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Regional variability of species-specific crown openness for aspen and spruce in western boreal Canada

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Abstract

In the Canadian boreal mixedwood region, there is currently increasing management desire to foster and release understory trees. Consequently, there is also an increased interest in modeling and predicting understory light levels.

In this study, species-specific crown openness is defined as the fraction of sky that can be seen through the crown of an individual tree of a given species. Species-specific crown openness is of general interest for understanding light transmission through forest canopies, and is an essential part of the light submodel in SORTIE. The main objective of this study was to investigate whether regional differences in mean species-specific crown openness exist for aspen (*Populus tremuloides* Michx) and white spruce (*Picea glauca* (Moench) Voss) in western boreal Canada. To ensure a robust comparison of regional mean species-specific crown openness, we initially investigated the underlying assumption that crown openness is unaffected by dbh and angle of view. In our data, both aspen and spruce crown openness was found to be independent of angle of view. Crown openness was also independent of dbh in aspen, while weak indications of a correlation between crown openness and dbh was found for white spruce. However, this relationship has little actual effect on crown openness and its effect on predicted understory light level is judged to be small.

We found significant regional differences in mean crown openness for both aspen and spruce. However, these regional differences are small and are likely to have relatively little effect on understory light levels predicted with SORTIE. The results from this study indicate that, although previous estimates of aspen and spruce crown openness in western boreal Canada varied greatly, this is more likely the result of different methodologies than actual differences in crown openness.

Keywords: Crown openness; Light model; SORTIE; Aspen; *Populus tremuloides*; White spruce; *Picea glauca*

1. Introduction

There is a large body of literature regarding the complex mechanisms of light transmission through forest canopies (e.g. Norman and Jarvis, 1975; Canham, 1988; Chazdon, 1988) and related methods to predict light transmission (reviewed in: Larsen and Kershaw, 1996; Brunner, 1998; Lieffers et al., 1999). Monsi and Saeki (1953) were the first to apply the Beer–Lambert law to light extinction in plant canopies. This law has since been the most frequently used method for predicting light levels under forest canopies. Application of the Beer–Lambert law in its original form produces an average light intensity, which is subject to several crude assumptions regarding canopy structure (Monsi and Saeki, 1953; Larsen and Kershaw, 1996). As reviewed by Brunner (1998) and Lieffers et al. (1999), several complex models have dealt with some of the shortcomings of the original canopy structure assumptions by accounting for non-random foliage distribution, inclination angles, foliage clumping, and reflection and transmission from foliage. A problem with these complex models is that they require extensive input data regarding canopy structure and have often proven difficult and costly to calibrate (Brunner, 1998; Canham et al., 1999; Stadt and Lieffers, 2000). Thus from a management perspective there is a need for a light model which can be applied with readily available inventory data (Lieffers et al., 1999; Stadt and Lieffers, 2000).

SORTIE is a spatially explicit individual tree model where tree growth mainly is driven by light availability and neighborhood composition. The model was initially developed for modeling successional dynamics in northern hardwood forests by Pacala et al. (1993, 1996). Since then, the model has been further developed (SORTIE-BC and SORTIE-ND) and made more suitable for application to forest management issues

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in boreal Canada (Coates et al., 2004). Canham et al. (1994) parameterized and tested the light submodel in SORTIE and showed that spatial variability in understory light levels can be predicted with relatively simple input data. Additionally, the results indicated that understory light levels can be predicted with a simple model where light transmission is equally extinguished by each encountered crown of a given species independent of size and angle of view. This type of model was termed an absolute hits model and in this terminology each tree can be referred to as a hit. Additionally, it was shown that the majority of spatial heterogeneity in understory light levels can be explained from the position and crown allometry of neighborhood trees (Canham et al., 1994). Most light models are not absolute hits models (e.g. Brunner, 1998; Stadt and Lieffers, 2000) and light extinction is dependent on the path length through the individual crowns. Although an absolute hits model cannot predict the light environment within individual crowns, it can be advantageous in the prediction of understory light levels because of its simplicity (Canham et al., 1994). Canham et al. (1999) further developed the absolute hits version of SORTIE′s light submodel and achieved good test results for subboreal sites in British Columbia.

In this paper, species-specific crown openness is defined as the fraction of sky that on average can be seen through the crown of an individual tree of a given species. The species-specific crown openness is assumed to be independent of tree size and angle of view. In the latest version of SORTIE′s light submodel (Canham et al., 1999), species-specific crown openness is the only input factor that is not available from the literature or from reanalysis of permanent sample plots. The initial method used to determine species-specific crown openness was complex and included a three-dimensional reconstruction of a stand in conjunction with fisheye photos (Canham et al., 1994). This initial method was replaced by a simplified and direct method introduced by Canham et al. (1999). In this method, species-specific crown openness is determined directly from fisheye photos.

The difference in canopy and crown openness among species has received attention due to the effects of shading and shade tolerance on forest stand dynamics and succession (e.g. Horn, 1971; Oliver and Larson, 1996; Canham et al., 1994, 1999). Intraspecific variability between regions has received less attention but is interesting from several perspectives. From a modeling perspective, it is necessary to determine transferability of species-specific crown openness between regions in order to judge when light models should be re-parameterized. From a silvicultural standpoint, geographic variation in species-specific crown openness might influence understory light levels. In this case, the performance of understory trees and the success and transferability of various silvicultural systems are likely influenced. Several studies have shown that leaf area index varies with climate (e.g. Gholz et al., 1976; Grier and Running, 1977) and it is also likely that species-specific crown openness varies with climate.

The main objective of this study was to investigate the intraspecific variability of species-specific crown openness for both aspen (*Populus tremuloides* Michx) and spruce (*Picea glauca* (Moench) Voss) within western boreal Canada. This was done by comparing mean species-specific crown openness estimates from five different regions in western boreal Canada. To ensure a robust comparison, we tested the assumptions that species-specific crown openness is independent of (1) tree size and (2) angle of view. The secondary objective of this study was to compare regional variation in species-specific crown openness to SORTIE′s sensitivity to this parameter. This was done to evaluate possible regional differences in understory light environments caused by regional differences in species-specific crown openness.

2. Methods

2.1. Sampling and measurements

Five sampling regions located in northern British Columbia (BC), Alberta (AB) and Saskatchewan (SK) were selected. A sampling region was defined as an area 40 km in radius with relatively uniform climatic conditions. The sampling regions were selected to capture the range of climatic conditions in areas dominated by mixed stands of aspen and spruce throughout western boreal and subboreal Canada. The selected sampling regions were located in the vicinity of Smithers (BC), Fort Nelson (BC), Peace River (AB), Calling Lake (AB) and Porcupine Hills (SK). The geographic distribution of the sampling regions is illustrated in Fig. 1. In all five regions, both aspen and spruce were sampled. In the Smithers region, interior spruce (*P. glauca* × *engelmannii*) was sampled because it is the most common spruce on mesic sites (e.g. Banner et al., 1993). In the remaining regions white spruce was sampled. A short summary of climatic characteristics and sample site characteristics of each region is presented in Table 1.

Sampling was performed from late June till mid August 2003. Within a sampling region, between 10 and 12 stands located on zonal sites were sampled. In this paper, the term zonal is used for a site that best reflects the regional climate rather than edaphic or topographic factors.[1] An observed difference between sampling regions will thus be an effect of local climate rather than edaphic or topographic factors. In this project, focus will be on zonal sites classified to site series in BC and ecosite in AB and SK. The actual site types are given in Table 1. The sampled stands were mature (>30 years) aspen and spruce mixtures that ranged from aspen to spruce dominated. In each stand, between one and seven trees of each species were sampled. In stands where multiple trees were sampled, an effort was made to maximize the range of sampled tree sizes. For each sampled tree, the general methodology of Canham et al. (1999) was used to determine species-specific crown openness. For each sampled tree one fisheye photo was taken. For each photo, the camera was placed in a location where the crown of the selected tree could clearly be distinguished against the sky without any other trees blocking the view. Locating an appropriate camera position often

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[1] This use of zonal site is equivalent to the use for classification in BC (Pojar et al., 1991) and equivalent to the term reference site used for classification in AB (Beckingham and Archibald, 1996) and SK (Beckingham et al., 1996).