

## Modelling wind damage for managed and old-growth stands in Québec

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### Abstract

Clear cutting has been the traditional silvicultural practice for most of eastern Canadian forests for many decades. However, more recently there has been a shift towards partial cutting regimes, in which individual trees are left standing mainly to improve the ecological value of the site and speed up the process of natural regeneration. Due to decreased stand density and the creation of gaps those stands are probably more vulnerable to wind damage than those managed with a traditional approach, which might counterbalance any beneficial aspects.

A quantification of the wind risk of an area is desirable to support decision processes in designing cutting plans. Here we present the results from a spatial modelling approach. The model design as well as the sensitivity of its modules are discussed. A major factor for uncertainty is the coarse resolution of the stand data information. A better model performance could be achieved using more data sources like remote sensing.

### 1. Introduction

The shift in silvicultural practise towards partial cutting regimes raises concerns about the wind stability of the remaining thinned stands. In general a higher thinning intensity is associated with a higher likelihood of wind damage and it is therefore desirable to quantify the wind risk for a large area.

Wind risk models are a suitable tool to estimate the impact of different thinning intensities on the wind stability of all stands in an area. Such results can deliver valuable information that can be used in for forest management decisions.

### 2. Study area

The study area is in the North Shore region located in the province of Québec, Canada (50°12'N, 68°14'W), about 450 km north-east of Québec city. The area is part of the spruce-moss ecological domain and its stands are old growth, unmanaged, and dominated by balsam fir (*Abies balsamea*) and black spruce (*Picea mariana*). The growing process in these stands is rather slow and the stand density is high.

### 3. pyFGE model

The model used in this study is a clone of the mechanistic British wind risk model ForestGALES (Gardiner et al., 2000), which has been used in many other studies to calculate the wind risk of forest stands. Due to its mechanistic approach it is easily adaptable for different tree species. The necessary information for the species parameterisation for the commercially most important eastern Canadian species has been derived from the

literature: (i) black spruce: Élie and Ruel, 2005; Bergeron et al., 2009 (ii) balsam fir: Achim et al., 2005a (iii) jack pine: Élie and Ruel, 2005; (iv) white spruce: Achim et al., 2005b.

#### 4. Model runs and validation

The model input (Fig. 1) was derived from (i) forest maps, (ii) digital terrain models, and (iii) wind speed maps. The forest maps contain stand information, which are based on aerial photograph interpretation. The model input parameters that were extracted from the forest maps are stand density (stocking), stand height, species composition, and soil drainage. All parameters are encoded and classified which means that the numerical parameters can only be defined within a defined interval. For some of the parameters the classes span a rather wide region, which in turn can have a significant impact on the wind risk calculations for the stand.

The impact of partial cutting management was simulated by applying harvesting scenarios in which a certain percentage of trees (range: 10 to 40 %, step size: 10 %) was removed from the stands.

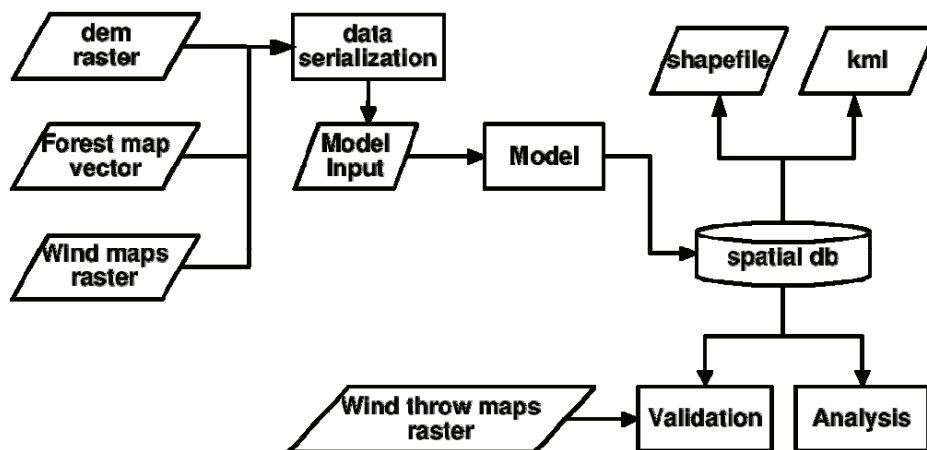


Fig. 1: Flow diagram of the model

#### 5. Results

The study area comprises more than 35000 stands. Almost 45 % of those stands were identified as pure black spruce stands, where the individual stand area covers a size range from less than 100 m<sup>2</sup> up to 1.3 km<sup>2</sup>. All model input data are only available as classes at the stand level, so that it is not possible to account for internal stand variation, even if the stand is large. The fact that the model input is only available as classes has an impact on the uncertainty of the model calculations. Fig. 2 gives an example of the differences in critical wind speed estimates caused by the stocking and stand top height. Stocking classes cover a range of several 100 trees ha<sup>-1</sup> and top height classes span several meters. The plot illustrates the differences in critical wind speed calculations, be-

tween model runs, for which the stocking and top height were set to the lower and upper limits of their classes. The figure shows that the uncertainty introduced by the top height parameter is significantly higher (median  $4.71 \text{ ms}^{-1}$ ) than the one introduced by the stocking parameter (median:  $0.95 \text{ ms}^{-1}$ ).

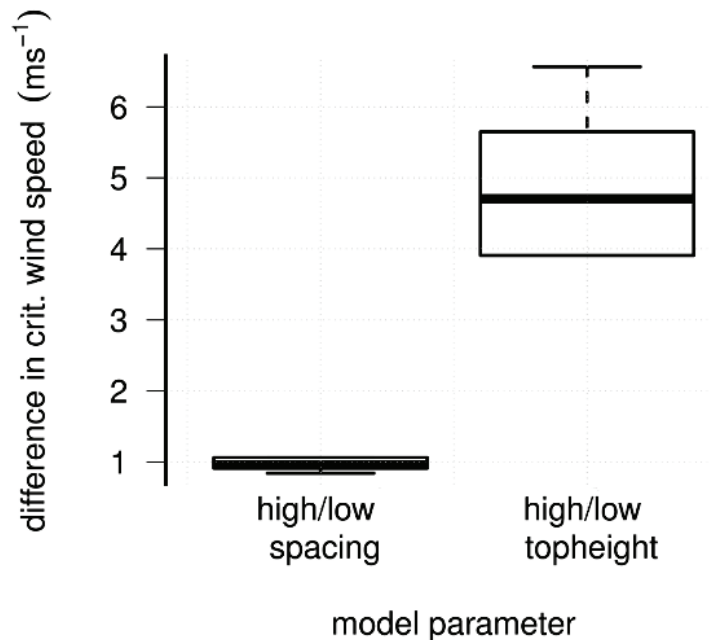


Fig. 2: Boxplot representation of the differences in model calculations for all black spruce stands ( $n=15303$ ); left plot: differences between high/low stocking density; right plot: differences between high/low top height values

The impact of different thinning intensities on the critical wind speed for the study area can be seen in Fig. 3, where the calculated critical wind speed for all black spruce stands is plotted against the percentage of total area ( $2126 \text{ km}^2$ ). The original (unthinned) stand is represented by the solid line, which is as expected the most stable scenario, with only  $\sim 15\%$  of the area experiencing damage at wind speeds up to  $20 \text{ ms}^{-1}$ .

The risk of wind damage increases with intensity of thinning. At  $40\%$  thinning, a wind speed of  $20 \text{ ms}^{-1}$  would cause damage across  $\sim 85\%$  of the area.

A comparison of the critical wind speed values for the different thinning scenarios shows that the removal of  $10\%$  of the trees lowers the critical wind speed by about  $1 \text{ ms}^{-1}$  (median) as it can be seen in Fig. 4. However in some circumstances a removal of  $10\%$  can lower the critical wind speed by more than  $2 \text{ ms}^{-1}$ . Although these changes do not appear to be big, they can have a significant impact on the likelihood of wind damage for an individual stand, depending on the wind speed distribution at the site. In general the wind speed distribution is approximated by a 2-parameter Weibull distribution. Depending on its shape, differences as they were observed in the thinning scenario study, can shift the estimated return period from a value as high as several decades towards one of only a few years or even less.

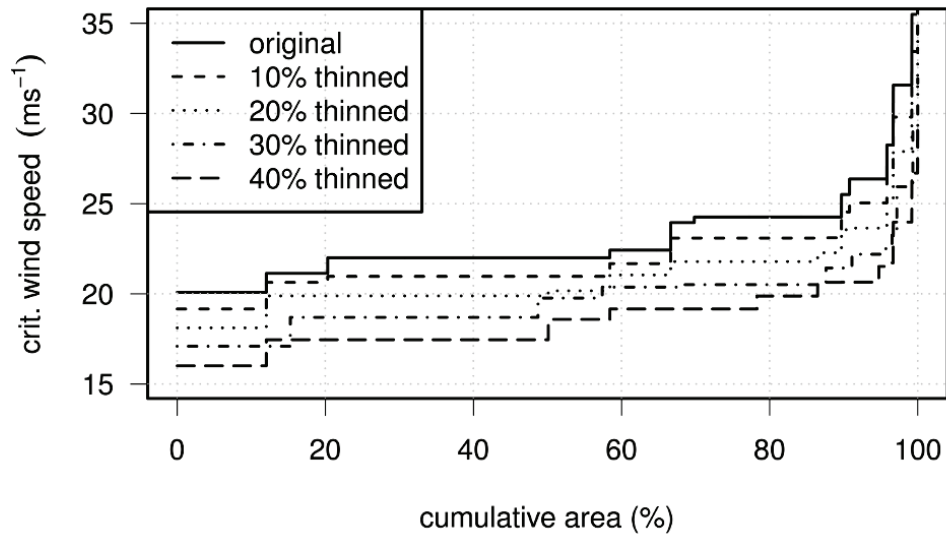


Fig. 3: Critical wind speed for all black spruce stands ( $n=15303$ ) in the study area plotted against their cumulative area; lines represent different thinning scenarios

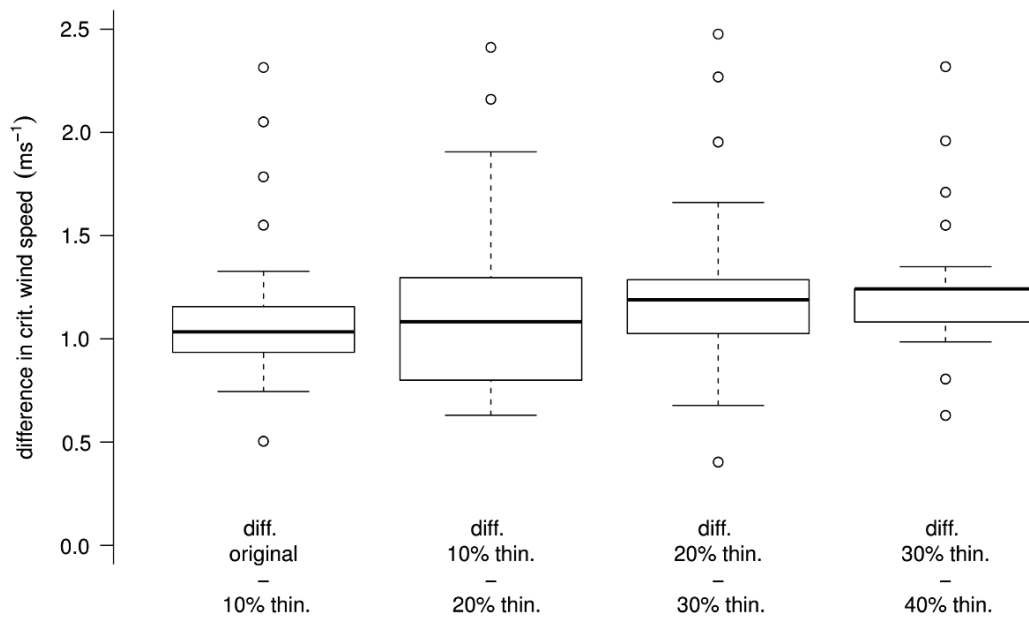


Fig. 4: Differences in critical wind speed between the thinning scenarios

## 6. Discussion

The model is very sensitive to the stand characteristics, which were derived from the forest map and are only available as rather coarse classes. As a consequence the model results need to be interpreted carefully at the stand level. However, these uncertainties should even out if the model's output is interpreted at the landscape scale rather than at

the stand level scale, so that the results are useful for strategic decision making and can support in the planing of thinning strategies in the area.

Further refinement of the model input and therefore more reliable results could be achieved if more data sources were used to determine the model input.

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