Extension Note

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The shelterwood silvicultural system in British Columbia – A practitioner's guide. Part 1: Implementation considerations

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Abstract

The shelterwood silvicultural system is not yet widely applied in British Columbia. However, it can be used to achieve particular forest land-use objectives, grow higher-value products, and incur lower silviculture costs when natural regeneration is secured. The first in a series of three extension notes guiding practitioners in the use of this system, Part 1 presents advantages and risks of the system. As well, it examines considerations related to forest health, natural disturbance, and administration that must be addressed before implementation of the system. Research results and practitioners' experiences suggest that although there are risks and administrative hurdles associated with partial cutting (including shelterwoods), the risks are manageable and the use of partial cutting results in significant benefits, especially on area-based tenures and private land.

KEYWORDS: *administrative issues; forest health; ice damage; implementation; risks/benefits; shelterwood silvicultural system; snow damage; windthrow.*

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Introduction

A silvicultural system is defined as a planned program for regenerating, tending, and harvesting forests (Matthews 1991). Troup (1928) described the shelterwood silviculture system as a means of attaining natural regeneration over a series of harvests, while protecting a new crop with cover provided by the overstorey. According to Smith et al. (1997), the shelterwood system is used to regenerate a "double-cohort" stand by partial cutting.[1] In the shelterwood method of regeneration, some members of an older cohort (the overstorey) are retained to provide seed for regeneration and shelter for the new stand, and to gain additional growth during the regeneration phase. Generally, the shelterwood system is intended to regenerate an even-aged or two-aged stand over a period of 20 years or so. In using the shelterwood method, a sequence of harvests reduces site occupancy to less than full capacity (Nyland 1996), thereby creating environmental conditions that encourage natural regeneration and growth of retained species (Matthews 1991; Tappeiner et al. 2007).

While the shelterwood silvicultural system is not yet commonly used in British Columbia, some practitioners in the province and elsewhere have experience to share. Research installations established across the province in the 1990s to test a variety of silvicultural systems, including shelterwood systems, as alternatives to clearcutting are providing operational direction (e.g., Roberts Creek Study Forest, Boston Bar Silviculture System Project, Montane Alternative Silvicultural Systems Project, Uniform Shelterwood Systems in the Sub-Boreal Spruce Zone, Aleza Lake Interior White Spruce Shelterwood Case Study, Kootenay Shelterwood Harvesting in Root Disease Infected Stands, Itcha-Ilgachuz Alternative Silvicultural Systems).

Planning for partial cutting of any kind combines all the fundamentals of forestry: management objectives, silvics, ecology, site, time, and stand dynamics. This extension note is the first of three intended to help practitioners understand the risks and benefits of employing the shelterwood silvicultural system.

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Genesis of the shelterwood silvicultural system in British Columbia

Tappeiner et al. (2007) cite European references from as early as 1911 regarding the shelterwood silvicultural system. These authors note that "the theory and practice of silviculture in North America is rooted in central Europe of the 19th century or earlier" (p. 4). An urgent need in Europe for fuelwood, building material, and cover for game at a time when forests had been severely depleted gave rise to planned systems for extraction and regeneration, and that body of knowledge arrived in North America in the late 1800s. However, forests in Europe were much different from the untouched first-growth native forests of North America (Tappeiner et al. 2007). Weetman (1996, p. 17) quotes D.M. Smith (1973) saying: "The variability [of forest stand conditions in the United States and Canada] is great enough that decisions about silvicultural treatments are best made by competent practitioners on the ground. Generalized guidelines and policies can be established from a distance but they lead to mistakes if they are too specific." This contextual distinction lives on today in most parts of British Columbia, where we are still setting plans and prescriptions for previously unmanaged stands.

In the 1920s, the Province of British Columbia established its first experimental station at Aleza Lake (now Aleza Lake Research Forest) and a program to study sustained yield forestry that continued until 1963 (Jull 2006a, 2006b). Although clearcutting dominated coastal forestry, the most widespread approach to timber harvesting in the Interior before 1960 was by diameter-limit cutting[2] for spruce (*Picea* sp.) and Douglas-fir (*Pseudotsuga menziesii*) sawlogs

[1] Partial cutting: to cut selected trees and leave desirable trees for various stand objectives.
[2] Diameter-limit cutting: partial cutting whereby trees above a certain diameter at breast height (e.g., 46 cm) were harvested.

(Jull 1997). According to Jull (1997), early attempts at partial cutting methods were carried out in the absence of a good understanding of site ecology, stand dynamics, and windthrow susceptibility, and outcomes were variable. The failures "could be rapid, spectacular, and of course conspicuous," but the successes were "inconspicuous . . . and suffered from poor documentation" (Jull 1997, p. 5).

Research priorities changed in the 1960s when innovations in logging and sawmilling technologies enabled efficient manufacturing of smaller logs in British Columbia's interior. Clearcutting became the most commonly used silvicultural system in the province. Regeneration relied initially on natural seeding and roughly treated advanced growth and then on planting programs beginning in the 1970s in the Interior (Jull 1997). Clearcutting, reports Jull (1997), accounted for over 90% of the area harvested in British Columbia between 1970 and 1995, with 10–20% of the harvest area in the Southern Interior being partial cutting and 0–2% in the balance of the province.

In 1996, the *Forest Practices Code of British Columbia Act* attempted to "codify" the use of silvicultural systems by standardizing terminology and categories of approaches (B.C. Ministry of Forests and B.C. Ministry of the Environment 1995a). In 2003, the *Forest and Range Practices Act* allowed for greater flexibility for, and reliance upon, professional resource managers to apply silvicultural systems. With data from multiple research projects established in a variety of forest conditions, some having more than 15 years of monitoring (Waterhouse and Newsome 2006 ; D'Anjou 2007), practitioners can apply new knowledge to management decisions.

Given this new knowledge, partial cut management approaches, including shelterwood silvicultural systems, may become more widespread in the province. A shift in the implementation of silvicultural systems other than the clearcutting of public forests has been happening since the late 1990s (Figure 1). Shelterwood systems allow for land-use objectives relating to visual quality, community watersheds, recreation, or biodiversity to be pursued simultaneously with timber production. Shelterwood silvicultural systems may thus be complementary to management goals for private forest holdings, for the growing number of community forest and woodlot tenures, and in additional situations where land-use pressures are more concentrated (e.g., the greatly reduced near- to mid-term green timber supply on public lands following the mountain pine beetle infestation).

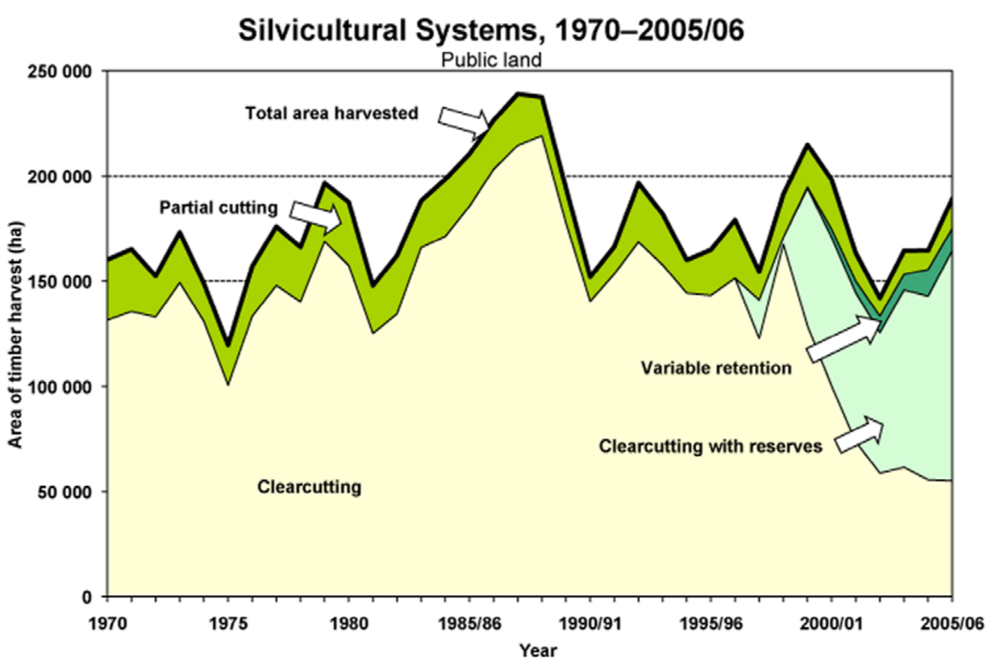

FIGURE 1. Silvicultural systems utilized on public lands in British Columbia (B.C. Ministry of Forests and Range 2006).

Benefits and risks of the shelterwood system

Troup (1928) recognized most of the same benefits and risks as we currently encounter in the use of the shelterwood systems. To the list of beneficial outcomes, we can now add some items reflecting more recent observations.

Benefits

1. The overstorey provides protection of regeneration from harsh environmental conditions, such as frost, drought, or extreme heat.
2. Moderation of surface soil drying improves germination and survival.
3. Reduced cover and vigour of competing vegetation and invasive plants improves survival and growth of regeneration.
4. Natural regeneration provides a lower-cost regeneration strategy than planting, and the trees are adapted to site and microsite.
5. Natural regeneration may be one strategy to deal with the uncertainty of climate change, by allowing the expression of genetic variability to challenge changing environmental conditions (Kellomäki et al. 2005).
6. The shelterwood method leads to increased soil-moisture capture and storage because of increased precipitation throughfall (relative to uncut condition) and extended snowmelt period (relative to clearcut situation) (Troendle and King 1987; Pike and Scherer 2003).
7. The overstorey can show enhanced growth during the regeneration period,[3] providing additional harvest volume if removed thereafter.
8. Shelterwood systems soften the visual impact of harvest compared to clearcutting.

Risks

1. The planning and implementation of shelterwood systems requires more experienced personnel than do clearcuts, and timber marking, if done, adds to layout costs (Phillips 1996; Dunham 2001).
2. With retention of an overstorey, harvest volumes are lower, and a greater area is required to provide the same harvest volume as a clearcut.
3. Falling and tree removal are more challenging, and perhaps more time-consuming and costly, as residual trees and established regeneration require protection.
4. Windthrow can be expected in residual stands following harvesting.
5. Regeneration periods are longer than in clearcuts because of slower regeneration growth while the overstorey is present.
6. Excessive natural regeneration may require density management to meet stocking objectives.
7. Since implementation of the shelterwood system occurs over a period of years, whereby the low-quality timber is removed initially and the high-quality timber is retained during the regeneration period, any overstorey losses affect the most valuable timber.
8. Elements of the administration of public forests in British Columbia, such as stumpage appraisal, the tenure system, and stocking standards, either fail to support or inhibit partial cutting methods.

Considerations regarding benefits and risks of the shelterwood method to non-timber values are specific to British Columbia (Table 1).

Forest health considerations and the shelterwood system

Windthrow, snow, and ice damage

Windthrow events are one of the principal risks of partial cutting (Jull and Sagar 2001). Windthrow, snow, and ice damage are part of the natural disturbance regime in all forest ecosystems of British Columbia. Mitchell (1995) found that sustained winds of 40 km/h were sufficient to cause windthrow along newly exposed edges and further reported that a strong wind event in 1990 with peak sustained winds of 54 km/h damaged in excess of 1.5 million m^3 of timber in the Quesnel Forest District. Retained overstorey trees are more prone to windthrow when uniformly dispersed than when aggregated into groups (Beese 2001; Jull and Sagar 2001).

Windthrow, snow, and ice damage are variable in time, space, and treatment. Jull et al. (1997) found only 1% of the residual trees were tipped or broken by wind 2 years after a heavy (60%) uniform removal in a spruce–subalpine fir stand, despite five separate wind events with gusts exceeding 72 km/h.

[3] Regeneration period: time required for the establishment of a new stand by natural or artificial regeneration.

TABLE 1. Benefits and risks of the shelterwood method to non-timber values

Value	Benefits	Risks
Biodiversity at stand and landscape levels	Overstorey grows to large size and increased age, providing important attributes while it is maintained.	Reduced development of early seral structures and habitats that are conducive to some species.
	Extended harvest period may serve to keep mid-to-late seral species in the stand through the regeneration period and pass them on to the regenerating stand.	Road networks and multiple entries into stands put repeated stress on biotic systems and habitats (Lindenmayer et al. 2008) and may disturb some habitat values repeatedly.
	Overstorey retention can provide large old trees and downed logs through the subsequent rotation.	Removal of wildlife trees and other poorly formed trees from overstorey may reduce habitat values of the stand for wildlife and other organisms.
	A component of structure and cover is provided during the regeneration period, shortening the early seral stage.	
	The sharp transition from closed forest to open ground as caused by clearcutting is averted.	
	Complexity is increased at the landscape level.	
Range	Increased production of desirable forage in some ecosystems.	Skid trails provide easy movement, and dead-end trails may induce cows to develop new travel routes.
	Greater diversity of grazing opportunities.	Shady conditions may be desirable for resting, causing damage to regeneration.
	Longer-lasting water sources.	Sheltered and moist conditions more conducive to biting insects.
Water	More precipitation throughfall than in uncut stands but reduced snowmelt and evapotranspiration than in clearcuts allow for accumulation of soil moisture.	Increased soil moisture can lead to soil compaction by logging machinery.
	Shelterwoods have been used to increase water yields (Troendle and King 1987).	Potential for erosion, puddling on trails if compaction occurs in logging.
		Repeated entries increase potential for soil compaction.
Non-timber forest products	Open forest conditions improve fruit production on important berry plants as compared to uncut stands.	Disturbance via repeated entries may impact some resources.
	Suppression of understorey growth reduces necessity of brushing operations.	Shaded conditions reduce growth and value of some products (e.g., boughs) compared to clearcut areas.
	Shaded conditions enhance growth and value of some products (e.g., salal).	
	Valuable trees can be retained in the overstorey (e.g., birch for birchbark).	
	Macrofungi diversity is greater than in clearcuts (Fogarty et al. 2001).	

Waterhouse (1999) reports that only 5 years after cutting, the overstorey in a uniform shelterwood which had undergone a preparatory cut was as or more stable than the uncut treatment. However, after a second partial-harvest entry in year 10, the flattest and moistest block of three replicates began to suffer significantly greater wind damage, and windthrow rates are increasing year after year on that block. Windthrown trees on the worst-damaged site had flat platelike root structures indicative of moist soil conditions (Waterhouse and Newsome 2006). In the authors' experience, if residual trees are still standing after 3 years, the probability of a catastrophic loss is much reduced.

Day (2007a) used stand-level assessments to support decisions regarding residual stand density, leave-tree characteristics, block boundary locations, and location and size of wildlife tree patches. Mitchell (1995) provides a framework for this process, which he terms the "windthrow triangle." The relative hazard of windthrow on forested sites can be evaluated using the following three-step assessment procedure.[4]

1. **Topographic exposure –** Are wind speeds average for the area, or do they vary due to the presence of terrain features?
2. **Soil properties –** Is root anchorage restricted by an impeding layer, low soil strength, or poor drainage?
3. **Stand and tree characteristics –** Are individual trees within the stand already adapted to wind loads? Is the stand comprised of uniformly tall and dense trees, such that individuals remain standing only by leaning on their neighbours? Will the proposed harvesting strategy increase wind loading on retained trees?

The trees at the greatest risk of loss to wind, snow, or ice damage are those that are tall and slender, recently exposed, and standing on a terrain feature where wind speeds are high. The height (metres) to diameter (centimetres) at breast height ratio (H/D) is a good indicator of the risk of stem breakage or windthrow. Stathers et al. (1994) recommended that breakage is less likely in trees with H/D ratios less than 60, whereas trees with H/D ratios greater than 100 are most prone to breakage and windthrow. Jull and Sagar (2001) found that for interior Douglas-fir in particular, leave trees with an H/D ratio of less than 50 experienced little wind damage, whereas those with increasingly higher ratio values were correspondingly prone. They also reported that percent live crown and tree height were not good indicators of wind firmness.

Species differences also affect windthrow and breakage risk. For example, the flexible crowns of redcedar and narrow crowns of true firs shed snow, while the wide, stiff crowns of Douglas-fir hold snow. On Vancouver Island, redcedar appeared to be more windfirm than either Pacific silver fir (*Abies amabilis*) or western hemlock (*Tsuga heterophylla*) (Beese 2001). However, since the interacting effects of site, stand, and individual tree characteristics also influence windthrow susceptibility, species alone is not a reliable predictor (Stathers et al. 1994).

Day (2007a) distinguished between catastrophic damage and acceptable losses and accepted that windthrow will occur after partial cutting. Prompt salvage of damaged trees is undertaken to reduce the risk of bark beetle outbreaks. Mitchell (2001) showed that codominant trees retained in a uniform shelterwood responded to thinning by significantly reducing height growth and increasing diameter growth in the lower boles. This reallocation of growth was an equilibration response to the new wind environment following thinning (Mitchell 1995), and it continued for a period of 10 years.

Lessons learned

- The risk of damage from windthrow, snow, and ice is variable, depending on tree, stand, and site characteristics.
- Residual trees should be chosen from among those that are the most resistant to windthrow, snow, and ice damage.
- Forked, leaning, and swept trees are more likely to suffer damage.
- Stability is possible on most sites, but residual stand density should be site and stand dependent. In uniformly tall and dense stands, even light to moderate thinning can lead to catastrophic failure.
- Damage in thinned stands appears much worse than in unthinned stands because of greater sight distances.
- Root decay caused by pathogenic fungi, stem decay, or saprophytic fungi introduced by previous logging damage all predispose trees to damage by windthrow, snow, and ice.

[4] Windthrow assessment field card, B.C. Ministry of Forests Forest Practices Branch, Form FS 712-2 HFP 98/05.

- Windthrow, snow, or ice damage can contribute to the rapid buildup of bark beetle populations and put the residual stand at risk.

Bark beetles

The potential of bark beetle attacks on the overstorey are an important factor to weigh when considering application of the shelterwood system. Ten bark beetle species are active in British Columbia (Henigman et al. 2001), each of which threatens various mature conifer species. Some bark beetle species (notably Douglas-fir and spruce bark beetle) are attracted by recently damaged or windthrown trees and can attack nearby standing green trees, particularly if they are suffering stress. Experience at the Alex Fraser Research Forest indicates that trees retained in the overstorey suffer a period of stress as they adapt to their new environment, and during that period of adjustment they are susceptible to bark beetle attack.

The following bark beetle detection and management activities are sufficient to control outbreaks resulting from partial cutting.

- Trees that have beetles under the bark at the time of logging should be identified and removed.
- Non-merchantable green logs or pieces (e.g., sections of Douglas-fir and spruce containing decay and discarded during harvesting or bucking) should be removed from the stand and destroyed so they are not attractive to bark beetles.
- Trees with significant logging damage, particularly falling damage (e.g., stripping of a significant part of the crown), should be removed because they are attractive to bark beetles.
- Stands should be monitored over successive years for breakage from windthrow, snow, or ice, and sanitation logging carried out as necessary to prevent the expansion of bark beetle populations.

Dwarf mistletoes

In British Columbia, four host-specific species of parasitic dwarf mistletoe (*Arceuthobium* sp.) affect lodgepole pine (*Pinus contorta*), Douglas-fir, western hemlock, and western larch (*Larix occidentalis*). Only 10 widely spaced mature trees per hectare are required to infect the regeneration on the whole hectare over a 15-year period (Henigman et al. 2001). Dwarf mistletoe infections reduce both volume growth and wood quality, particularly on poor sites (Henigman et al. 2001). An overstorey of infected parents will regenerate both trees and dwarf mistletoe plants, so if a shelterwood system is required, there must be a regeneration strategy that favours species different from the dwarf mistletoe host.

Root diseases

In British Columbia, five principal root diseases affect mature trees and stands and contribute to ecosystem processes (B.C. Ministry of Forests and B.C. Ministry of the Environment 1995b; Henigman et al. 2001). It is critically important that practitioners identify the presence of root disease and understand the host/disease interactions in order to forecast the impact on both overstorey and regeneration. Here are the key considerations when using the shelterwood silvicultural system.

- Stumps and roots of recently cut trees can be colonized rapidly by root disease-causing fungi, providing energy and conduits for infection of healthy residual trees and regeneration (B.C. Ministry of Forests and B.C. Ministry of the Environment 1995b). As such, each harvest entry in the overstorey can encourage virulence and persistence of the disease in the stand.
- Infected trees may be predisposed to windthrow (Whitney et al. 2002) and snow or ice damage, even if they are not symptomatic.
- Incidence of infection and extent of damage may increase over time in the absence of treatment.

As with clearcutting, control options for root disease in a shelterwood are limited. Day (2007a) considered root disease to be a feature of a site, meaning that eradication of the disease is probably not possible. Instead, management options include:

- identifying root disease centres before harvesting;
- favouring root disease centres as in-block reserves (e.g., wildlife tree patches);
- retaining vigorous trees of resistant or immune species in the overstorey;
- regenerating a mixed-species stand including resistant or immune species in higher densities to allow for disease-induced mortality; and
- favouring competitive fungi by maintaining woody debris (B. Chapman, pers. comm., January 2009).

If treatment to reduce disease inoculum is pursued, then cutting should be aggregated into groups to ease treatment operations. The dominant treatment approach advocates mechanical removal of stumps and large roots (Cleary et al. 2008). A second approach, currently under investigation, advocates the use of an antagonistic saprophytic fungus (*Hypholoma fasciculare*) to colonize stumps and roots, thereby excluding the root disease fungus (Chapman et al. 2004). If inoculum reduction treatment plans need to be developed for a stand, consultation with specialists is recommended.

Stem and butt decays

Henigman et al. (2001) described nine stem decays that affect commercial tree species throughout British Columbia. Most stem decays have noticeable external indicators, usually fruiting bodies or "conks" growing on the outside of the tree, indicating the extent of the decay inside the tree. Trees with stem and butt decay should be cut in the first harvest entry because they may be susceptible to windthrow, snow, or ice damage. However, such trees, especially living trees with heart rot, are necessary for cavity-using wildlife (Martin et al. 2004), so there should be some retention of this limited resource on the landscape.

Wounding to the overstorey

Despite the best efforts of personnel to reduce logging damage to residual trees, some will occur. Wounds where the bark is broken, exposing the wood to the air, lead to wood discolouration and decay. Even though new bark and sapwood can enclose a wound, decay fungi quickly establish on exposed wood (Zeglen 1997). It is important to develop a strategy to reduce the impacts of decay on residual stands after harvesting activities.

Some species are less likely than others to decay after wounding (Aho et al. 1983; Zeglen 1997). Only 7.8% of scars on lodgepole pine (Allen and White 1997) and 5% of scars on interior Douglas-fir (Craig 1970) resulted in decay. Spruces, hemlock, true firs, redcedar, and larch decay readily after wounding (Aho et al. 1983; Allen and White 1997; B.C. Ministry of Forests and B.C. Ministry of the Environment 1997). In Sitka spruce, decay volumes in wounds larger than 9 dm^2 doubled every 3 years, and those in western hemlock and true firs doubled every 10 years after injury (Zeglen 1997).

The following cautions and guidelines are based on local experience and five pertinent reports (Craig 1970; Aho et al. 1983; Allen and White 1997; B.C. Ministry of Forests and B.C. Ministry of the Environment 1997; Zeglen 1997).

- Bark is easily wounded in spring and early summer.
- Large or wide wounds are more likely to cause decay than small or narrow wounds.
- Wounds that gouge or splinter the wood are more likely to cause decay than wounds that do not.
- The larger the tree is when wounded, the greater the decay volume that can be expected to result. (Decay will occur within the diameter of the tree at the time of injury due to wound compartmentalization.)
- Wounds in contact with the ground are more likely to result in decay than those higher up the stem, and decay there progresses more rapidly.
- Decay is established relatively quickly, and 5% wood volume losses can occur in just 10 years.
- Some wounded Douglas-fir or lodgepole pine may be left.
- Wounded spruce, true firs, hemlock, and redcedar should be cut.
- Wounded aspen, birch, and cottonwood should be cut if their contribution to timber values is important.

Damage to the tops of trees is most critical, since the resulting wounds cause the tree to become very attractive to bark beetles. Wounds in the upper bole also have a higher incidence of infection by decay fungi (Craig 1970). A tree with a broken top or limbs sheared off will not contribute well to the desired stand and should be cut.

If the stand will not be entered again within 10 years of a harvest entry, damaged trees should be marked for a final clean-up pass before logging is complete. Farrar (1996) recommended that 3–5% of the harvest be retained unmarked until this final clean-up pass, to hedge against overcutting.

Administrative issues on public forests in British Columbia

Partial cutting approaches present a challenge to silviculture administration in British Columbia's public forests. Administrative systems such as stumpage appraisals, stocking standards, and site plans are oriented generally toward clearcutting, because the vast majority of forest harvesting in the province has been carried out this way (see Figure 1). Delays arise when novel approaches bump into administrative systems.

Appraisal and tenure

Calculations used in the current appraisal system[5] can create disincentives to the implementation of shelterwood systems. For instance, if licensees are removing lowest-quality stems in the stand during the initial tree removal phase, stumpage rates may exceed the rate for a clearcut of the same site (B.C. Ministry of Forests and Range 2008). In addition, over the longer term, licensees with volume-based tenures who initiate shelterwood systems will not necessarily have the right to the final harvest (if a final cut is an objective). This is because the geographic areas in which such tenures apply can change over the time required to fully implement a shelterwood system.

Area-based tenures are better suited to longer-term management because the same licensee will more likely realize the economic benefits of these activities. However, corporate and individual philosophy has much to do with the value a company or landowner places on the future. Such administrative hurdles do not imply that government actively discourages partial cutting. In fact, the *Forest Range and Practices Act* is amenable to innovative approaches to forestry. As a body of knowledge develops about the implementation of partial cutting and as precedents are established, administrative processes should get simpler for shelterwoods.

Stocking standards

Stocking standards are the criteria used to evaluate the probability that silvicultural systems will achieve long-term forest management objectives. Until such time as government deems a reforested area "free-growing," licensees are responsible to ensure agreed-upon stand conditions. Stocking standards from the era of the Forest Practices Code (e.g., B.C. Ministry of Forests 2002), generally oriented toward the clearcut system, were grandfathered through the transition to the *Forest and Range Practices Act* and remain as the usual standards unless a licensee proposes (and the district manager approves) others in a forest stewardship plan.

Overstorey

According to the Forest Planning and Practices Regulation, a licence-holder is exempted from the requirement to establish a free-growing stand for "commercial thinning, removal of individual trees, or a similar type of intermediate cutting."[6] Day (2007b) utilized this exemption to create a stocking standard that applied to the initial harvest in a shelterwood system where an average of 60% of the pre-harvest basal area was retained. This density is approximately equivalent to that at which competition-induced mortality begins in an unmanaged stand (Day 1998). As such, a previously unlogged stand with 60% overstorey retention following harvest theoretically has no surplus growing space.

If the residual overstorey following initial harvest will be less than 60% of pre-harvest basal area, a different stocking standard will be required. Day (2007b) created a standard that combined the overstorey basal area and the understorey regeneration to declare the stand free-growing. Martin et al. (2005) developed a means of estimating the deviation from potential volume growth (DFP) that allows a surveyor to declare whether there is a lack of both overstorey and understorey. This system would also provide an opportunity to develop a stocking standard for use with a shelterwood cut more heavily than 60% residual basal area.

Regeneration

Regeneration stocking standards are necessary to ensure that the stand is stocked when the overstorey is removed. Stocking standards for clearcuts are generally acceptable in shelterwood systems, but regeneration densities may have to be higher than targets before the final removal to allow for logging damage that may occur to the regeneration. For instance, the final harvest in a dispersed retention application at the Roberts Creek Study Forest killed 8–11% of planted seedlings (D'Anjou 2001). Successful shelterwoods can provide very high regeneration densities and will favour shade-tolerant species over intolerant species (D'Anjou 2001). Practitioners should manage the timing of overstorey removal to maintain regeneration performance, and they should consider the necessity of thinning to adjust species composition and density.

Site plans

A site plan is a document required by provincial law that contains a prescribing forester's assessment of a site and a plan to achieve a free-growing stand. The site plan commits the licence holder to undertake work in the future, so there is a future liability and a legal responsibility to achieve free-growing status for the new stand, despite possible disturbance by

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5 An appraisal system determines stumpage rates payable to the province by licensees for timber harvested on Crown land.
6 Forest Planning and Practices Regulation, Section 44(3).

fire, windthrow, or forest health agents. Because of those legal liabilities, most licensees seek to limit the duration of their exposure by achieving free-growing status as early as possible.

Within the shelterwood silvicultural system, regeneration develops over an extended period. With trees developing beneath an overstorey and under lower light levels compared to those in a clearcut, regeneration occurs more slowly. Additionally, regeneration is not considered free-growing until the overstorey has been fully removed and logging damage is assessed.

At the Alex Fraser Research Forest, these contrary considerations have been managed in two different ways.

1. By creating a single site plan to complete regeneration and overstorey removal within the free-growing period.
   - The stocking standard created for complex stands (Day 2007b) was used to allow a stand to be free-growing based on overstorey stocking or regeneration stocking or a combination thereof.
   - The stands were harvested to remove dead and dying lodgepole pine, retaining healthy, vigorous Douglas-fir and spruce in the overstorey.
   - Natural regeneration has been abundant, and the overstorey will be removed at about year 10, under the same site plan.
2. By creating a new site plan for each harvest entry.
   - The first site plan seeks to maintain an average of 60% of the pre-harvest basal area. While we expect regeneration to occur after the first entry, there is no commitment to regenerate at that time. This site plan has a short life span—ending only 1 year after the completion of the first harvesting entry.
   - The second site plan seeks to remove all, or a portion of, the overstorey, releasing the established regeneration. If some of the overstorey will remain, then the stocking standards identified in the site plan will refer to both overstorey and regeneration.
   - The final overstorey removal will be accomplished in the second or third site plan, at which time the stocking standards will refer to regeneration only. The regeneration period will be shortened to one year after harvest.

The shelterwood silvicultural system can be an effective approach for achieving forest land-use objectives and growing high-value forest products.

A single site plan allows for reduced planning costs and the certainty of tenure over a stand, but it also presents risks if a stand is lost to a disturbance before the final removal. Multiple site plans reduce the liability but provide no certainty of tenure to the licensee.

Summary

The shelterwood silvicultural system can be an effective approach for achieving forest land-use objectives and growing high-value forest products. Although harvesting costs are higher on average than for clearcuts, the system leads to reduced silviculture costs due to natural regeneration. Silvicultural goals are achievable in some situations where the clearcut method generally fails (e.g., for regeneration of Douglas-fir in ecosystems prone to summer frost [Burton et al. 2000]).

Applying partial cutting entails challenges compared to utilizing the clearcut system. Abiotic and biotic forest health agents, natural disturbance, and administrative issues do need to be considered when contemplating implementation of the shelterwood system. However, risks of this system may be managed through careful planning and recognition of the inherent characteristics of individual sites. Where time is on your side, such as with area-based tenures and private land, shelterwoods offer real opportunities to manage for both timber and non-timber values.

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Test Your Knowledge . . .

The shelterwood silvicultural system in British Columbia – A practitioner's guide.
Part 1: Implementation considerations

How well can you recall some of the main messages in the preceding Extension Note?
Test your knowledge by answering the following questions. Answers are at the bottom of the page.

1. Which of the following result(s) from the implementation of a shelterwood system?
   - A) Establishment of natural regeneration under the moderating effects of a partial overstorey
   - B) Enhanced growth of the overstorey while regeneration is becoming established
   - C) Reduced silviculture costs but higher logging costs as compared to a clearcut
   - D) Avoidance of the sharp transition from closed forest to open ground as caused by clearcutting
   - E) All of the above

2. Name three forms of forest health agents you should confirm the presence or absence of before implementing a shelterwood system.

3. When residual trees are wounded during logging, you should
   - A) Leave them until the next harvesting entry
   - B) Pick them up when bark beetle or windthrow salvage is conducted
   - C) Leave them for wildlife trees and coarse woody debris
   - D) Assess and remove trees with wounds if they will suffer decay before the removal phase is complete

ANSWERS

1. E; 2. Dwarf mistletoe, root or stem decay, and bark beetles.
3. D