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Portability of stand-level empirical windthrow risk models

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Abstract

Wind damage to stand edges recently exposed by harvesting is a significant management problem. Large datasets were assembled for clearcut edges in three coastal and three continental locations in British Columbia. The datasets were produced by dividing cutblock boundaries into 25 m deep by 25 m long edge segments. The sample was restricted to cutblocks that had been harvested between 1 and 10 years prior to the most recent aerial photography and further restricted to produce equal sample sizes of 6700 segments per location. Each dataset was then randomly partitioned into 80% for model building and 20% for model testing. Forest cover, ecosystem, wind speed and elevation data were compiled within a geographic information system. Additional topographic variables were derived from digital elevation models. The orientation and exposure of each edge segment was derived with customized scripts. Windthrow polygons were mapped using stereo-photographs. Logistic regression models were fit for each location and were then tested in each other location. Datasets were pooled to enable fitting and testing of generic models. Models correctly predicted outcomes 67–83% of the time for the model building locations. Portability of local models to other locations varied from excellent to poor. The models built for continental locations were the least portable. Calibration by multiplying predictions by the ratio of local mean observed damage to the mean predicted damage substantially improved local model portability. Well-fitting models were produced with pooled coastal, interior and provincial datasets. The similarity between models in the contribution of geographic wind exposure, boundary wind exposure and stand stability factors indicate an underlying consistency in the factors leading to windthrow across the province. The methods are applicable to other forest regions where synoptic weather systems produce damaging winds.

Keywords: Windthrow; Blowdown; Wind; Risk assessment; Empirical models

1. Introduction

Strong wind events impact forests over the globe in both temperate and tropical regions (Everham and Brokaw, 1996). Windthrow, also referred to as blowdown, is the breakage or uprooting of trees by wind. This is a natural phenomenon in forests and results from the interaction between climate, topographic, stand, tree and soil factors. The mode of failure can be in the form of stem failure, root failure, or uprooting (Mergen, 1954; Somerville, 1979; Stathers et al., 1994; Moore, 2000). In a census conducted by the BC Ministry of Forests, it was found that timber equivalent to 4% of the annual allowable cut was damaged by wind in 1991. This was a volume

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equivalent to the damage caused by insects or wildfire in that year (Mitchell, 1995). In addition to the loss of revenues from non-salvaged timber, loss of designated forested streamside buffers, wildlife corridors and visual quality to windthrow seriously disrupts the intent and implementation of integrated resource planning.

Windthrow can be termed endemic or catastrophic. The latter results from winds with longer return periods and is influenced primarily by local windspeed and wind direction. Endemic windthrow results from routine peak winds with return intervals of less than 5 years. It is influenced more strongly by site conditions, and recently exposed cutblock edges and partial cuts are more susceptible than other stands (Miller, 1985). Endemic windthrow is more predictable and more manageable than catastrophic windthrow and is therefore the focus of modelling and management efforts (e.g. Miller, 1985; Gardiner and Quine, 2000; Mitchell et al., 2001).

There are two approaches to predicting windthrow risk, mechanistic and empirical. In mechanistic modeling, the likelihood of damage is based on calculation of the critical windspeed for tree failure, and the probability of a wind of that speed occurring at a given location. Models such as ForestGALES and HWIND (Gardiner et al., 2000) enable managers to identify the risk of damage for different parts of a forested area and to evaluate new harvesting or stand tending strategies (e.g. Talkkari et al., 2000). These models have been developed for structurally uniform, single species stands. Drag and critical turning moment relationships have not been determined for large, old trees and presently there are no mechanistic models suitable for complex stand structures, trees with stem or root decay or mixed species stands (Lanquaye, 2003). Furthermore, the current mechanistic models treat critical wind speeds and stand level wind behaviour deterministically. The need for process models to become more probabilistic is recognized as a broad issue in forestry (e.g. SAF, 1993).

Empirical windthrow risk models are statistical models that relate the presence or magnitude of wind damage to sampling unit attributes. Because windthrow is a rare event, these models typically assign a probability value to the occurrence of damage (e.g. Valinger and Fridman, 1997; Mitchell et al., 2001; Lanquaye, 2003; Scott, 2005). Empirical modeling is suitable for stands with complex and variable structure and composition, and where geography and soils are heterogeneous. Large samples are needed to fit and test empirical models. To date it has not been clear how well models fit in one location will predict for another location. In the absence of evidence for model portability, it has been recommended that predictions should be limited to locations with site conditions and management strategies that are very similar to the area used to build the model and this limits model application (Mitchell et al., 2001).

Our main objectives in this study, therefore, were to: (1) test the portability of local models fit for different locations in coastal and continental BC; (2) determine whether well fitting generic models could be developed for coastal, continental, and all of BC; and (3) gain an improved understanding of the factors that contributed to windthrow risk throughout this broad and diverse geographic region. The methods used in this study are clearly applicable to other locations in the world. Insights gained into model calibration procedures and the relative importance of risk factors should also be generally applicable.

2. Methods

2.1. Study locations

The coast mountain range broadly divides BC into coastal and continental (interior) regions. Three coastal and three interior locations were selected for study (Table 1). Two of the coastal locations are on Vancouver Island (West Island Timberlands; WIT, and North Island Timberlands; NIT), the third is in the Queen Charlotte Islands (Queen Charlotte Timberlands; QCT). Each of these study areas includes both coastal lowlands and valley and mountain terrain. The three interior study locations are in the mountain ranges that border the Rocky Mountains. Each includes smaller valley-ridge complexes and borders a major river valley (Tembec, Lemon, and McGregor). The coastal locations have a strongly maritime climate and are dominated by western hemlock and redcedar forests. The interior locations have a modified continental climate and contain a mix of spruce-lodgepole pine forests and Douglas-fir, redcedar