwood/West Fraser in 1990. Final reporting on that research project is in hand (Waterhouse et al. 2021, Waterhouse and Baleshta (In Review)) and would support exploration of this method in the Dry-Belt. This method would support the conversion of pine-leading stands to Douglas-fir stands.

Shelterwoods can be used to regenerate Douglas-fir provided there is sufficient overstory retention to provide shelter, regardless of the species of the overstory. In several examples in the SBSdw1 on the Alex Fraser Research Forest, Douglas-fir successfully regenerated under a pine overstory, either by natural regeneration (from scattered overstory Douglas-fir trees) or by planting.

Day et al. (2011c) set out a practitioner's guide for operational implementation of shelterwoods in which they set out an assumption that a shelterwood should have two cuts over a 10-year period, thinning from below to retain 50% of the Basal Area at the Seed Cut, and then a final removal cut 10 years later. Preparatory cutting or Restoration Thinning in advance of the seed cut would help to increase the stability of the stand and increase germination space. To our knowledge, no-one has practised uniform shelterwood silvicultural systems in the Dry-Belt Douglas-fir Area, and adaptive management will be required to explore this system.

BMP # 2: Enhancing Characteristics of Douglas-fir Stands (Pine and Aspen Leading)

1. Carry out uniform shelterwood in two harvest entries (seed cut, removal cut) 10 years apart.
2. Seed cut by Restoration Thinning, retaining 50% of the stand basal area.
3. Retain up to 2 m^2/ha of the largest trees (preferring Douglas-fir) at the removal cut.
4. Explore the utility of uniform shelterwood by adaptive management.

c. Basal Area Across Diameter Classes: Restoration Thinning and Stocking Control

Draft LAO Amendment - Direction

Basal area across diameter classes sufficient to achieve uneven-aged stand structure where practicable

According to Franklin et al. (2013, pg 10), "Ecological restoration focuses on re-establishing ecosystem functions by modifying or managing the composition, structure, spatial arrangement and processes necessary to make terrestrial and aquatic ecosystems ecologically functional and resilient to disturbances expected under current and future conditions." Reducing stand density while increasing mean diameter is a key element of restoration prescriptions (Franklin et al. 2013). According to Ashton and Kelty (2018) thinning is a silvicultural practise that regulates tree and stand growth by removing certain trees from a stand, thus shifting growth to other trees or to other values.

'Restoration Thinning' is commercial thinning from below according to Ashton and Kelty (2018). We aim to reduce understory and mid-story density while producing commercial timber products and retaining overstory trees, thereby increasing the quadratic mean diameter of the stand. Harvesting is typically directed to the high-risk saplings and poles (tall and slender) between 5 and 30 cm DBH.

In Restoration Thinning (see sidebar) we aim to shift growing space from an over-stocked low-vigour understory to improve overstory vigour (including large and old trees) and culturally important plants. We will accomplish this by thinning heavily amongst the low-vigour growing stock, typically trees between 5 and 30 cm DBH. This low thinning can reduce the chance of catastrophic crown fire by removing ladder fuels from the understory. This also reduces root competition for water, increases soil water availability, and increases the vigour and health of remaining canopy trees. Low thinning also increases the herbaceous diversity in the understory (Ashton and Kelty2018).

Density control is the purpose of any thinning, but setting density targets is complicated by the variable size of the leave-trees particularly in selection management. Reducing density while retaining sufficient growing stock to satisfy the stand management objectives is critical to ensuring that overstory trees retained after thinning have improved health and vigour, while providing an environment suitable to regeneration. Of course, inter-tree density must vary according to the size of the leave-trees, and so it is preferable to specify a target residual density both in terms of basal area and number of trees. There is a sweet spot, (a management zone) in terms of stand density, and we estimate that to be approximated by 20-35 m^2/ha of basal area (all sizes) on approximately 500-1200 stems/ha (all sizes). Within that range of density, sites are fully occupied and free of competition-induced mortality.

Matthews (1991) emphasizes that selection management requires thinning in all size classes to ensure that:

- Numbers of stems are maintained in appropriate proportions by diameter class;
- Species composition is controlled;
- Saplings are maintained free of suppression, and
- Defective stems are removed.

Stand structure (the distribution of growing stock throughout size classes) has a strong influence on the growth of trees and stands. Most growth per tree occurs in the tallest cohort at any time (Oliver and

Larson 1996) because they are growing without overhead shade. According to PrognosisBC model output, the most vigorous trees tend to be in the 20 to 40 cm DBH size classes, with very large trees and very small trees contributing much less volume to basal area increments (I. Moss, personal communication, 2023-04-04).

It is most critical, however, that more vigorous trees are retained to grow, and less vigorous trees are cut to free up growing space. This is because less vigorous trees have less foliage, and a slender form. It takes ample foliage for trees respond to newly available growing space, and sufficient taper to withstand wind and snow loading after thinning. To achieve this stand improvement, seek to keep the target density (18 m^2/ha) of the most vigorous trees in each cutting decision plus the 2 m2/ha of old trees.

> "Wood doesn't grow wood, foliage grows wood."
>
> *Bruce Larson, Professor Emeritus, UBC Forestry*

Think of it this way: there is a fixed amount of foliage that a particular site can support. High-density stands have less foliage per tree than low-density stands. Within a fairly wide range of density, growth per hectare is roughly equal, so a lower density stand means higher growth per tree and roughly equal growth per hectare. Disturbance temporarily reduces leaf-area, making growing space available for the survivors. But the survivors must be sufficiently vigorous to be able to respond to the new opportunity without getting broken by weather events.

Pre-Commercial Thinning in Diameter-Limit Cut Stands

Restoration thinning includes pre-commercial thinning (also known as juvenile spacing). Uneven-aged Douglas-fir stands harvested between 1962 and 1980 were cut by diameter-limit, whereby trees exceeding a prescribed size were available for harvesting (Day 1996). Diameter limits were set as low as 8 inches (20.3 cm) DBH. This method was economically efficient but was disastrous for stand structure (Day 1996). Residual trees retained after diameter-limit cutting formed low-quality dense single-cohort stands that have severely restricted ability to respond to additional growing space due to intense competition and poor condition. The sort of stagnation described above in section 3b is now prevalent over large portions of the landscape because of this practise.

Although we don't presently have an estimate of the area harvested by diameter limit cutting in the Dry-Belt Douglas-fir Area, it was substantial. About 50% of the Knife Creek Block of the UBC Alex Fraser Research Forest was harvested in this fashion (Day 1998).

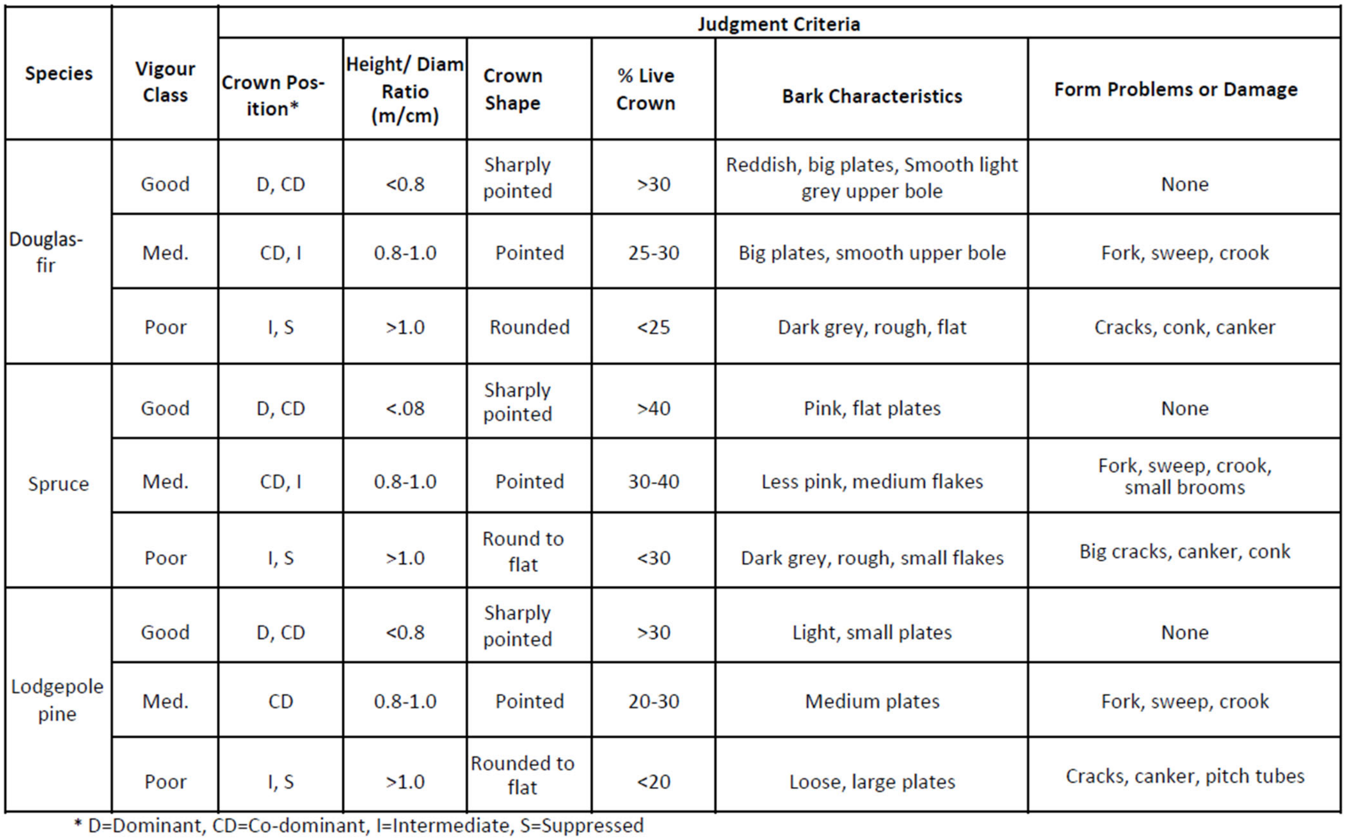
Pre-Commercial Thinning has been limited in general, and the thinning that has been accomplished through various funding programs (e.g. EBAP, FRDA, FRBC, SWPI) has not all been tracked in the forest inventory. Day (1998) noted that a Pre-Commercial Thinning program was implemented on the Research Forest to "restore stand structure to a productive condition."

Pre-Commercial Thinning is a critical intervention (see Recommendation 1 and Recommendation 2, page 34) and should be part of the silviculture regimes. Pre-Commercial thinning should follow the Best Management Practices described below for leave-tree selection, post thinning density, and abatement of fuels. We will need to develop methods of accomplishing our objectives while using mechanical methods.

Leave-Tree Quality Matters

In restoration thinning, it is critical to retain productive growing stock that has the potential to respond rapidly to the growing space released by the thinning. This ensures that the health status of the stand improves after thinning, because the retained trees have more resources to grow, defend themselves and heal their wounds (see section 2.b, page 6).

Table 2: Vigour classes for selection of conifer leave-trees (from Day, 2015). Retain good or medium vigour classes as productive growing stock.



Species	Vigour Class	Judgment Criteria					
		Crown Position*	Height/ Diam Ratio (m/cm)	Crown Shape	% Live Crown	Bark Characteristics	Form Problems or Damage
Douglas-fir	Good	D, CD	<0.8	Sharply pointed	>30	Reddish, big plates, Smooth light grey upper bole	None
	Med.	CD, I	0.8-1.0	Pointed	25-30	Big plates, smooth upper bole	Fork, sweep, crook
	Poor	I, S	>1.0	Rounded	<25	Dark grey, rough, flat	Cracks, conk, canker
Spruce	Good	D, CD	<.08	Sharply pointed	>40	Pink, flat plates	None
	Med.	CD, I	0.8-1.0	Pointed	30-40	Less pink, medium flakes	Fork, sweep, crook, small brooms
	Poor	I, S	>1.0	Round to flat	<30	Dark grey, rough, small flakes	Big cracks, canker, conk
Lodgepole pine	Good	D, CD	<0.8	Sharply pointed	>30	Light, small plates	None
	Med.	CD	0.8-1.0	Pointed	20-30	Medium plates	Fork, sweep, crook
	Poor	I, S	>1.0	Rounded to flat	<20	Loose, large plates	Cracks, canker, pitch tubes

* D=Dominant, CD=Co-dominant, I=Intermediate, S=Suppressed

Density and Stand Structure Matter

Clearly, density and stand structure matter in restoration thinning. Cariboo Aboriginal Forestry Enterprises Ltd. (2023) has looked at plots as case studies, to set out silviculture regimes for various stand structures. In that analysis, they found that Periodic Annual Increment ranged from 1 to 4.2 m^3/ha*year depending upon stand structure (distribution of growing stock by diameter class) and density. It is important to find silvicultural regimes that maintain appropriate density and improve stand structures to achieve the best growth outcomes and stand vigour, while meeting land management objectives. (See Recommendation 3 page 34). Harvest prescriptions need to be based upon accurate estimates of stand structure by creating stand and stock tables that consider all diameter classes. Post-treatment re-measurements are important to assess the impacts of harvesting on future growth. Without this kind of information, we will never be able to accurately forecast growth and yield from Dry-Belt Douglas-fir stands, and we will miss the opportunity to make improvements and to quantify yield impacts when setting the Annual Allowable Cut. (See Recommendation 3: Fulsome guidance with respect to post-harvest stand structure is a necessary component of implementing management in the Dry-Belt Douglas-fir Area, and the creation of silvicultural regimes is recommended for the numerous stand structures existing.

Recommendation 4 and Recommendation 5, page 34.)

Stocking Rates for Dry-belt Douglas-fir

A range of stocking rates[9] should be contemplated, depending upon the stand structure. Moss and Day (2019) developed a stocking chart patterned after Gingrich (1967) and Day (1998) for Dry-Belt Douglas-fir stands in the Cariboo, showing graphically the interplay between density and tree size, and describing the growth and mortality rates associated with various stand densities. See Appendix 4: Gingrich Chart for the Dry-Belt Douglas-fir Area for more information. Interpretation and model runs support a basal area of 20 – 35 m^2/ha and a density of 500-1200 stems/ha (all diameters) will support the best growth and resilience of Dry-Belt Douglas-fir stands. These estimates inform the BMP recommendations following.

BMP # 3: Basal Area Across Diameter Classes: Restoration Thinning and Stocking Control

1. To be considered productive growing stock, leave trees should have Good or Moderate vigour as described in Table 1, and should be undamaged through the thinning process.
2. Each cut-or-leave decision is based upon the tree's ability to fulfill management objectives into the future. Leave the best, cut the rest.
3. Collect stand data that supports the creation of stand and stock tables (Basal Area/ha) including all diameter classes and remeasure plots post-harvest to determine if treatment accomplished the prescription. Retain pre- and post-harvest stand tables in RESULTS or other reporting method that links silviculture activities with the forest inventory.

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[9] For a more thorough review of quantitative thinning guidance, refer to Ashton and Kelty (2018, pg 496-504).

d. Retention of Large Old Trees

Draft LAO Amendment - Direction

"…continued presence and recruitment of large diameter, healthy Douglas-fir trees, "

Large-diameter and old trees are a key feature of ecocultural landscapes in the Dry-Belt Douglas-fir Area. These Grandfather Trees play important roles in stand conditions, including providing shade and shelter for regenerating trees, below-ground connections through mycelial networks, nesting and roosting space for a wide variety of wildlife species, and a supply of large dead trees and coarse woody debris into the future. They have thick bark and resist wildfire mortality, contributing to stand and landscape resilience. Large-diameter trees often have large branches and deep crowns because they have grown for some part of their life in open conditions.

BMP # 4: Retention of Large Old Trees

1. Retain or promote 10% (2 m^2/ha basal area, 5-6 trees/ha) of the stand basal area in live trees >67.5 cm DBH. Old trees with large limbs, fire scars and other signs of cultural or ecological importance are preferred as retention trees.

e. Appropriate Regeneration Density

Draft LAO Amendment - Direction

"…appropriate stem densities of Douglas-fir regeneration, in consideration of ecological limitations, and regeneration requirements,"

Desired regeneration density depends upon silvicultural system and management objectives. The concept of preferred and acceptable species likewise needs to be informed by management objectives.

As discussed in section 3a, appropriate regeneration density and species composition requires retention of an appropriate overstory density. Therefore, we describe best management practices for overstory retention and for regeneration.

Overstory Retention Stocking

Stocking standards for uneven-aged stands should incorporate tree numbers and basal area, in recognition that full stocking is achieved with fewer larger trees or more smaller trees. Stocking standards are a tool by which stocking is judged after harvest and after regeneration.

Stocking is a measure of the occupancy of available growing space and is a function of the number of trees and their size, relative to the ideal stand (Davis and Johnson 1987).

If a harvest prescription cannot retain the minimum desired basal area of 20 m^2/ha, a greater reliance on regeneration results. In such a case, the target density would be 1800 stems/ha for those strata where the minimum desired basal area is not retained. Bear in mind, however, that shelter is necessary for the successful establishment of Douglas-fir (Figure 2) and retention of overstory for shelter is a critical step in regeneration silviculture. In these cases, regeneration density would be reduced by the ratio of overstory density, according to the calculation described in Table 5.

Regeneration after fire is a particular challenge that requires careful consideration of the ability to retain overstory for shelter. If post-fire salvage removes all the sheltering overstory, regeneration with Douglas-fir will be challenging because of the full exposure resulting (see Figure 2 below). In this situation a silviculturist will need to identify slope and aspect positions where Douglas-fir can be established, and site preparation will be critical. Follow best management practices recommended by Hegan and Armstrong-Whitworth (n.d) to establish Douglas-fir where possible. In areas that are in-hospitable to Douglas-fir after salvage clearcutting, consider using a nurse-crop of lodgepole pine or trembling aspen. Within a clear-cut, intimate mixtures of species should be used sparingly. Instead, species should be mixed at the stratum level to ensure that each species has appropriate growing conditions and stratified mixtures [10]are avoided (except where deployed as nurse crops).

Regeneration

Natural regeneration is generally freely available under a retained overstory in Dry-Belt Douglas-fir forests, because the forest floor is generally thin, there are frequent seed crops, and the sheltered environment is conducive to germination and early growth. However, regeneration by planting is also a

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[10] A stratified mixture is one where two or more species are regenerated in an intimate mixture but their silvical characteristics mean that the species with better early height growth will overtop the slower-growing species. As a result the faster growing species has low effective density, and the slower growing species is confined to the shade. An example in the Dry-Belt Douglas-fir Area would be lodgepole pine and Douglas-fir mixtures.

viable option that presents opportunities for facilitated migration of genetic material to adapt to climate change.

Recommended Stocking Rates (Assuming Zonal Sites and a Timber Objective)

Timber harvesting generally results in an obligation to regenerate a site to a commercially valuable species at a stocking rate expected to provide a timber value and volume suitable to the management objectives. Similarly, thinning confers an obligation to retain a minimum amount of overstory stocking of appropriate trees to meet the management objectives. In our current paradigm, stands that are measured to provide the appropriate retention or regeneration stocking can be declared free-growing, and the license-holder is therefore clear of their obligations for that harvest activity.

At present, regulations require regeneration stocking standards to be filed in a Forest Stewardship Plan for Major Licensees and Community Forest Agreements, or in a Woodlot Plan. Those stocking standards only deal with expectations for regeneration (especially in a clearcut situation) and do not address overstory retention standards. This section addresses that shortcoming by setting out expectations for both regeneration and retention.

Table 3 sets out retention standards for stands where free-growing will be declared on overstory retained after harvest. Table 4 sets out regeneration standards for stands where free-growing will be declared on regeneration alone. Table 5 sets out regeneration and retention standards for those situations where insufficient retention will not capture the site resources sufficiently to maintain sufficient volume growth.

It is important to note that the stocking standards below have different species expectations based on the overstory and understory growing position and the silvical characteristics of the species under management.

Table 3: Stocking Declared on Overstory (Single Tree Selection or Wildfire Risk Reduction)

<table>
<tr><th colspan="6">Preferred Species (80% BA):</th><th colspan="6">Acceptable Species (20% BA)</th></tr>
<tr><td colspan="3">Overstory:
Douglas-fir
Ponderosa pine
Aspen
Paper birch</td><td colspan="3">Understory:
Douglas-fir</td><td colspan="3">Overstory:
Lodgepole pine
White spruce
Rocky Mountain Juniper</td><td colspan="3">Understory:
White spruce
Lodgepole pine</td></tr>
<tr><td colspan="4">Overstory Min Density</td><td colspan="4">12.5 cm ≤ DBH < 67.5 cm
DBH ≥ 67.5</td><td colspan="4">18 m^2/ha
2 m^2/ha</td></tr>
<tr><td colspan="4">Understory Min Density</td><td colspan="4">Layer[11] 2,3,4</td><td colspan="4">500 stems/ha</td></tr>
<tr><td colspan="4">Understory Max Density</td><td colspan="4">Layer 2,3</td><td colspan="4">1000 stems/ha</td></tr>
</table>

Table 4: Stocking Declared on Regeneration (Uniform Shelterwood, clearcut with reserves)

Preferred Species:		**Acceptable Species**:	
Overstory: Douglas-fir	**Understory:** Douglas-fir	**Overstory**: Lodgepole pine	**Understory:** White spruce

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[11] Layer 1 -= DBH ≥ 12.5 cm, Layer2 = 7.5≤ DBH <12.5 cm, Layer 3 = 0 ≤ DBH <7.5 cm, Layer 4 = Height ≤ 1.3 m

<table>
<tr><td>Ponderosa pine
Aspen
Paper birch</td><td>Lodgepole pine
Ponderosa pine</td><td>White spruce
Rocky Mountain Juniper</td><td>Western larch[12]?
Rocky Mountain Juniper
Aspen
Paper birch</td></tr>
<tr><td>Overstory Min Density</td><td colspan="2">DBH > 67.5</td><td>2 m²/ha</td></tr>
<tr><td>Understory Target Density</td><td colspan="2">Layer 2,3,4</td><td>1800 stems/ha</td></tr>
<tr><td>Understory Min Density</td><td colspan="2">Layer 2,3,4</td><td>1200 stems/ha</td></tr>
<tr><td>Understory Max Density</td><td colspan="2">Layer 2,3,4</td><td>3000 stems/ha</td></tr>
</table>

Table 5 Stocking Declared on a Combination of Overstory and Understory (Irregular Shelterwood, shelterwood, salvage)

<table>
<tr><th colspan="2">Preferred Species:</th><th colspan="2">Acceptable Species:</th></tr>
<tr><td>Overstory:
Douglas-fir
Ponderosa Pine
(Or others depending upon target species composition.)</td><td>Understory:
Douglas-fir</td><td>Overstory:
Lodgepole pine
White spruce
Aspen
Paper birch
Rocky Mountain Juniper</td><td>Understory:
Lodgepole pine
Ponderosa pine
White spruce
Rocky Mountain Juniper
Aspen
Paper birch</td></tr>
<tr><td>Overstory Min Density</td><td colspan="2">12.5 cm < DBH < 67.5 cm
DBH > 67.5</td><td>10 m²/ha
2 m²/ha</td></tr>
<tr><td>Understory Target Density</td><td colspan="2">Layer 2,3,4</td><td>1800 * (1-(retained BA/20)) stems/ha</td></tr>
<tr><td>Understory Min Density</td><td colspan="2">Layer 2,3,4</td><td>(target density * 0.58) stems/ha</td></tr>
<tr><td>Understory Max Density</td><td colspan="2">Layer 2,3</td><td>3000 * (1-(retained BA/20)) stems/ha</td></tr>
</table>

BMP # 5: Appropriate Regeneration Density.

1. Retain a minimum density of 20 m^2/ha to declare a stand stocked in overstory, and regenerate at a density described in Table 3.
2. Regenerate even-aged stands after clearcutting or shelterwood in accordance with Table 4.
3. If less than 20 m^2/ha of overstory is available in a stratum of the post-harvest stand, retain as much overstory as possible to provide shelter and regenerate at a density described in Table 5.
4. Regenerate stands, in part, by planting using improved seed to adapt to climate change by facilitated migration of climate-ready genotypes.

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[12] Consistent with Chief Forester's Standards for Seed Use.

f. Access Structures

Permanent access for repeated entries to harvest areas is a necessary feature of partial cutting. Area converted to access should be minimized while still achieving long term objectives.

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"access structures which support long term stand objectives and minimize *roadside work area*,"

BMP # 6: Access Structures

1. Roads should be thoughtfully located to avoid sensitive sites and create fuel breaks and defensible space.
2. For partial cutting on flat ground, road density should be reduced by extending skid distance to 300 m in recognition that there is less volume per hectare over which to amortize the road. Target road density of 4% of Total Area Under the Plan (TAUP). Old roads should be renovated and re-used rather than building new road at each harvest entry.
3. Partial cutting should be implemented with logging to landings to accumulate logs and logging debris. Roadside processing is not appropriate in uneven-aged stands in the Dry-Belt Douglas-fir Area. This method was implemented to improve logging efficiency in clearcuts. Since the method requires clearance of up to 25% of the Net Area to be Reforested (NAR), it creates large gaps in the overstory resulting in strata without sufficient shelter.
4. Landings should not be larger than 0.25 ha and should serve 25-30 ha if on flat ground.

g. Resilience to Disturbance

Draft LAO Amendment - Direction

"…ecological resilience to disturbance,"

Resilience is the capacity of an ecosystem to return to the original state after a disturbance, maintaining its essential characteristics, composition, structures, functions and processes (Holling 1973). In effect, resilient systems return to their pre-disturbance state over time, despite a disturbance that was sufficient to alter its state (Franklin et al. 2013). As an example, if a Dry-Belt Douglas-fir forest burns and is then salvage logged, it is in a changed state. If it retains the key elements (e.g. large live trees, wildlife trees, large coarse wood, intact soils etc.) it will return to a state over time that approximates the structure and ecological function before the disturbance, because the stand was resilient. If a different state develops, then the stand was not resilient to the disturbance.

Fires since 2010 have demonstrated that the current stand and landscape condition is conducive to extreme fire behaviour (Figure 5). Large areas of the Dry-Belt Douglas-fir Area have burned at uncharacteristically high severity, resulting in high levels of mortality in both overstory and understory. Salvage logging of those fires was a high priority to recover the commercial value of the affected stands while mitigating the potential of bark beetle expansion and future re-burning. The post-salvage stands and landscapes are pushed back to open regeneration conditions, and regeneration to Douglas-fir is difficult due to the lack of shelter remaining on site.

Figure 5 Above: severely burnt mule deer winter range in the IDFdk3 in 2018, one year post fire. Below: post-salvage conditions are not favorable to Douglas-fir regeneration.

Stands that are salvaged have a lower risk of high severity reburning some time after the first fire. Returning the burnt forest to a resilient Douglas-fir ecosystem will require thoughtful planning and numerous silvicultural interventions to return to the desired condition of a multi-cohort Douglas-fir stand.

Critical steps to maintaining resilience are:

- Improving the health and vigour of trees and stands by reducing competition for growing space through restoration thinning (see section 41 above);
- Maintaining key structural stand attributes for biodiversity (see section 40 below); and
- Limiting the severity of disturbances.

Cultural and Prescribed Fire

The Dry-Belt Douglas-fir Management Plan sets out an understanding that widespread thinning needs to be coupled with the reintroduction of cultural and prescribed fire.

First Nations throughout the Dry-Belt Douglas-fir Area have objectives to restore cultural fire to the landscapes within their territories. British Columbia has committed to the reintroduction of cultural and prescribed fire[13]. BC Wildfire Service and First Nations are collaborating to make these aims a reality.

To limit fire intensity and improve the opportunity to carry out cultural and prescribed fire, Objective 4 of the Dry-Belt Douglas-fir Management Plan calls for limits to Head Fire Intensity by limiting post-harvest fuel accumulations. Restoration thinning should actively facilitate the application of cultural and prescribed fire to the Dry-Belt Douglas-fir Area. This will require collaborative and adaptive application of harvest planning and operations.

> "For our own safety and well-being, Indigenous fire use is needed to bring back balance in the forest. Fire Keepers' knowledge and use of fire must now include fire control, fire management, and other new disciplines to ensure fire is used in a safe way."
>
> Joe Gilchrist and Harry Spahan (FireSmart Canada, N.D.)

> 2.11 Integrate traditional practices and cultural uses of fire into wildfire prevention and land management practices and support the reintroduction of strategized burning. (Ministry of Forests, Emergency Management BC)
>
> DRIPA Action Plan 2022-2027

BMP # 7: Resilience to Disturbance

1. Abate post-thinning fuels <7cm such that that Head Fire Intensity[14] would not exceed 4,000 kW/m at the 90th percentile of fire weather.
2. Reduce potential for crown fire by reducing crown bulk density and increasing fuel strata gap – target ladder fuels in restoration thinning.
3. Thin the matrix of the stand on 80% of the stand area plus 10% in gaps and 10% in unthinned skips.
4. Restoration thinning (see section 41 above) should actively facilitate the application of cultural and prescribed fire to the Dry-Belt Douglas-fir Area.
5. Prepare restoration thinning areas for prescribed or cultural fire by reducing fuels under leave trees.
6. Tenure holders undertaking restoration thinning should collaborate with First Nations, BC Wildfire Service and the Land Manager, to establish an adaptive management process towards planning and implementing restoration thinning that supports the use of cultural and prescribed fire.

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[13] Action 2.12 of the DRIPA Action Plan 2022-2027. https://www2.gov.bc.ca/assets/gov/government/ministries-organizations/ministries/indigenous-relations-reconciliation/declaration_act_action_plan.pdf

[14] Head Fire Intensity is a measure of the amount of energy released at the head of the fire. HFI of 4,000 kw/m is approximately the upper limit of fire intensity where direct attack can be safely pursued.

h. Resistance to Pests and Pathogens

Draft LAO Amendment - Direction

"resistance to pest and pathogens,"

Management in the Dry-Belt Douglas-fir Area requires awareness and consideration of important forest health agents.

Forest health is directly related to tree and stand vigour – trees growing with limited resources are more likely to be damaged by weather events or suffer damage by insect or diseases. Low vigour status results in higher success for defoliator and bark-beetle attack (Day 1998). Trees grown at high density tend to have very tall and slender form and become mechanically unstable (Hermann and Lavender 1990). This results in increased risk of snow and ice damage and wind throw, particularly for the first few years after thinning, which can give rise to bark beetle outbreaks.

Competition for growing space between all size classes means that, without thinning, trees are growing poorly if at all, and have little energy to create defensive chemicals to protect themselves from herbivores (including insects). Outbreaks of spruce budworm have affected Douglas-fir forests starting in about 2000, except in the southern reaches of the Region where budworm has been established for many decades. Budworm outbreaks cause significant impacts, particularly on intermediate and suppressed trees or dense understories. Douglas-fir bark beetle outbreaks have been recurrent causing mortality primarily in overstory trees. Bark beetles have complex interactions with defoliators, fire, weather and climate.

Forest District and Region staff prepare District Forest Health Strategies[15] annually in response to developing forest health conditions as informed by the annual forest health overview surveys and subsequent ground sampling. Those strategies direct the management of forest health agents that are active in a given year.

Management of Douglas-fir bark beetle populations and mortality is a primary concern. Effective management requires vigilant detection and aggressive harvesting to control bark beetle spread during periods of high population pressure (Day 2007). Prevention is the best long-term management option but requires significant manipulation of forest cover over long time periods to increase stand vigour, thereby increasing resistance to bark beetles (Day 2007). Refer to best practices, strategies and tactics provided by Cariboo-Chilcotin Forest District[16] and 100 Mile House Forest District[17]. In addition, in the Dry-Belt Douglas-fir Area we add the following Best Management Practices.

Table 6 presents a list of forest health agents to consider in setting prescriptions for harvesting and regeneration in the Dry-Belt Douglas-fir Area, for the principal tree species under management.

Thinning can temporarily result in instability as leave-trees respond to their new environment. Tall slender trees may be overturned by wind events or broken by snow and ice storms. Disturbance effects have generally resolved within three years of thinning.

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[15] https://www.for.gov.bc.ca/ftp/DCC/external/!publish/Forest%20Health/Forest%20Health%20Strategy/

[16] https://www.for.gov.bc.ca/ftp/DCC/external/!publish/Forest%20Health/Douglas-fir%20Bark%20Beetle%20Documents/Best%20Management%20Practices%20for%20Managing%20Douglas-fir%20Beetle/DFB%20Management%20tactics_Jan%2015_2018.pdf

[17] Add link to DMH Forest Health Strategy

Silviculture activities need to focus on improvement of tree and stand vigour, and the protection of residual trees from damage during and after treatments. Silviculture treatments can have complex outcomes: the thinning that improves growing space for residual trees can increase windthrow or snow/ice breakage, resulting in mortality caused by bark beetle, or accumulate fuel to increase fire severity.

Table 6: Hazard rating for forest health agents affecting conifer tree species in the IDF. Hazard classes are as follows: L=Low, M=Moderate, H=High hazard, + denotes a significant presence without detailed information about distribution or hazard. (From Day and Swift 2016)

	Tree species			
Forest health agent	Fdi	Pli	Py	Sx
Armillaria (Southern Interior)	H	H	M	M-H
Laminated root rot	L-M dry subzones M-H? wet subzones	+	+	+
Black stain root disease	L-M	L-M		
Dwarf mistletoes	+ Frequent in SE BC	H		
Terminal Weevil Lodgepole pine, spruce		H		H (dm subzone)
Root collar weevil		L		?
Stem rusts of hard pines: Western gall rust, Comandra blister rust, and stalactiform blister rust		L in moist subzones, M-H in dry subzones	L in moist subzones, M-H in dry subzones	
Needle casts				
Lophodermella		H		
Elytroderma		+	+	
Douglas-fir needle cast	+			
Douglas-fir tussock moth	+ dry subzones			
Western spruce budworm	M-H			+
Bark beetles (Primary)	H	H	H	H
Bark beetles (Secondary)	L-M	L-M		

Thinning in root disease (*Armillaria, Phellinus*) sites creates a flush of carbohydrate for the established fungi, allowing a rapid colonization of trees that have been walling off the fungi. Leave root disease sites as biodiversity hotspots and understand that adjacent (apparently) healthy trees are likely already infected.

Partial-cutting can also cause mechanical damage to trees by damaging bark, breaking roots, or stripping branches out of the crown. Such damage may stimulate bark beetle attack and may also provide an entry site for decay fungi. Spruce is highly susceptible to decay after injury, while Douglas-fir and lodgepole pine are less likely to suffer injury-induced decay (Allen and White 1997).

Successful reforestation after harvesting is a key forest management challenge. Partially harvested sites tend to regenerate freely to Douglas-fir if there is sufficient cover to mitigate growing-season frosts, but regeneration performs poorly under a closed canopy (Burton 1996, Klinka et al. 1999). Clearcut sites tend to be very frosty, with significant grass competition, and even natural regeneration of pine can be patchy (Steen et al. 1990).

Climate change is expected to cause hotter / drier summers and warmer / wetter winters. The subzones of the IDF are all judged to be moderately to highly sensitive to these changes in climate, implying a moderate to high impact on management values (Nelson et al. 2011). Management adaptation to climate change is hindered by the low productivity and timber value in those ecosystems (Nelson et al. 2011). We are seeing novel forest health agents developing or migrating into the Cariboo from further south. Vigilance and communication are necessary to identify and mitigate emerging threats.

BMP # 8: Resistance to Pests and Pathogens

1. Deploy trap trees proactively by effective operational planning. Pre-falling roads and landings or thinning in the winter, skid or forward the trap trees in the summer/fall. Use MCH (Methylcyclohexnone – a synthetic anti-aggregation pheromone) and/or trap trees as a push-pull strategy when populations are high or rising.
2. Identify and manage sites and trees currently infested by Douglas-fir bark beetles, as the first priority.
3. Salvage beetle-killed logs while they retain commercial value, while retaining dispersed wildlife trees and coarse woody debris at a rate that complies with the direction on page 33 below.
4. Prepare a windthrow assessment as part of the silviculture prescription process, to consider the windthrow hazard at the Treatment Unit level. Document stand, soil and topographic attributes that most contribute to concentrations of windthrow.
5. Monitor thinned stands for 3 years after treatment to detect windthrow or other unexpected forest health effects.
6. Map and exclude root disease (Phellinus, Armillaria) centres from thinning treatments.
7. Employ harvest methods, seasonality and contractors that reduce the likelihood of mechanical damage. Training and supervision are critical to success.
8. Consistent monitoring, reporting and communication of developing forest health issues is critical to success. Support the Forest Health Committees.

i. Key Structural Stand Attributes for Biodiversity
Drafting is still underway.

Draft LAO Amendment - Direction

"…key *structural stand attributes for biodiversity."*

Franklin et al. (2013) set out principles for restoring dry forests. "Most importantly, restoration… is holistic, focusing on all aspects of ecosystem structure and function on entire landscapes." Their stated principles are:

1. Plan and implement at the landscape level.
2. Provide for heterogeneity at all spatial scales.
3. Retain and restore old tree populations and other foundational elements.
4. Learn from the past but look to the future.
5. Restore fire.
6. Consider operational and economic issues at all stages of planning.
7. Engage.
8. Learn, innovate and adapt.

Franklin et al. (2013) go on to describe areas of special significance that are important elements of landscapes and need special management:

- Streams, rivers, ponds and other aquatic features.
- Specialized habitats such as meadows and rocky outcrops
- Biological hotspots such as calving and spawning habitat
- Cultural sites

At the stand level we define the key attributes that support biodiversity to include:

- Variability of stand structure and species composition.
- Features such as coarse woody debris, wildlife trees in various stages of decay, and large live trees.
- Wet sites and riparian areas.
- Wildlife features such as mineral licks, nests and dens.
- Understory species with sufficient growing space to flower and produce seed.

Within-stand spatial patterns matter. Spatial heterogeneity is a critical component of ecosystem resilience (Churchill et al. 2012). Franklin et al. (2013) say that skips, gaps and clumps create a structural mosaic that provides wildlife habitat, facilitates regeneration, increases understory abundance and diversity, increases snow retention in shaded gaps, inhibits the buildup of insects and some diseases, and inhibits the spread of crown-fire.

According to Churchill et al. (2013) dry forests are characterized by an uneven-aged mosaic of individual trees, clumps comprised of two to more than 20 trees, and openings. This fine scale mosaic persisted for centuries in a gap-phase replacement driven primarily by frequent fire and insect mortality. Churchill et al. (2013) set out a process for defining and marking clumps to be retained during restoration thinning, which has been adapted by Dan Bedford, RPF (DWB Consulting Ltd. on behalf of Williams Lake First Nation). In his process, clumps are comprised of trees that are within 4 m of each other, measured from bark to bark. Clumps are measured during treatment monitoring or post-treatment cruising. The tree nearest plot centre is tree 1. A distribution of clump sizes (from one - many trees) is thereby measured across a harvest unit. A target of 6-9 trees in clumps has yielded good results as judged by Habitat staff (Dan Bedford, Personal Communication Nov 21, 2023).

BMP # 9: Key Structural Stand Attributes for Biodiversity

1. Retain aspen, birch, cottonwood, and infrequent species such as hawthorn, Rocky Mountain juniper[18] and water birch.
2. Retain and promote culturally important shrubs and plants.
3. Retain large live trees (see page 16). Ladder fuels exposing large live trees to high scorch should be thinned away from beneath the large live trees. Large live trees should be pruned to 3.5 m height, ground fuels and surface fuels should be reduced under the drip line.
4. Retain wildlife trees[19] at a target density of xx trees/ha. Danger trees should be retained within No Work Zones, which may anchor retention patches.
5. Retain Large Coarse Woody Debris (xx tonnes/ha). Large CWD may anchor retention patches.
6. Create skips of unthinned forest approximating 10% of the NAR retained in clumps of about 0.25 ha distributed throughout the stand and anchored, when possible, on wildlife trees, large Coarse Woody Debris, wet ground, or wildlife features.
7. Cut gaps for regeneration approximating 10% of the NAR and not larger than 25 m in the narrow dimension.
8. Restoration thinning should retain individual trees and clumps of 3-9 trees and small openings. Spatial heterogeneity should result from thinning without restrictions on inter-tree distance within a clump.

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[18] What are the First Nations objectives around retention of infrequent species? Do we need species-specific retention strategies?

[19] “Any standing dead or living tree with special characteristics that provide vitally important habitat for the conservation or enhancement of wildlife.” (Fenger et al. 2006)

5. Recommendations to Government

Recommendation 1: Establish and fund a Pre-Commercial Thinning Program to address Diameter-Limit Cut stands and identify the spatial extent of these stands in the Forest Inventory.

Recommendation 2: Investigate mechanical approaches to Pre-Commercial Thinning to abate surface fuels and improve thinning efficiency.

Recommendation 3: Fulsome guidance with respect to post-harvest stand structure is a necessary component of implementing management in the Dry-Belt Douglas-fir Area, and the creation of silvicultural regimes is recommended for the numerous stand structures existing.

Recommendation 4: Create a network of monitoring plots for periodic remeasurement to track changes in density, stand structure and growth and yield outcomes.

Recommendation 5: Investigate the Growth (and therefore resilience) impacts of target stand structure in the Dry-Belt Douglas-fir Area.

6. Summary

The Dry-Belt Douglas-fir Area in the Cariboo Forest Region surrounds most of our communities and occupies the hottest and driest climates in the Region. This area, including the forests, grasslands, meadows and aspen stands, have been managed by First Nations since time immemorial, particularly through the cultural use of fire.

Changed conditions resulted from colonization and industrial development in the latter part of the 19th century. Now coupled with climate change, these changes have brought us to a situation where forest health and frequent high-intensity wildfire threaten our communities and the ecological values in these landscapes.

The Cariboo Forest Region has drafted a strategic plan for the management of the Dry-Belt Douglas-fir Area (Day and Wood, 2023). To support the implementation of that strategic plan, Cariboo Forest Region is preparing an amendment to the Land Use Order in the Cariboo. That amendment will set legal expectations for the management of Dry-Belt Douglas-fir stands in the Cariboo Forest Region. This document provides Best Management Practices along with supporting rationale, to guide practices on the ground. This completes one item identified in the “Agenda For Change” within the strategic plan.

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Appendix 1: Draft Land Act Order Amendment

Objective

Appendix 2: Uneven-aged Management – Designing Target Stand Structure (Copied from Day 1996[20])

a. Stand Structure Regulation

While regeneration is a critical factor in uneven-aged management (Davis and Johnson, 1986), regeneration success alone is not a good reflection of success of stand prescriptions. It is quite possible to develop good regeneration and growth of small stems by highgrading a stand. Regulation of stand structure and control of stocking is critical to ensuring that stand growth is maintained, and management objectives are met (Hann and Bare 1979).

Uneven-aged management requires regulation of stand structure to ensure:

- regeneration;
- growth; and
- salvage of mortality.

Regulation of stand structure is an exercise of setting and achieving objectives. Setting stand structure objectives is a process of <u>design</u> (Daniel et al. 1979; Fiedler 1995).

Design factors include the diameter distribution, the maximum diameter of managed trees, the minimum stocking to be retained, and the cutting cycle (Matthews 1991; Guldin 1991; Fiedler 1995). This is frequently termed BDq regulation: residual **B**asal area, maximum **D**iameter; diminution **q**uotient (Guldin 1991; Fiedler 1995).

Regulation of stand structure must be explicit to control over-cutting and ensure operable volumes are available in later entries (Guldin 1991). Regulation also ensures that the desired structure of the stand is maintained for wildlife habitat or other management objectives (Fiedler 1995).

Stand structure is critical to all facets of the uneven-aged system. Changes to stand structure imply changes to growth and yield, allowable cut, harvest practices, inventory, and economics (Leak 1976). Stand structure also dictates regeneration success and species composition (Fiedler 1995).

Selection management requires thinnings amongst all size classes at each entry (Marquis 1976, Matthews 1991, Becker 1995). This ensures that diameter classes are maintained in correct proportions, species composition is suitable, saplings are growing without suppression, and defective trees are removed from the stand.

Early attempts at selection cutting failed due to a lack of regulation, because cutting concentrated on large size classes (Marquis 1976). If little attention is paid to regeneration and maintenance of the stand, the forest is degraded and sustained yield is not provided (Matthews 1991).

Daniel et al. (1979) state that factors to consider in design of stand structure goals include: current vigour in all diameter classes; impact on (or of) windfall, insects, and disease; impacts on wildlife; slash loading; and creation of regeneration opportunities. All of these factors influence the intensity of harvest, distribution of harvest, and return period.

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[20] https://afrf-forestry.sites.olt.ubc.ca/files/2012/03/Interior-Douglas-fir-and-selection-management.pdf

b. Setting Stand Structure Variables (BDq)

Residual Basal Area (B)

Setting the residual basal area for a prescription is important because appropriate levels of growing stock ensure that full site potential is captured, and individual tree growth is maximized. Marquis (1976) states that stands cut to 60% of full stocking will exhibit the same stand growth as a fully stocked stand and maximize individual tree growth.

Matthews (1991) states it as "the principle of gaining maximum increment from the smallest possible growing stock". The level is based upon the relationship of increment to growing stock, as described by Langsaetter (1941, Referenced by Lotan et al. 1988).

Figure 3 below shows Langsaetter's curve.

Simply put, growth is a function of stocking. Too much stocking reduces stand growth, whereas too little stocking results in poor utilization of growing space by trees. There is a fairly wide range of stocking, however, which produces the maximum growth of the stand (Daniel et al. 1979; Lotan et al. 1988). Growing a stand at the lowest stocking which still captures all the growing space (B-level stocking) maximizes both stand growth and individual tree growth (Daniel et al. 1979; SIWG 1992).

In Europe B-level stocking is set based upon periodic inventory before harvesting (Matthews 1991). Marquis (1976) suggests a residual stocking of 80 ft 2/ac for trees 10 inches dbh and greater (18.4 m2/ha 25.4 cm dbh and greater). Guidelines for the IDF in British Columbia recommend residual stocking of 50 to 75% of the stand volume and 15 to 25 m2/ha of basal area (SIWG 1992). Ginrich [sic] (1965) suggests that B-level stocking is equivalent to 57 to 59% of full stocking.

Since carrying capacity is a function of site quality, B-level stocking must vary from place to place. Research is necessary to determine appropriate levels of residual stocking by bio geoclimatic subzone. Modify this text to reflect that BDq is just a name.

Diameter (D)

Maximum D

Setting the maximum diameter class is dependent on site quality and stand management objectives. (Marquis 1976; SIWG 1992; Fiedler 1995). Larger diameters imply greater maximum tree age, and maximum diameter must be consistent with biological capability (Fiedler 1995). Better site quality suggests greater maximum diameter (Fiedler 1995).

Fiedler (1995) recommends that maximum diameter should be set at the size where growth slows, or at a diameter beyond which few trees grow. He further recommends that maximum diameter should not be increased beyond this size on account of non-timber objectives. Rather, he suggests that a basal area reserve be instituted for trees greater than the maximum diameter.

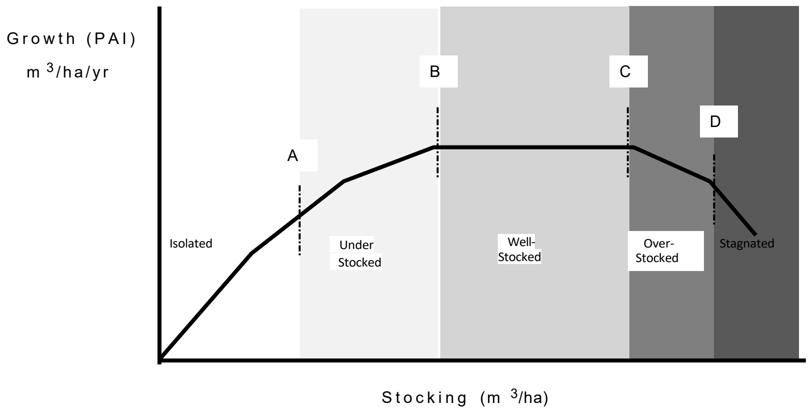


Figure 3: Langsaetter's curve, adapted from Lotan et al. (1988).

Guldin (1991) suggests that maximum diameter depends upon operability and risk. Large maximum diameters provide large logs, but present increased risk of loss. Smaller maximum diameter may provide slightly higher volume growth, but lower value. While risk of loss of the largest trees is reduced by managing to a smaller maximum, logging damage to the residual stand is increased.

Minimum D

A minimum diameter for regulation should also be explicitly stated (SIWG 1992; Fiedler 1995). The lower limit may be based upon merchantability, or on the need for management of stand density below merchantability limits.

A limit of 12.5 cm is suggested by SIWG (1992), but since the publication of their report the Chief Forester has imposed a maximum density of 2,000 stems/ha between breast height and 7.5 cm dbh. This suggests that all diameter classes should be considered in setting stand structure goals. Marquis (1976) cautions that, since management depends heavily on the stocking of small classes, it behooves a manager to know what is happening in those classes.

Diameter Class Width

Diameter class width should be specified. Changing class width has a direct impact on the number of trees to be kept, because it changes the number of diameter classes (and therefore the q-factor) (Guldin 1991). Diameter classes of 5 cm or 2 in. are most often referenced in the literature (Guldin 1991; SIWG 1992; Fiedler 1995) but larger diameter classes may be used and are preferred by some authors (Becker 1995; Fiedler 1995).

Diminution Quotient (q)

The q-factor is a constant ratio of the number of trees in successively smaller diameter classes (Fiedler 1995). The concept of q-factors was first developed by de Liocourt in the late 1800's, and when drawn on logarithmic scales, is referred to as de Liocourt's constant (Matthews 1991). High q-factors provide for more small trees, whereas low q- factors provide for more large trees. Low q-factors concentrate basal area in larger diameter classes (Daniel et al. 1979; Fiedler 1995), and therefore favour the production of large sawlogs (Guldin 1991).

Selection of an appropriate q-factor is a function of stand management objectives (Daniel et al. 1979). Open forests which naturally developed under a fire-maintained subclimax would have had a relatively low q-factor (Fiedler 1995). A wide range of q-factors are suggested in the literature. For 2 inch or 5 cm classes, suggested q-factors range from 1.1 to 2.0 (Marquis 1976; SIWG 1992; Fiedler 1995).

Lower q-factors tend to produce better volume growth because more of the increment is being concentrated on larger stems (Marquis 1976; Leak 1988). Initial harvest in an unregulated stand should employ a q-factor slightly higher than the eventual target q- factor (Marquis 1976; Daniel et al. 1979; SIWG 1992; Fiedler 1995). To approach a low q-factor on the first cut will result in a very open understocked stand (Leak 1976; Daniel et al. 1979).

Cutting Cycle

The cutting cycle is the cornerstone of the management prescription in uneven-aged management (Davis and Johnson 1987). The cutting cycle should be set so that periodic diameter growth averages one diameter class (Fiedler 1995). Schutz (1975) shows, however, that in forests managed for many decades under uneven-aged methods, the rate of diameter growth increases with increasing diameter.

Based upon the assumption that forest management should approximate natural disturbance (Province of BC 1995c) it follows that cutting cycle should be set at an interval which approximates the dominant stand-maintaining disturbance.

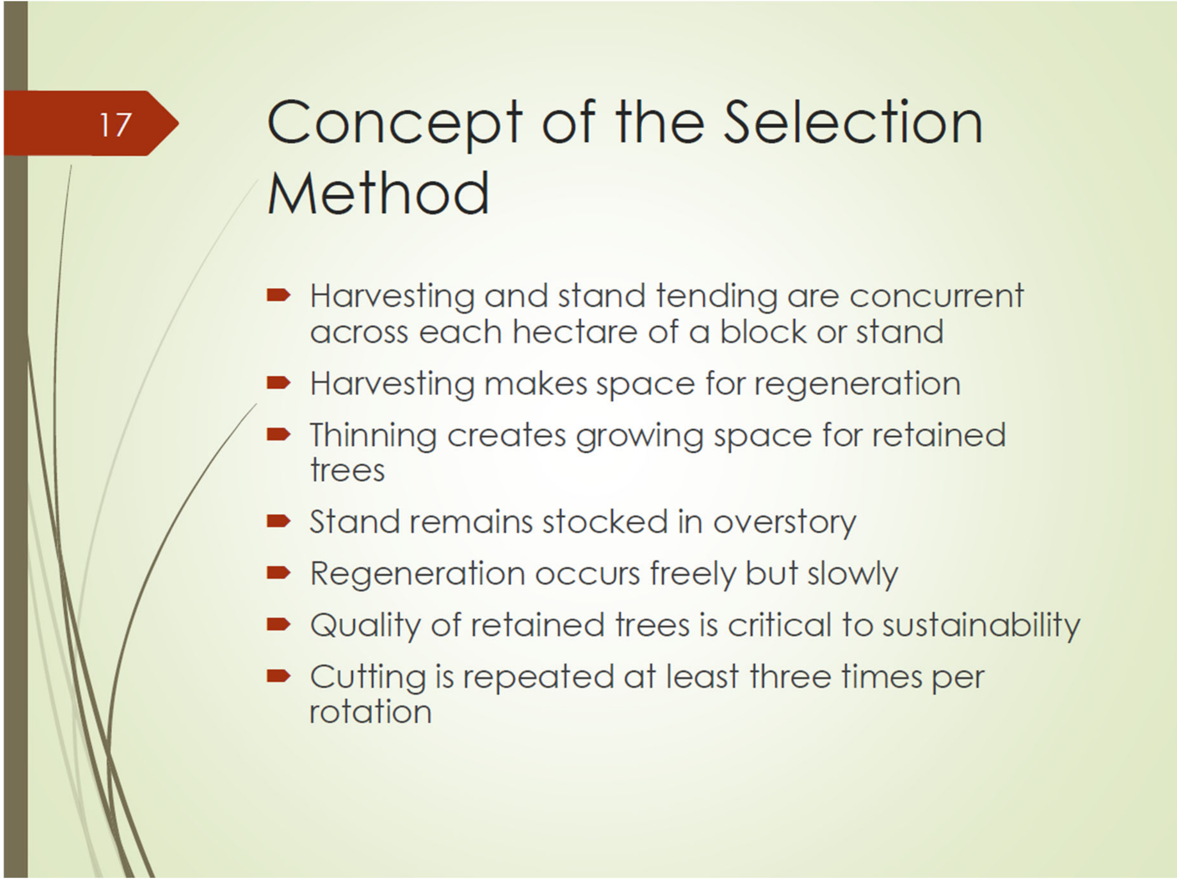
According to Marquis (1976) cutting cycle depends upon growth rate, residual stocking after cutting, and site quality. The cycle should be long enough to allow the stand to return to 80 or 90% of full stocking [i.e. the onset of competition-induced mortality]. Cutting cycles of 15-25 years are appropriate for many types (Marquis 1976), but European cycles are generally less than 10 years (Matthews 1991).

In practice, the forest is divided into roughly equal compartments, equal in number to the length of the cutting cycle. One compartment is then cut in each year (Matthews 1991). Short cutting cycles give large felling areas for small volume (Matthews 1991), but assure the salvage of all mortality and more constant control over stocking. Long felling cycles reduce the area of each compartment, and thereby improve the economic efficiency of the harvest (Matthews 1991). Longer cycles increase the risk of loss through mortality and reduce the stocking control exerted. Matthews (1991) also states that long cycles with small compartments favour more light-demanding species, because of relatively more intensive cutting.

Appendix 3: Developing Target and Prescribed Stand Structure (From PowerPoint)

Uneven-Aged Management

Ken Day, MF, RPF
FRST 305 | October 14, 2020



Concept of the Selection Method

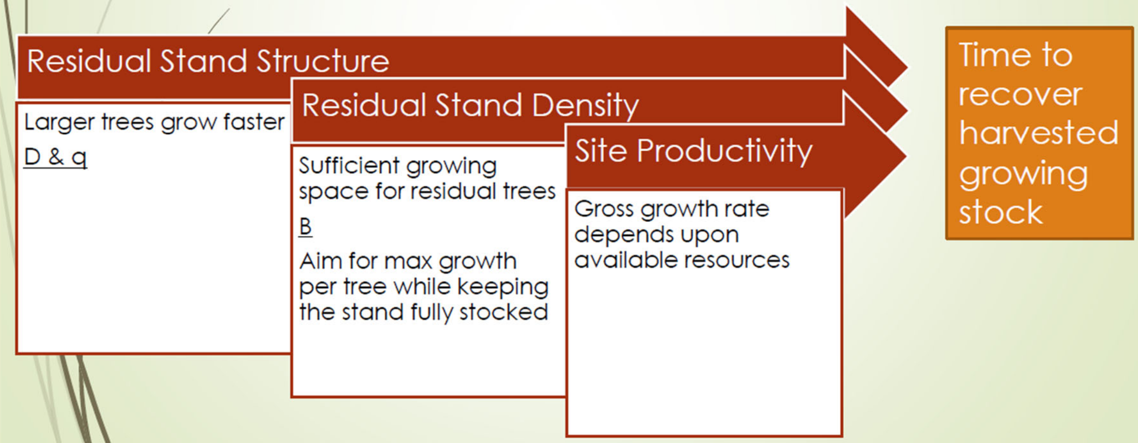
- Harvesting and stand tending are concurrent across each hectare of a block or stand
- Harvesting makes space for regeneration
- Thinning creates growing space for retained trees
- Stand remains stocked in overstory
- Regeneration occurs freely but slowly
- Quality of retained trees is critical to sustainability
- Cutting is repeated at least three times per rotation

Uneven-aged Methods In Practice

- Single Tree Selection
  - creates at least 3 age classes
    - intimately mixed
    - balanced distribution
  - harvest controlled by density
  - gap size depends upon silvics and site
  - favors shade tolerants

Re-Entry Period

- Link between stand-level harvest plan and AAC
- Long re-entry periods yield larger cut – more efficient
- Less cut harvest more frequently



Residual Stand Structure

Larger trees grow faster

D & q

Residual Stand Density

Sufficient growing space for residual trees

B

Aim for max growth per tree while keeping the stand fully stocked

Site Productivity

Gross growth rate depends upon available resources

Time to recover harvested growing stock

Describing the Desired Stand Q-Math

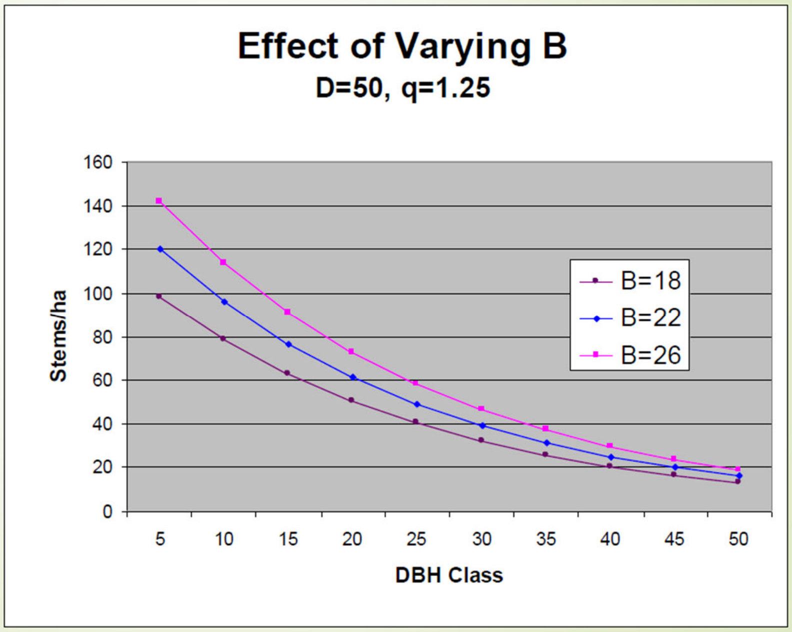
Managing by Unevenaged stands by BDq

- "B" is basal area, which is TPH $*$ D^2 (so X-axis times Y-axis)
  - *'places' the curve; as B gets bigger curve moves high*
- "D" is the largest diameter
  - *How long is the tail?*
- "q" is the q-ratio
  - *How steep is the curve?*

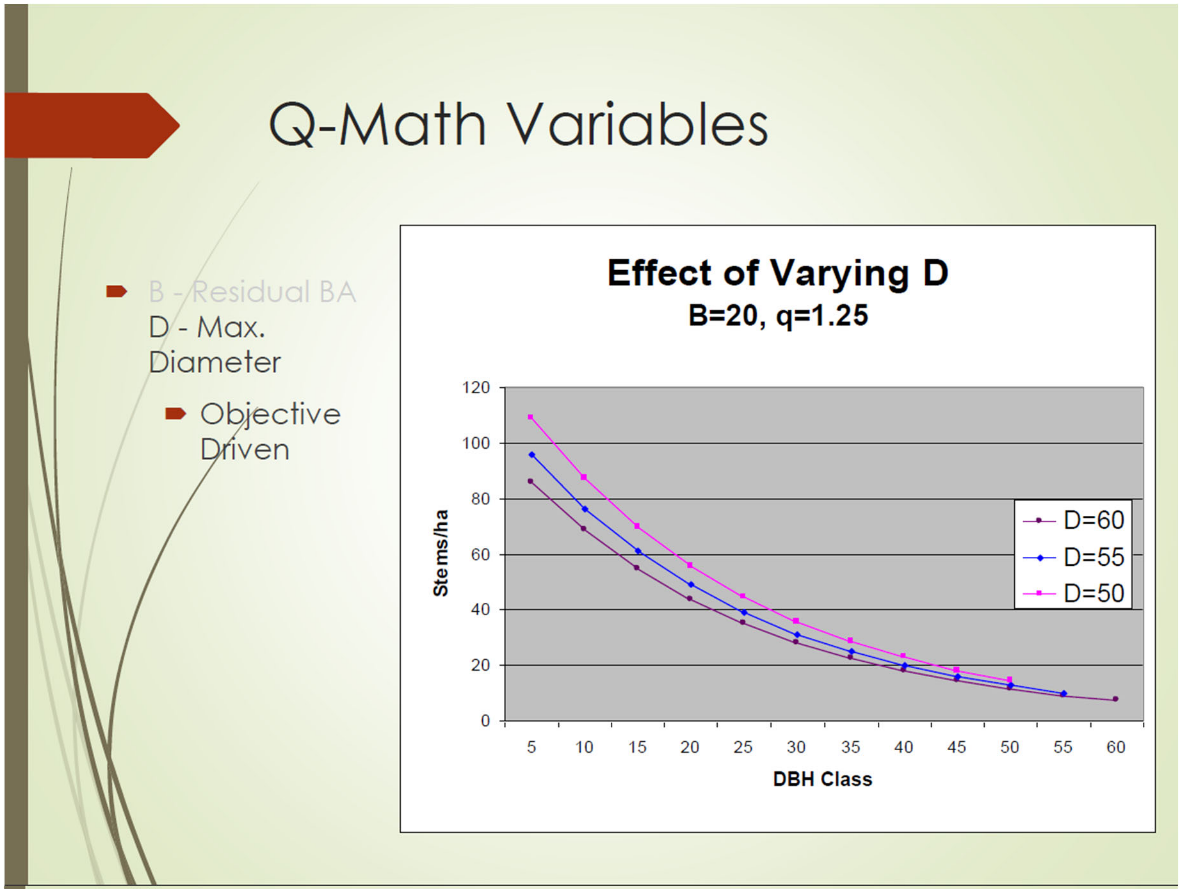
Warning – Rote Arithmetic

Q-Math Variables

- B -- Residual BA
  - Ecological limitations

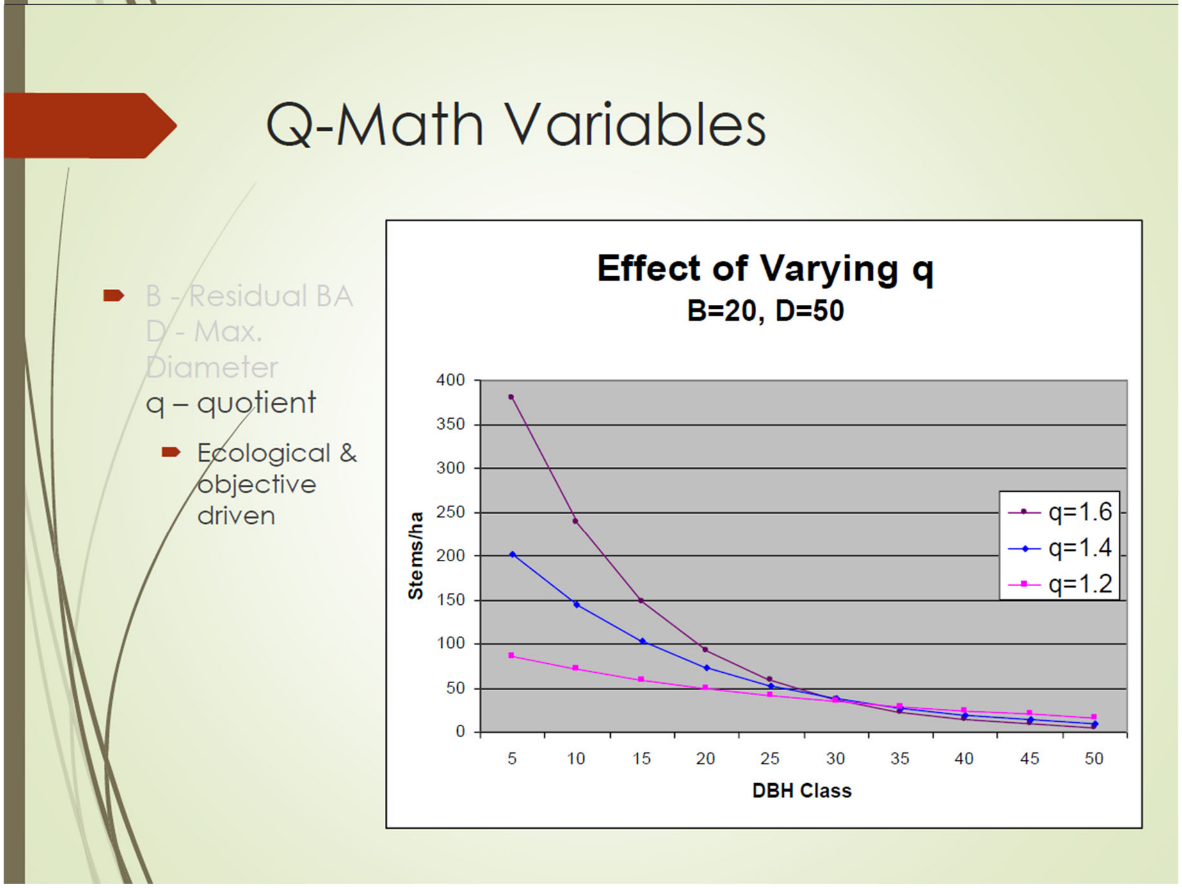

Effect of Varying B

D=50, q=1.25



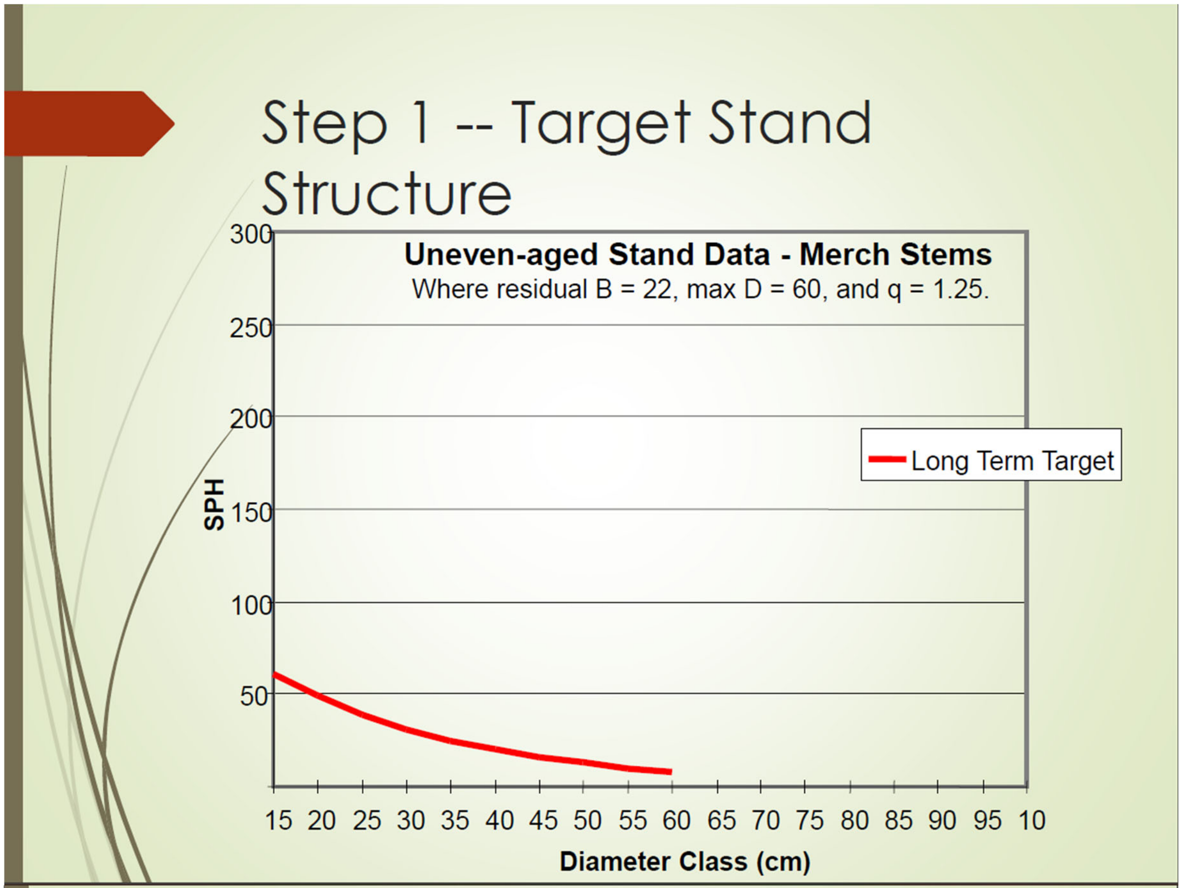
Q-Math Variables

- B - Residual BA
  D - Max. Diameter
  - Objective Driven

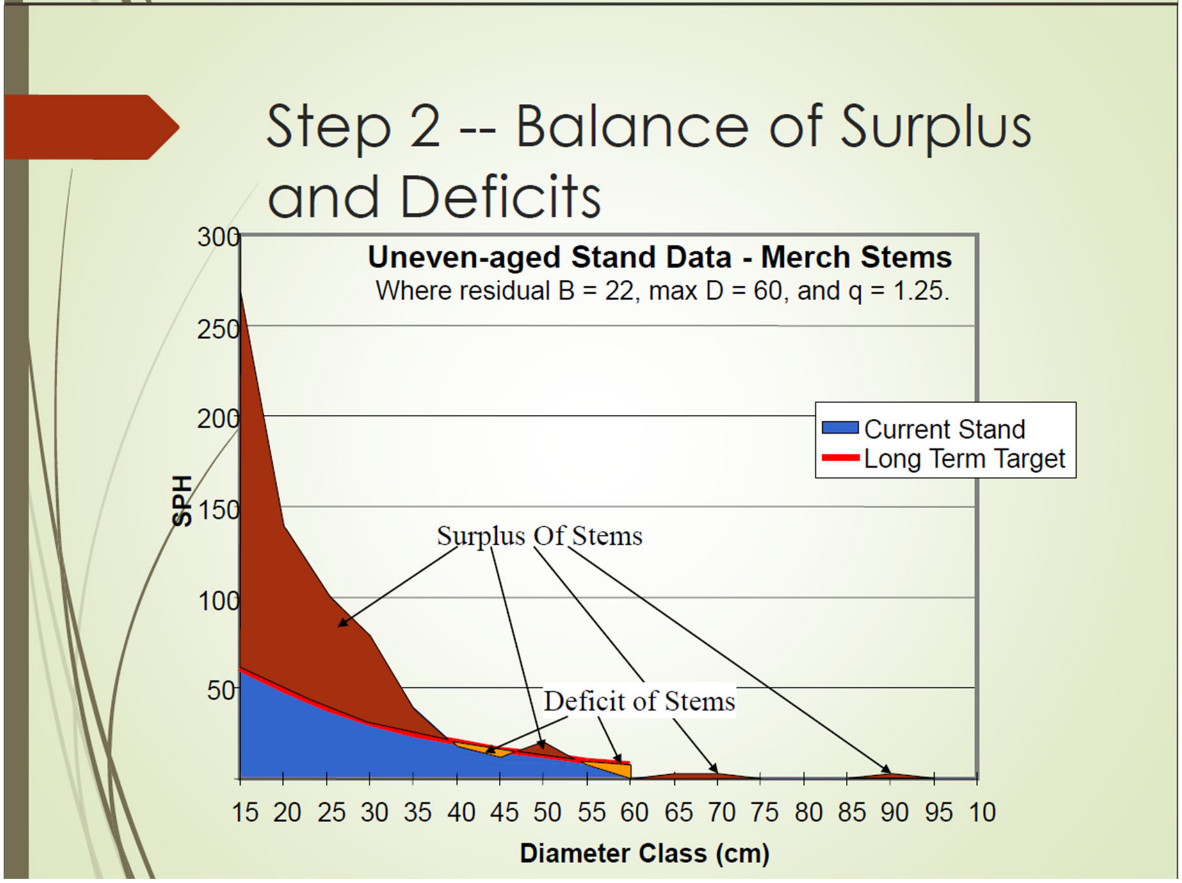


Q-Math Variables

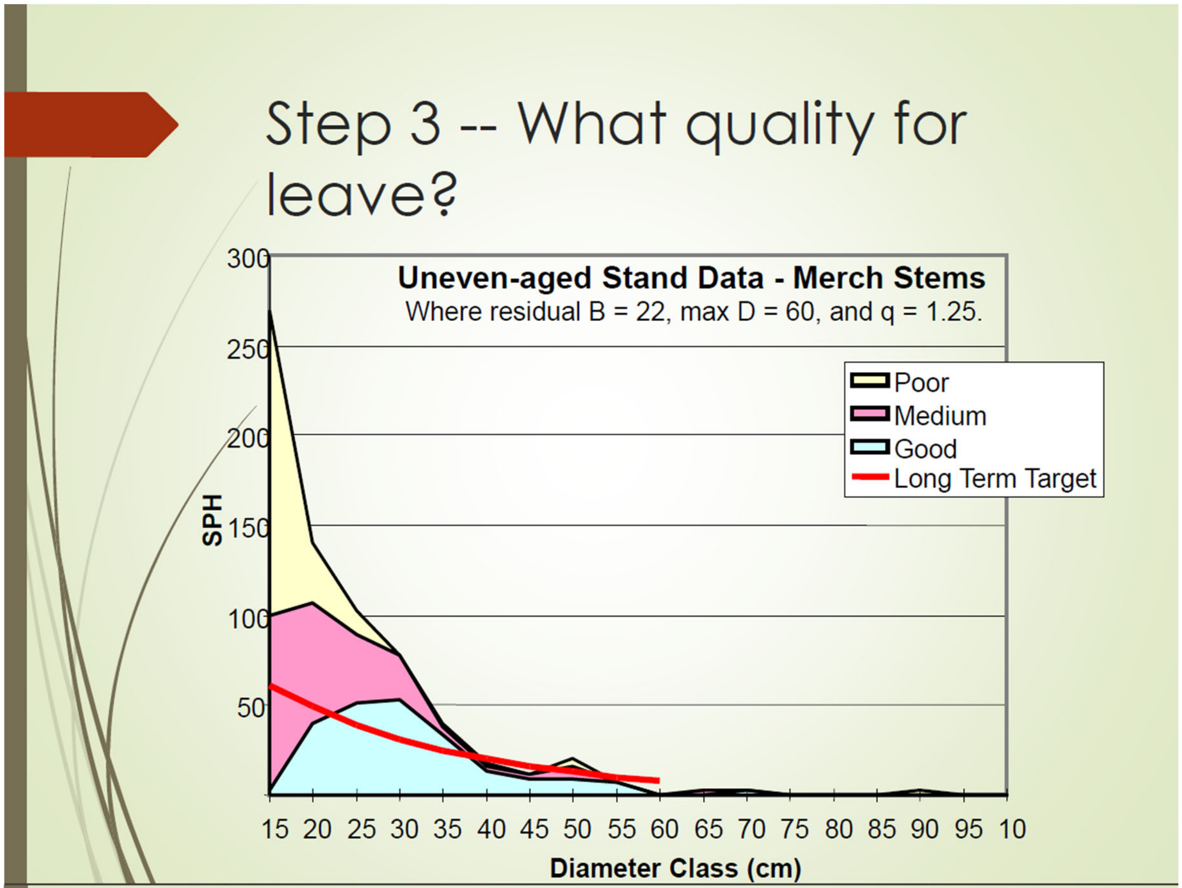
- B - Residual BA
  D - Max. Diameter
  q – quotient
  - Ecological & objective driven



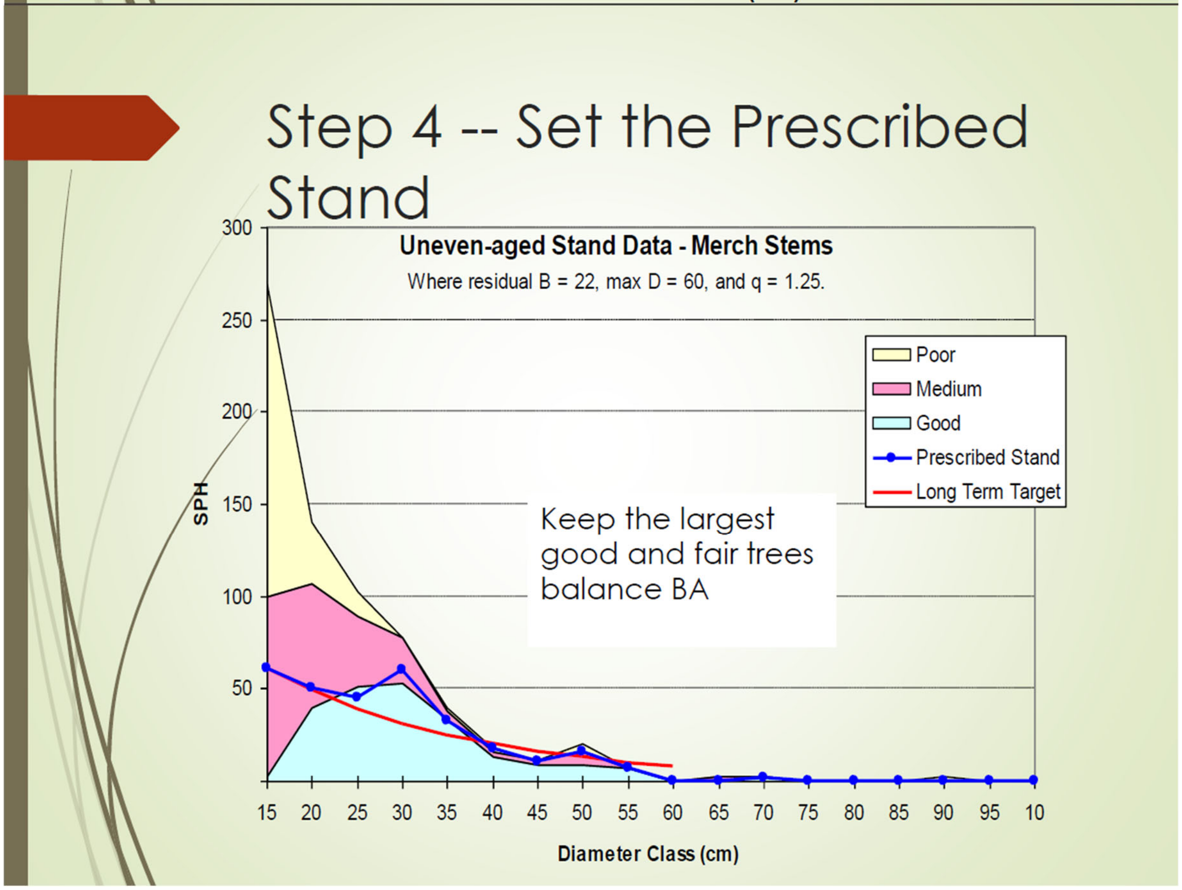
Step 1 -- Target Stand Structure



Step 2 -- Balance of Surplus and Deficits



Step 3 -- What quality for leave?



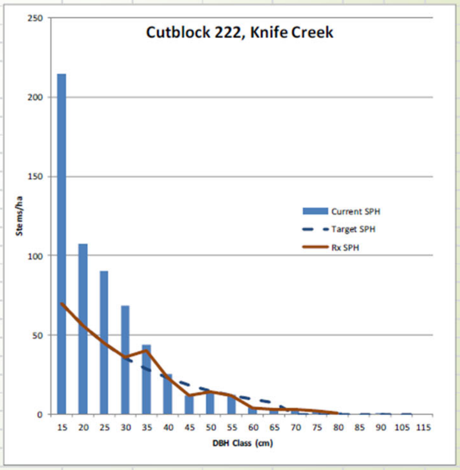
Step 4 -- Set the Prescribed Stand

Keep the largest
good and fair trees
balance BA

Set A Stand-Level Prescription

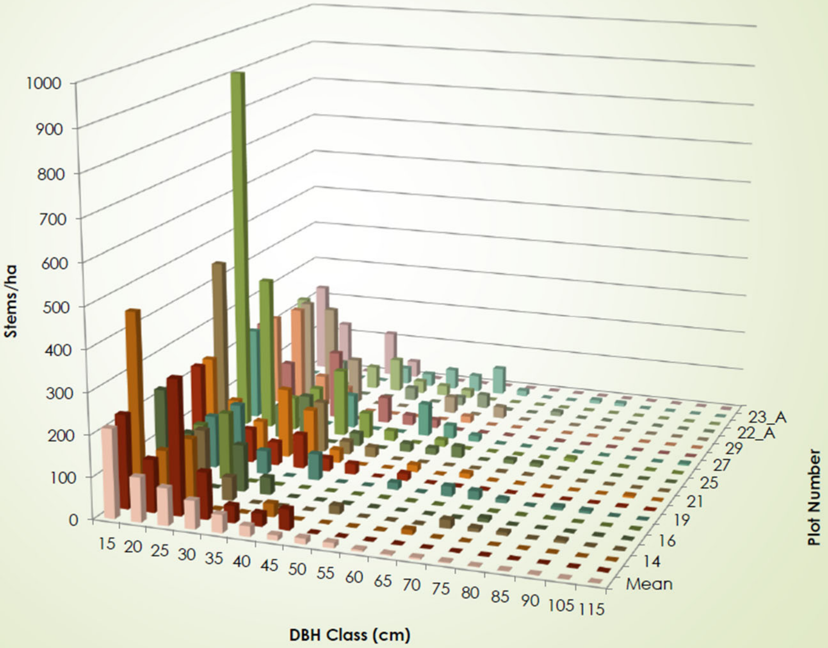
B= 27
D= 65
q= 1.25

DBH Class	Current SPH	Structure Go	Goal BA	Target SPH	Target BA	Rx SPH	Rx BA
15	214	9.31	0.16	69.71	1.23	70.00	1.24
20	107	7.45	0.23	55.77	1.75	56.00	1.76
25	90	5.96	0.29	44.62	2.19	45.00	2.21
30	69	4.77	0.34	35.69	2.52	36.00	2.54
35	44	3.81	0.37	28.55	2.75	40.00	3.85
40	25	3.05	0.38	22.84	2.87	23.00	2.89
45	12	2.44	0.39	18.27	2.91	12.00	1.91
50	14	1.95	0.38	14.62	2.87	14.00	2.75
55	12	1.56	0.37	11.70	2.78	12.00	2.85
60	4	1.25	0.35	9.36	2.65	4.00	1.13
65	3	1.00	0.33	7.49	2.48	3.00	1.00
70	3					3.00	1.15
75	2					2.00	0.88
80	1					1.00	0.50
85	0						
90	1					1.00	0.64
105	0						
115	0						
	603		3.61	318.62	27.00	322.00	27.30



Stand Structure in IDF is Variable

Both fine scale variability and the average condition are important!



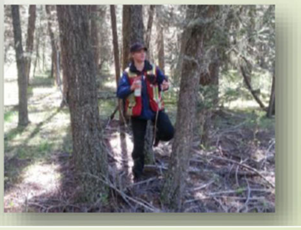
Work With Variability

Stand Level Plans

- Planning, scheduling
- Volume for harvest
- Road and landings to build
- Contractor
- Equipment
- Costs
- Revenues

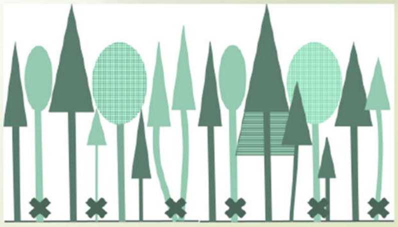
Tree Level Implementation

- Cut or leave this tree?
- Leave the best, cut the rest
  - Species, vigour, form
  - Insects and disease
  - Damage



Leave-Tree Selection

- Trees chosen for retention should be:
  - Achieving your objectives
  - Good vigour
  - Able to survive through the following cutting cycle;
  - Favoured species;
  - Good form;
  - Capable of producing seed;
  - Exerting desired influence on microclimate.

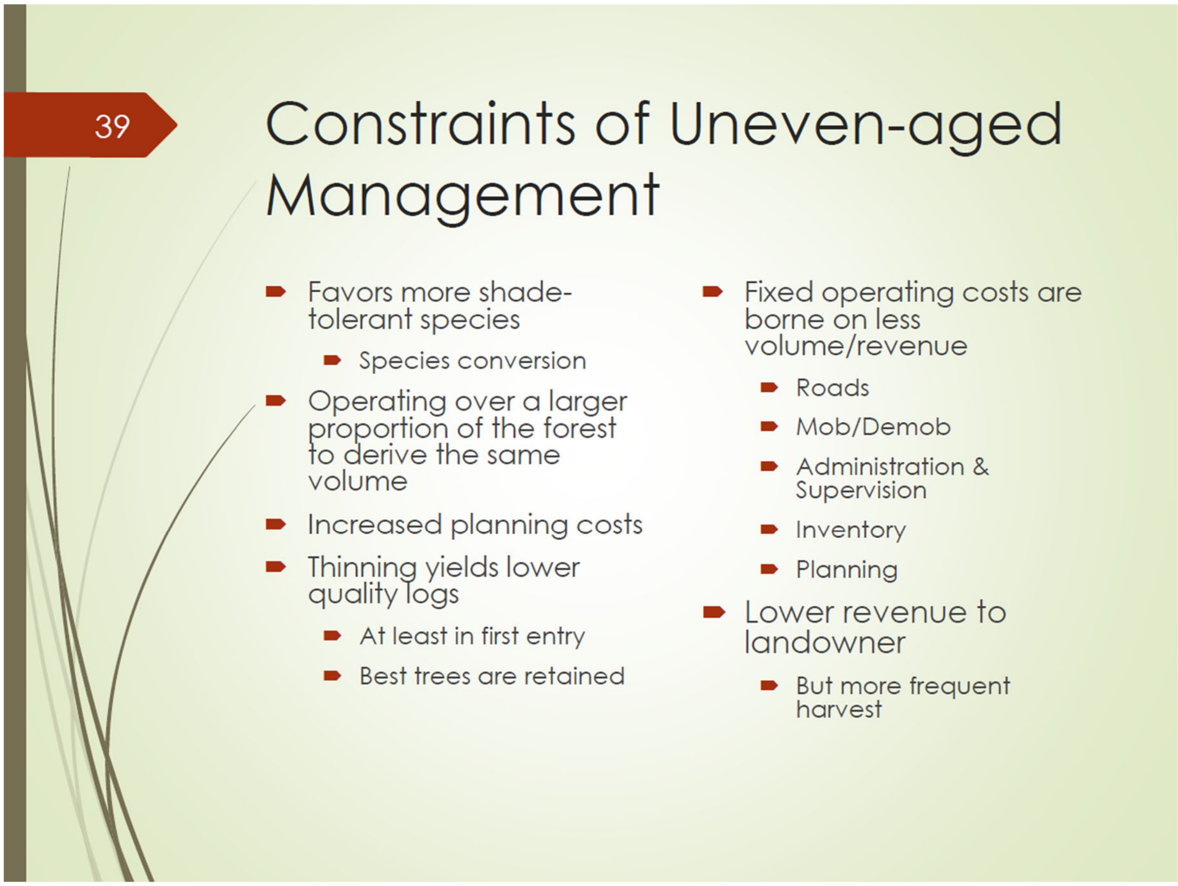


Which Trees Provide What You Value?

Leave trees that are productive

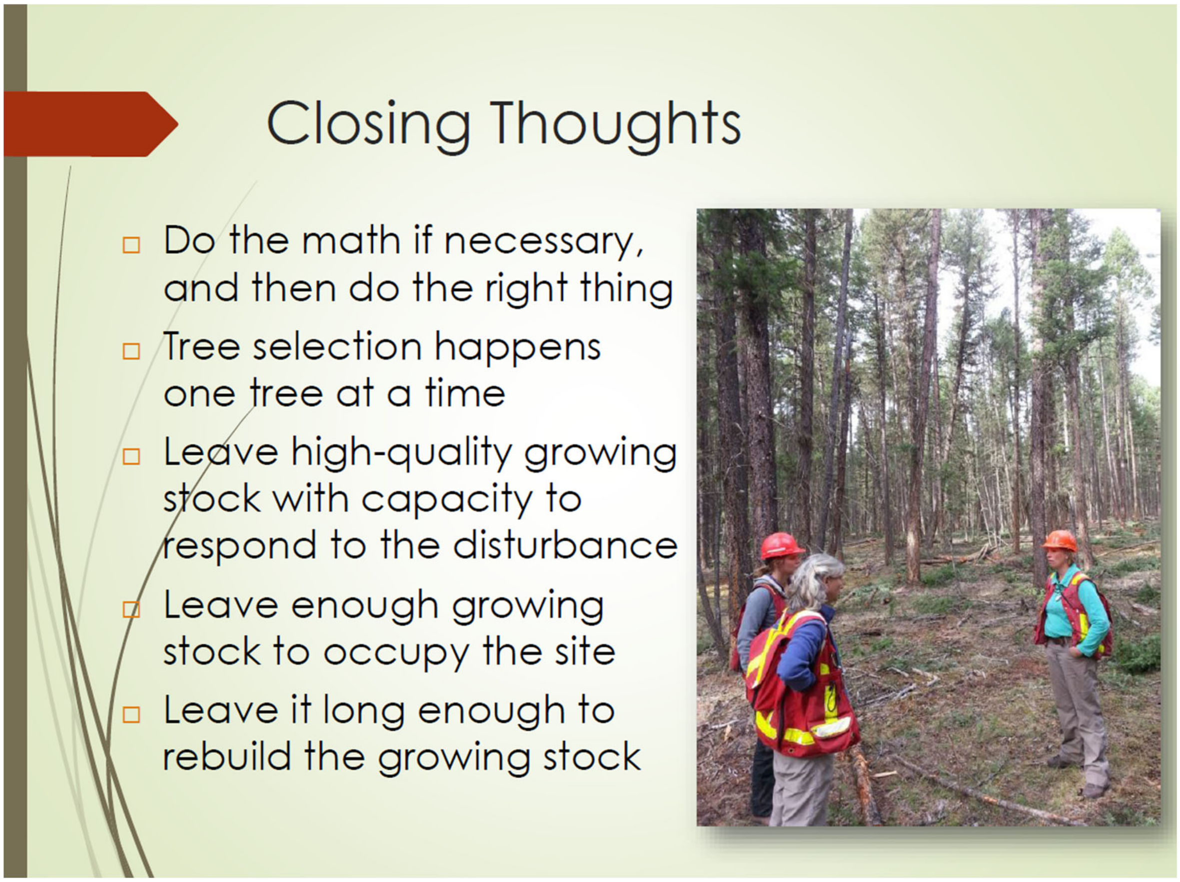
Take Away Points

- Retain good growing stock that can respond to new space
- Develop or use a classification system if it helps communication
- Faller's selection or marking crew?
  - Cost/benefit, risk reduction
  - Training and supervision are necessary
  - Consider the contractor's equipment constraints and motivation



Constraints of Uneven-aged Management

- Favors more shade-tolerant species
  - Species conversion
- Operating over a larger proportion of the forest to derive the same volume
- Increased planning costs
- Thinning yields lower quality logs
  - At least in first entry
  - Best trees are retained
- Fixed operating costs are borne on less volume/revenue
  - Roads
  - Mob/Demob
  - Administration & Supervision
  - Inventory
  - Planning
- Lower revenue to landowner
  - But more frequent harvest



Closing Thoughts

- ☐ Do the math if necessary, and then do the right thing
- ☐ Tree selection happens one tree at a time
- ☐ Leave high-quality growing stock with capacity to respond to the disturbance
- ☐ Leave enough growing stock to occupy the site
- ☐ Leave it long enough to rebuild the growing stock

Appendix 4: Gingrich Chart for the Dry-Belt Douglas-fir Area

A range of stocking rates[21] should be contemplated for Dry-Belt Douglas-fir, depending upon the stand structure. Furthermore, stands are generally grossly overstocked in the current condition and target stocking rates are difficult to visualize. Moss and Day (2019) developed a stocking chart patterned after Gingrich (1967) and Day (1998) for Dry-Belt Douglas-fir stands in the Cariboo, showing graphically the interplay between density and tree size, and describing the mortality rates associated with various stand densities. Built on approximately 275 growth and yield sample plots throughout the IDFxm, dk3 and dk4 subzones, the stocking chart shows:

- The maximum Basal Area observed;
- 65% of the maximum Basal Area, which is assumed to be the onset of competition-induced mortality;
- 35% of the maximum Basal Area, which is assumed to be the onset of crown closure;
- A management zone, where Basal Area Increment and mortality are optimized

To use the Gingrich Chart, stand inventory data (all diameters > 0 cm DBH) can be compiled to find the Basal Area and stems/ha for the stand. A thinning prescription can then be created to move the stand towards the lower left corner of the management zone. PrognosisBC can be used to forecast growth, or the growth rates on the chart can be used to estimate the time to arrive at a target Basal Area.

It is important to note that the important variables of stand structure are not fully represented on the Gingrich Chart at Figure 6, and a given point on the chart could have many different stand structures. As noted above, stand structure has a significant impact on stand growth and therefore resilience. It will be worthwhile exploring the impacts of stand structure on stand growth because each stand structure will have unique growth trajectories.

If a harvest prescription can retain the desired basal area of 20 m^2/ha then we would expect that established regeneration will take advantage of canopy gaps and grow up into the diameter distribution as trees in the first diameter class. Figure 7shows an example stand after thinning going through two periods of growth and regeneration, followed by thinning of the accumulated Basal Area. This demonstrates the utility of the Gingrich chart in setting targets for a thinning prescription.

Moss (2012) has developed a means of classifying stand structure. Initially, he recognized 17 stand structure classes, classified by the difference between the diameter distributions of trees/ha and basal area/ha. More recently Moss (2023, personal communications) has determined that stand structure can be easily described by three variables:

- Mean Tree Diameter – the simple mean diameter divided by number of trees
- Quadratic Mean Diameter – the diameter of the tree of average basal area; and
- Mean Basal Area-Weighted Diameter – where the sum of DBH multiplied by the basal area for each tree is divided by basal area for the stand.

These three variables, when coupled to trees per hectare and basal area per hectare, describe stand structure effectively and go a long way to explaining productivity in complex stands.

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[21] For a more thorough review of quantitative thinning guidance, refer to Ashton and Kelty (2018, pg 496-504).

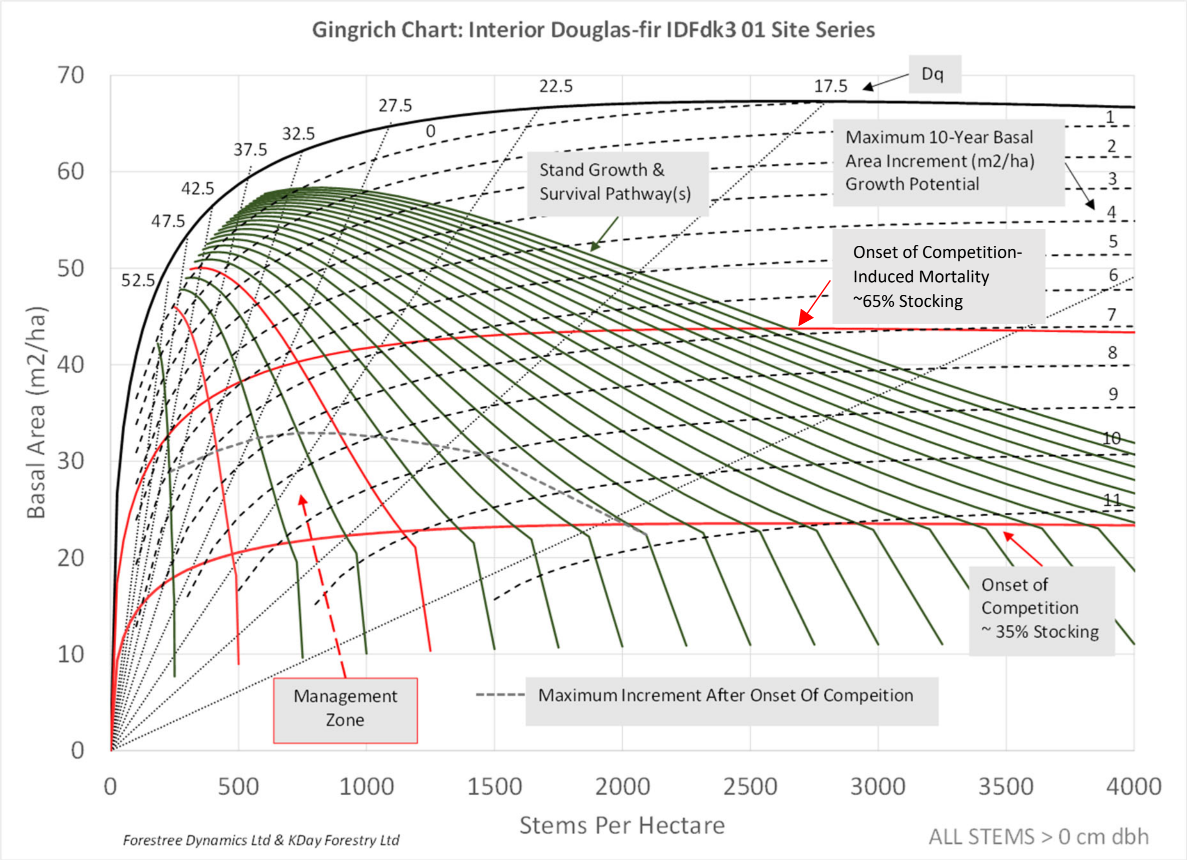

Figure 6: Gingrich Chart showing survival pathways (growth and mortality curves) and estimated basal area growth rates. Radial lines represent Quadratic Mean Diameter (Dq). The red lines on the chart bound a management zone, where the stand is fully stocked (more than 35% of the maximum BA), but not suffering competition-induced mortality (less than 65% of the maximum BA), and where stand growth and survival are optimized. Both axes represent all stems down to 0 cm DBH. From Ian Moss, Forestree Dynamics Ltd.

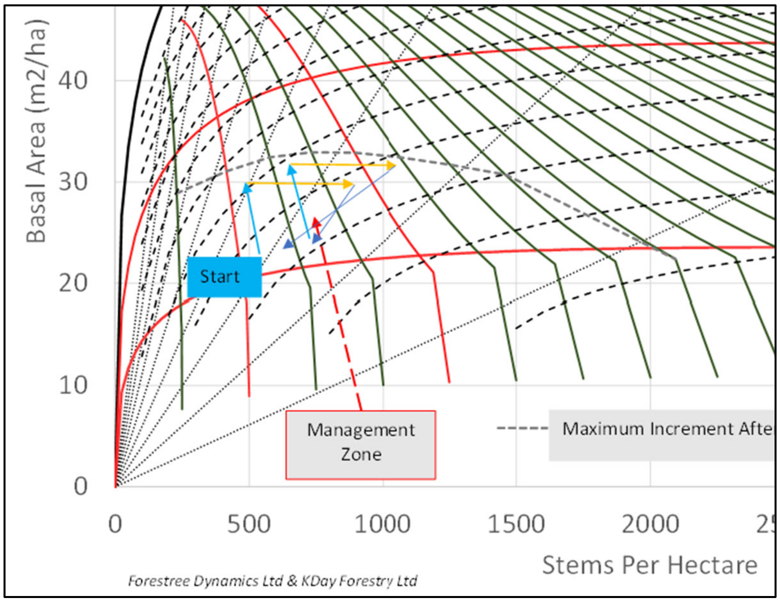

Figure 7: Close-up of Gingrich Chart showing two 30-year periods of growth (light blue arrows) and regeneration (yellow arrows) followed by thinning (dark blue arrows). The addition of 500 stems/ha of saplings by regeneration upgrowth are necessary after each entry. The harvest cycles described provide a yield of about 75 m3/ha in 20-30 years.