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Growth of 10 tree species in relation to location and microclimatic gradients in a strip shelterwood

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Abstract
Preliminary results indicate that patterns of tree growth are related to microclimatic gradients in these openings. Height growth of the various tree species reflects their tolerance to drought and shade in openings. Among the tree species evaluated, Western hemlock and Engelmann spruce were best suited at the south edge and in the intact forest, but Douglas fir performed best at north edge and inside the opening. Regardless of their shade tolerance classification, all the species grow best near the centre of the opening, where light levels are highest.

Introduction
Regeneration of even-aged stands with the clearcut method has proved aesthetically unacceptable in many cases, and the selection method used to create uneven-aged stands, has frequently not achieved regeneration and stand structure objectives (Hannah 1988). Consequently, there is a renewed interest in the use of shelterwood method in recent years. In the shelterwood method of regeneration, the old stand is gradually removed in a series of cuttings to promote the establishment of a new even aged stand under the partial shade of the existing forest canopy.

Shelterwood systems are applied in Southern British Columbia to facilitate forest regeneration and to achieve visual and watershed management objectives. Group and patch shelterwood systems are desired to maintain or recreate naturally patchy forests and are easier to harvest than uniform shelterwood systems. They are also more amenable for creating conditions that favour regeneration of moderately tolerant to intolerant tree species. In addition, group shelterwood systems can also be less susceptible to windthrow.

In small opening like stripcut, patterns of microclimate like light, air temperature, soil temperature, and soil moisture can develop due to the position of the sun and changes in sun angle. Several studies reported that light levels increase as opening size increases and south sides of openings are typically influenced by shade from adjacent stands, resulting in lower amounts of direct sunlight near the southern edge compared to the northern edge (Messier 1996; Coates 2000; Delong et al. 2000; Spittlehouse et al. 2004). Light levels
also generally increase under the intact stand located to the north of newly created openings. Snow may persist longer in the spring near the south edges of gaps compared to north edges (Huggard and Vyse 2002; Spittlehouse et al. 2004). Air and soil temperatures tend to increase with opening size and are higher at the north edge, adjacent to the edge of the stand, than at the south edge due to higher energy inputs associated with higher levels of direct sunlight (Huggard and Vyse 2002; Grey et al. 2002; Spittlehouse et al. 2004).

There are a number of tree species available for reforestation in the Interior Cedar-Hemlock Zone of the interior B.C. The species had a wide range of shade tolerances. Hence it is not clear how those species growth can be influenced by the pattern of microclimatic gradients in narrow openings.

With the financial support from B.C. Forest Science Program, a study is underway at Burton creek to fulfill following objectives:

1. To characterize microclimatic gradients across the strip
2. To measure and compare the pattern of growth of ten species in relation to location and microclimate in stripcut.

**Experimental design and methods**

**Study area:**
The study site is located at 3.5 km on the Burton Creek Forest Service Road, about 40-50 km south of Nakusp, British Columbia. The site is located in a level area in the Columbia-Shuswap variant of the Interior Cedar-Hemlock moist warm biogeoclimatic subzone (ICHmw2), on a circum mesic site. The mature stand consists of 53% Douglas-fir, 25% cedar, 15% larch, and 5% pine and birch. The dominant height is 35 m, and density is 650 stems/ha. 50 m wide by 150 m long strips were conventionally harvested during the winter of 1994/95 by a hand faller and a line skidder (DeLong et al. 2000).

**Experimental design:**
A study examining the growth of ten tree species planted across clearcut strips was initiated at Burton Creek in 1994 (DeLong et al. 2000). Two small (50 m wide by 150 m long) clearcuts were created in a mixed stand dominated by Douglas-fir, western redcedar, and western larch. The long axis of each clearcut goes east-west. Seedlings of each of ten species (Douglas fir, western larch, Engelmann spruce, western redcedar, western hemlock, white pine, ponderosa pine, lodgepole pine, subalpine fir, and paper birch) were planted at 3 m spacing in rows oriented north-south across each block in the spring of 1995 extending 20 m into the uncut stand south and north of each clearcut. Three replicate rows were established for each species.
Figure 1. The two 50x150-m cutblocks included in the study were planted with seedlings oriented in north-south rows, and based on previous study twelve gap environments (as labeled in figure) were established to monitor environmental conditions and seedling performance. Arrows pointing the location of the sensors installed to collect microclimatic data.

Data collection

Tree measurement and mapping of tree location:

- The location of all planted trees and of stand edges at Burton Creek were mapped during the spring and summer of 2007.
- All planted saplings (1860 i.e. 31 trees per row and 60 rows of trees in two blocks) were measured (root collar diameter, dbh, height, initial tree size and leader length) in the spring of 2007. Trees were remeasured in late September of 2007. Trees were assigned to each of the 12 gap environments. Annual tree growth (May to September) will be recorded in terms of diameter and height increment.

Measurements of microclimatic variable:

- Light (% transmittance) were measured at midcrown height of all planted seedlings in midsummer using LICOR LAI-2000 sensors (LI-COR Inc., Lincoln, Nebraska).
- Light sensors (calibrated photodiodes; Fielder and Comeau 2000) were installed at 1.5 m height at 12 of locations in each block and used to calibrate light estimates obtained from the LAI-2000 sensors and the LITE model.
• In 2007 hemispherical photographs were taken at 1.5 m height at the 12 distances from the south edge of the clearcut (as used above) along 6 rows of seedlings, distributed evenly across each block. Photographs were analyzed using SLIM software (Comeau et al. 2004) to determine gap fraction and to calculate the contribution of beam and diffuse radiation at each measured point.

• Air temperature, soil temperature and soil moisture sensors were installed at 24 locations in each of the two blocks (the 2 sensors installed in each gap environment were located at similar distances from the stand edges and adjacent to trees at selected locations along two rows located 6 m apart. Limited numbers of sensors and dataloggers are available. As a limitation of our study it will not be possible to measure soil temperature, soil moisture and air temperature on several locations for each gap environment. An average value of the two locations will only be obtained to represent a particular gap environment. However, efforts are underway to install more sensors in different locations for each gap environment as they become available.

**Statistical analysis**

Non-linear regression models were developed relating microclimatic variables to location for use in estimating microclimatic values at each seedling based on seedling location.

**Preliminary Results**

**Microclimate within strip**

Preliminary results clearly indicated that microclimatic gradients (light, air and soil temperature, and soil moisture) develop across the strip.

![Figure 1. Correlation between two methods of measuring total light (PPFD in µmol m⁻² hr⁻¹). Values combined for Block 1 and Block 2](image)
Figure 2. Light gradient across the strip (direct and diffuse PPFD summed over the period from May to September) estimated from fisheye photos using slim.

Figure 3. Air temperature gradients

Figure 4. Soil moisture gradients
We have measured light using two different methods. Direct and diffuse radiation was measured by analyzing hemispherical photographs using SLIM software. For calibration, we also took direct measurement of total light by quantum sensors at 1.5 m height and diffuse radiation by Lai-2000.

Total PPFD measured by quantum sensors and hemispherical photographs were strongly correlated ($r^2=0.71$; see Figure 1). Light levels, both direct and diffuse, were higher at the centre of the opening and decreased at the edges. Surprisingly, light levels measures from hemispherical photographs showed nearly equal light level at south and north edge (Figure 2). This was unexpected. One reason might be the formation of gap at the south edge which equals the amount of light at both north and south. Moreover, light is the most heterogeneous condition in the forest (Messier, 1996), therefore, it needs further investigation or evaluation of the methods of light estimation before any definite conclusion can be reached.

Soil moisture stress, as expected, was higher at the centre and continues to remain high at the north edge (Figure 4). South edges show less soil moisture stress than the north edges. However, in the intact forest at the south, soil moisture stress was higher than the edge (data not shown). Moreover, in block 1, we recorded less soil water stress than the intact forest. Our result was in conformity with Minckler and Woerhide (1965) and Gray et al. (2002). In contrast, we found higher water stress inside the forest than edge in the second block. In the second block, north edge is not continuous; rather, gaps are formed due to tree fall as a result of windthrow. This causes the north edge to extend into the forest further than the south edge. However, soil moisture can also vary for a number of reasons and since it can be an important variable explaining tree growth, 72 soil moisture sensors
will be installed this year to obtain better estimates of soil moisture gradient. We expect this would help to obtain better estimates of soil moisture variability in small openings.

Temperatures below 5 °C occurred more frequently at the centre and occurred less frequent at the edges or under the adjacent intact stand (Figure 3). This is expected because taller canopies replace a larger proportion of the sky view with foliage and stems leading to greater reduction of longwave radiation losses (Pritchard and Comeau 2004). This is how height and density of the surrounding canopy within created gaps might affect the temperature conditions and thus decrease the rate of nocturnal radiative cooling in shelterwoods. The temperature difference between the north and south edges, north edge having lower air temperature than the south, may be due to the difference in height and density of the surrounding edge trees. The density of trees at the north edge is less which results in greater sky view factor and higher losses of longwave radiation.

We found a very week gradient of soil temperature across the strip (Figure 5). The spatial gradient of soil temperature can be affected by several factors including thickness of the duff, vegetation cover and soil moisture condition (Balisky and Burton, 1995; Spittlehouse et al. 2004). Groot and Carlson (1996) report that the difference in soil temperature between clearcut and forest interior gradually diminishes as the vegetation cover increases. Our study site was created in 1995. Therefore, it is expected to get a week trend of soil temperature after 14 years after harvesting since the development of natural vegetative cover.

Characterization of microclimatic gradients is contributing to better understanding of observed difference in tree growth in small openings and in the intact forest.

**Tree growth response**

![Figure 6. Height of planted conifers (2007)–Block 1](image1)

![Figure 7. Height of planted conifers (2007)–Block 2](image2)

For the purposes of this progress report data are shown for the 3 selected tree species (Douglas-fir, Western hemlock and Engelmann spruce). Trends in height growth along the gradient of microclimate reflect the tolerance of these species to shade and drought. As expected, regardless of shade tolerance all the species grow well at the centre of the opening, which receives the highest amount of light (Figure 2). Douglas-fir showed
highest height growth at the centre; but was poorest at the south edge. This was not surprising given that Douglas-fir is the least shade tolerant and most drought tolerant of the three species. Western hemlock and Engelmann spruce due to their shade tolerance characteristics performed better in the light limited environment at the south than Douglas-fir but was not able to perform better in the water limited condition at the north due to their least drought tolerance. However, in our study Western hemlock was able to maintain a good height growth at high light condition at the centre.

Collection of physiological measurements (photosynthesis, transpiration rate, and stomatal conductance) during 2008 will provide additional information on factors influencing patterns of growth of these species.

References