DESIGNING CUTBLOCKS TO MINIMIZE THE NEGATIVE EFFECTS OF WINDTHROW

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Abstract

The effects of windthrow on harvested areas in coastal British Columbia have the potential to increase fuel loading, bark beetle habitat, and loss of valuable timber as well as decrease soil stability. The most susceptible trees are found at freshly exposed forest edges. The areas affected are commonly salvaged. Salvaging in reserve zones must be minimized to reduce negative affects of removing large woody debris from ecosystems. There are a number of strategies that can be implemented by forest professionals to minimize the windthrow hazard of forest edges. These include cutblock shape and orientation relative to endemic winds, and locating boundaries where soil and stand characteristics promote stability, and topographical features reduce wind loading. If necessary, windfirming treatments can be used to further reduce the windthrow hazard to acceptable levels. Resources used to increase success of managing windthrow include a range of mapping tools and computer modelling programs that are designed to predict the probability of lethal damage and areas of high hazard. Further research of both mechanistic and empirical modelling is needed for more precise site level predictions as well as implementing a provincial windthrow monitoring program. Both of which could be used to create more successful windthrow management strategies. By recognizing signs that indicate windthrow will compromise management objectives, site-specific strategies can be designed and implemented to reduce this hazard.

Keywords: Forestry, Forest Management, Wind, Windthrow Risk, Windthrow Hazard, Cutblock design

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Introduction

The earth's atmosphere is a turbulent and dynamic system; the sun powers a variable climate that affects the flora and fauna. In the coastal temperate rainforests of British Columbia the natural disturbance regime includes: fire, wind, pathogens, insects, and soil mass movements (Dorner & Wong, 2003). Wind is a particular threat to forests along the coast of BC. The adjacency of the Pacific Ocean allows for the frequent passage of cyclonic storms that strongly influence coastal British Columbian forests (Salmon, 1997). Consequently, trees in these forests have evolved to resist this natural disturbance agent and have managed to persist for thousands of years. There are two ways in which a tree can be adapted to this disturbance. The first being genetic evolution of populations over multiple generations and the second being the morphological acclimation of individual trees throughout their lifetime. Yet wind still presents a significant threat and their ability to withstand this disturbance partially determines their survival. Natural disturbance regimes of the area predispose stands to increased resilience through morphological and genetic adaptations, but when altered by forest harvests this increased exposure often leads to windthrow.

Windthrow can be classified into two categories, catastrophic and endemic (Miller, 1985). Zielke et al, (2010) defines a catastrophic event as a rare event with a return frequency of greater than twenty years that yields extreme wind events that affect both natural, and managed stands, often having a higher frequecy of stem breakage. Endemic events, on the other hand, are much more common, with peak winds occuring every 1-3 years and affecting primarily managed stands with newly created forest edges (Zielke et al, 2010). Lethal damage occurs when the applied forces of wind and gravity exceed the root-soil or stem resistance (Strathers et al, 1994). The associated wind speed is referred to as the critical wind speed and results in the tree uprooting or the bole breaking (Smith et al, 1987). Lethal damage has implications for forest management such as: increased fuel loading, bark beetle habitat, and loss of timber as well as decreased soil stability, and can disrupt riparian ecosystems (Mitchell, 1995a; Kimmins, 2004).

Damage from endemic events can be mitigated through in depth stand and site analysis and management strategies. For edges exposed by harvesting to become windfirm they must persist for at least 5 years (Mitchell, 1995a). There are many strategies that can be used to decrease the likelihood of post-harvest wind damage occurring during this period of high susceptibility. Assessment of windthrow hazard can be achieved through the utilization of windthrow risk field cards, modelling programs, recognition of wind signs and symptoms in the field, and knowledge of the historic variability of wind in the area. Through these assessments site-specific strategies can be used to mitigate windthrow. These strategies can include: proper cutblock design and boundary location, crown modifications, and edge treatments. If a catastrophic event were to occur, the likelihood of these strategies being successful is minimal, it may however, reduce the potential damage of such a storm.

A windthrow survey conducted by the BC Ministry of Forests in 1992 estimated that the area of windthrow equalled 4% of the annual allowable cut (AAC) (Mitchell, 1995b). These losses are not only along the edges of cutblocks but riparian buffers, wildlife corridors, recreation areas, and areas managed for aesthetics. Having a proactive approach to managing windthrow risk can reduce the potential threats to management objectives. Mitchell (1995a) sums up windthrow management when he states that, "The goal ... is to reduce the likelihood of critical winds acting on residual or boundary trees and to increase their resistance to overturning". The purpose of this paper is to determine practices that increase the likelihood of windthrow in logged areas, how to decrease the likelihood of windthrow, and review the potential effects of windthrow on the coast of British Columbia.

Windthrow and its potential effects

Poor layout of a cutblock occurs when none of the natural processes, ecosystem traits, nor social, economic or safety factors are taken into consideration when determining boundaries. The characteristics of a cutblock are ultimately determined by the silvicultural system chosen as well as the size, shape and retention level. These systems include clear-cut, variable retention, shelter wood, or seed tree systems. All of which have their place in forest management. However, if signs are overlooked while determining windthrow hazard in the field, windthrow may compromise some ecological factors and management objective.

Salvage Logging

Salvage logging occurs when it is economical for a company to re-enter an area and extract the affected trees. This takes place wherever there is windthrow, whether along an edge or within a reserve zone. The removal of this wood can have adverse effects on ecosystems such as riparian ecosystems and the windfirmness of the remaining boundary (Blackburn & Petty, 1988; Bahuguna et al, 2010). While the affected trees are being harvested, some live standing trees are taken to allow for the extraction of as much salvage wood as possible. The belief is that it will improve the windfirmness of the remaining boundaries by not leaving small patches of standing timber (Mitchell, 1995b). If green trees are cut in order to extract as much salvage as possible this may further decrease the windfirmness of the forest edge. This is caused by the decreased the root support systems between individual trees and the increased exposure of the forest edge (Blackburn & Petty, 1988). By removing these trees there will be a reoccurrence of the initial problem of a fresh boundary with susceptible trees.

Riparian areas classified as a S1B-S3 under the Forest Planning and Practices Regulation (FPPR) requires that a riparian reserve zone (buffer) be left. This means that a buffer of trees must be left on either side of the stream to reduce the impact of harvesting on the stream ecosystem. These buffers can range from 20-50 meters, but can be larger if the forester decides it is necessary. Windthrow in these riparian buffer areas can have both positive and negative effects on the stream ecosystem. Bahuguna et al (2010), concludes that there was no significant difference in amount of post-harvest windthrow occurred between 10m and 30m buffers. According to the FPPA, windthrown trees may be taken from a reserve zone if doing so does not compromise the riparian reserve zone. According to FPPA, salvaging in the reserve zone does not take into account the positive factors that the tree will have on the stream ecosystem if it is left in the forest. In the case of either an endemic or catastrophic event this may leave a portion of the stream completely clear of tree cover. It would be then up to the discretion of the forester to make the decision. Standing trees in riparian areas help stabilize stream banks, provide shade and are a source of large woody debris (LWD) (Grizzel & Wolff, 1998). Whereas fallen trees still provide shade, input LWD into the stream over the long term, and may slow the process of erosion (Bahuguna et al, 2010). Decreased bank stability as a result of windthrow event could cause a mass-wasting event, which can degrade salmonid spawning sites (Ferreira et al, 2010).

LWD plays a key role in shaping channel morphology (Robison & Beschta, 1990). This includes pool depth, stream depth, and erosion factors.

Economic Losses

Downed *Abies, Picea, Pseudotsuga* and *Tsuga* species attract the ambrosia beetle (*Trypodendron spp.* and *Gnathotrichus spp.*). These beetles may move on to decked timber causing an economic loss due to degraded wood. Maclean (1985), reports that ambrosia beetle causes an estimated annual loss of $63 million due to downgraded timber in B.C. This is a prime example of the added implications windthrown timber can pose. Further losses can be caused by: increased wild fire risk due to fuel build-up, landslides caused by the decreased soil stability of trees being uprooted, and the volume that those trees would have gained, over time, up to when they would have been harvested (Mitchell, 1995a; Kimmins, 2004).

Contributing Factors to Windthrow Potential

Tree species and stands have adapted in numerous ways to live with wind. This includes utilizing wind to spread pollen and seed to keep a healthy genetic diversity of a forest, having physical adaptations to keep them alive and healthy and increasing the biodiversity of a stand through the creation of gaps caused by blowdown. Wind loading adaptations include: flexible foliage and branches, thick tapered stems, low modulus of elasticity, and a high modulus of rupture (Stathers et al, 1994). Where and in what conditions these trees grow determines these characteristics. In areas of high exposure such as an open ridge top the tree will have a stunted growth that will cause a tapered stem and a widespread root base. Whereas a tree growing in a dense stand, will input its energy into growing up, resulting in a high height diameter ratio, (Alexander, 1987). These different growing scenarios will determine some of the stand characteristics, which is just one of three sides of the windthrow triangle (Figure 1) (Mitchell, 1995a). The windthrow triangle is used to analyze the biophysical components of windthrow hazard.

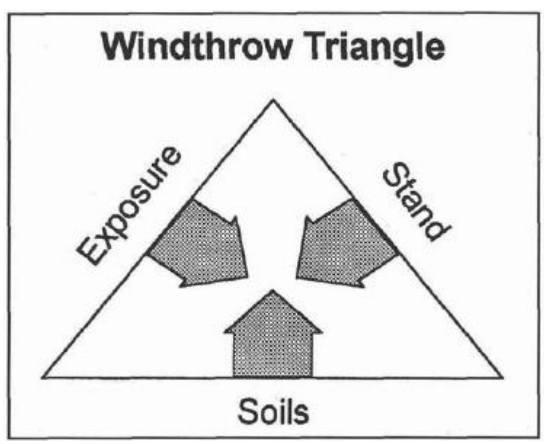

FIGURE 1: ENVIRONMENTAL FACTORS INFLUENCING THE LIKELIHOOD OF WINDTHROW (MITCHELL, 1995B)

Tree Factors

Individual tree characteristics are a sound indicator of windfirmness. Observing these characteristics are useful when a forester is locating trees to leave as seed trees, to leave behind in a multiple pass harvesting system, and in recreation areas. In cases of planned natural regeneration, the healthiest of trees are preferred to be left on site. This is done to allow these trees to pass on preferred genetics, to ensure that these trees are able to survive long enough to do so, and to reduce damage to the wood for future harvests. These objectives can be contradictory. For example a tree with high taper (low values of height/DBH) is not the ideal form when it comes to milling forest products. The higher the taper the less likely the bole will snap, this is shown in Figure 2 (Petty & Swain, 1985). Trees with a height/diameter ratio above 100 indicated instability (Petty & Swain, 1985). Tree level factors affecting the likelihood of a tree overturning are: tree height and form, crown density, root structure and presence of root and butt rots (Stathers et al, 1994). By using these characteristics along with the stand, soil, and exposure factors a manager can make a good estimation of windfirmness of individual trees and forest edges.

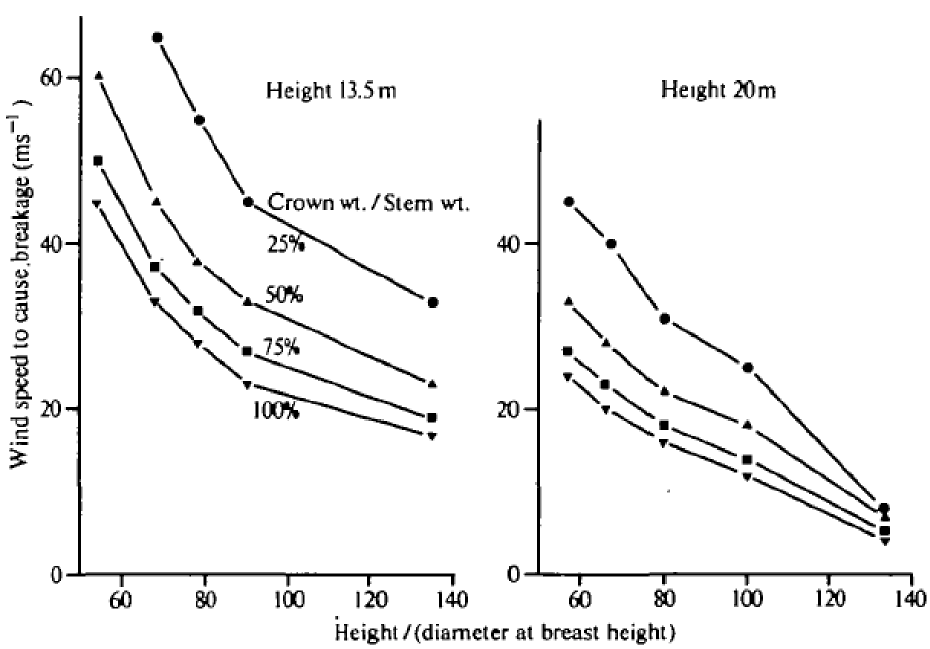

FIGURE 2. VARIATION OF WIND SPEED CALCULATED TO CAUSE BREAKAGE WITH HEIGHT/DBH FOR SPRUCE TREES OF TWO HEIGHTS AND FOUR VALUES OF CROWN WEIGHTS AS A PERCENTAGE OF STEM WEIGHT (PETTY & SWAIN, 1985)

Stand Factors

By observing the stand-level characteristics of a proposed harvest area, a forester will be able to locate the most susceptible areas. The stand height, density, species composition, age, cutblock shape and size are all factors that affect the windfirmness of a stand (Alexander, 1987). Stand characteristics have a greater influence on the occurrence of windthrow than soil characteristics (Zielke et al, 2010). Stem and root rot signs, such as the presence armillaria or phellinus species must also be looked for (Mitchell, 1995a).

Soil Factors

Soil must be observed in the field when determining the windthrow hazard of a proposed cutblock. Soil composition, moisture content, and depth are all important factors that resist the tree from overturning (Alexander, 1987). The ability of a root system to hold on to the soil and other substrates (root anchorage), partially determines the risk of windthrow. The other substrates referred to include; root systems of adjacent trees, and cracks in bedrock (Zielke et al, 2010). According to the windthrow hazard and risk assessment cards developed by the Ministry of Forests (2009), poorly drained, organic soils on unfractured bedrock yield a high soil hazard.

Topographic Factors

Topographic exposure is the final side to the “windthrow triangle”; this refers to the exposure of the cutblock to prevailing endemic winds. The topographic location of the cutblock such as inlets or mountain valleys will create local variations in wind behaviour (Dorner & Wong, 2003). According to Alexander (1987) the topographic location which yields the highest hazard of windthrow are: valley middle and upper slopes parallel to prevailing wind, windward upper slopes valley bends or constrictions, and shoulders or crests (Figure 3). Combining observations such as these, with the stand level and soil characteristics, a windthrow hazard can be determined.

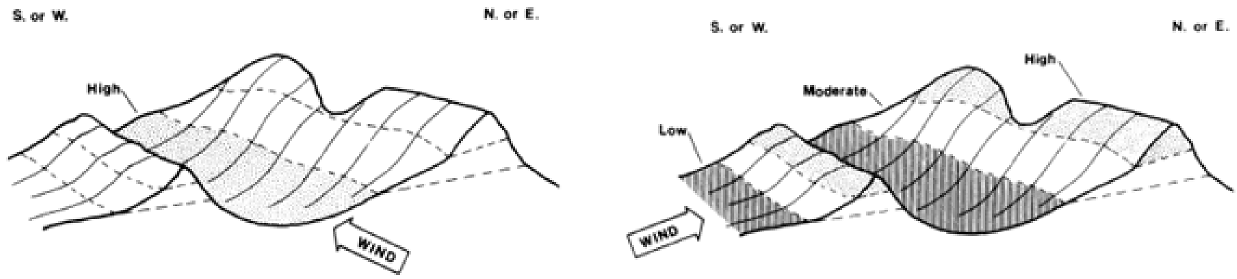

FIGURE 3: TOPOGRAPHIC EXPOSURE TO ENDEMIC WINDS AND THEIR ASSOCIATED RISK (ALEXANDER, 1987)

Design Features

When designing a cutblock there are many features that can increase the potential of windthrow occurring. The design features that affect this are: shape, size, and orientation (Zielke et al., 2010). Cutblock shapes have the ability funnel winds, which result in higher wind speeds (Zielke et al., 2010). An example of a funnel point created by block shape can be seen below on Figure 4.

FIGURE 4: FUNNEL POINT OF WIND IN A MOUNTAIN VALLEY DUE TO BOUNDARY LOCATION. LOCATED USING GOOGLE EARTH©.

Cutblock size affects the overall fetch. Burton (2001) defines fetch as, “The uninterrupted distance the wind travels across an opening before hitting an edge…”. Scott and Mitchell (2005) found that increased damage was found with increasing fetch, height diameter and crown density. To decrease fetch, a partial harvesting system can be used. Scott and Mitchell (2005) recommend using a partial harvesting system and retain at least 20% of the original stand density to decrease the windthrow hazard. The 20% retention should be chosen by tree characteristics that suggest windfirmness. Correct block orientation to the prevailing winds will also decrease the windthrow hazard. The creation of a static boundary, which is exposed to prevailing winds, will experience a higher frequency of windthrow (Mitchell, 1998).

Risk Assessment

In British Columbia there are many ways in which foresters can estimate windthrow hazard, and then decrease the likelihood of wind damage occurring. These management techniques are used when the risk of windthrow threatens forest management objectives, human values, and human safety. Risk can be calculated as the factor of probability and consequences. The assessment of possible consequences should occur where windthrow may compromise management objectives, human values, and safety. The probability of windthrow can be estimated using resources such as the windthrow field cards developed by the Ministry of Forests (2009) , modelling programs and by looking at the historic variability of wind events in the area. The higher the risk of windthrow the more likely managers will use intensive strategies to reduce the risk.

The windthrow field cards mentioned above were created to aid forest practitioners in accurately assessing the windthrow risk of a cutblock. These cards are used to determine the "biophysical hazard" and "treatment risk" to further determine the overall "windthrow risk". The block boundary is divided into segments then each segment is assessed. The biophysical hazard is defined by an assessment of the site and stand characteristics. This will result in a rating of either: low, medium, high, or very high. The site hazard is defined by the way in which a particular treatment will increase or decrease the windloading of trees; particularly observing the shape of the cutblock, its orientation to damaging winds and soil characteristics of the segment. The site hazard will receive a rating of either: low, medium, or high. These hazard assessments take into account numerous characteristics of each of the fore mentioned. This includes existing windthrow patterns of the proposed cutblock, and a hazard classification of a similar cutblock in close proximity. The classification of a nearby cutblock is done to calibrate the card user's original estimation. These ratings are then used to determine the windthrow risk of the specific segment of the cutblock boundary (none, low, medium, high, and very high) and are compared to the nearby cutblock's ratings. If the windthrow hazard threatens management objectives, it is then recommended that the treatment is modified to decrease the hazard to an acceptable level.

Risk Mitigation

When the windthrow risk is at an unacceptable level, there are many strategies that can be used to mitigate the risk. These strategies can be used in a variety of windthrow settings, both industrial and residential. Ministry of Forests (2003) suggests a range of treatment options. This includes altering the block boundary or silvicultural system, and conducting windfirming treatments.

Industrially the most cost effective way to reduce the risk is to alter the block shape, size and location of the high-risk boundary. Choosing boundary locations in more suitable areas with deep well-drained soils can reduce the site hazard as well as altering the shape to reduce the funnelling of wind (Ministry of Forests, 2009). The silvicultural system chosen affects the site hazard of a cutblock and therefore its windthrow risk. In a study done by Beese (2001) it was found that most windthrow occurred under the shelterwood system while the clear-cut received the least amount of damage. Mitchell (1995b) states that, "For clearcuts the key considerations in the prescriptions are opening size, opening orientation, boundary placement, and boundary modification. For partial cuts they are basal area removal, tree selection, edge buffering and access placement." Windfirming treatments can be done at the tree level and stand level. Both of which can be used simultaneously. Ministry of Forests (2003) explains each treatment as follows:

Crown Modifications - Aimed at reducing the force of the wind on the root complex and bole.

- Topping - The top one third of the crown is removed
- Top Pruning - Branches in the top one third of the tree are removed. Helicopters equipped with mechanical devices can be utilized in achieving this
- Tree crown thinning - Crowns are uniformly thinned by 30-40%

Edge Feathering - Aimed at reducing the wind speed as it enters the stand.

- Edge-profiling - Used in mutli-story stands. Smaller trees are left to uplift the wind over the mature edge.

- Edge Thinning - Used in uniform even-aged stands. Trees that are expected to blow over are removed.

In a study done in coastal British Columbia by Rowan et al. (2003); the effectiveness of these treatments was tested. In their study area it was found that, “Helicopter-based pruning and manual topping techniques reduced damage by 40% in comparison with controls. Crown modification treatments did not increase direct tree mortality in the first 3 years after treatment. Edge feathering reduced damage in some stands and increased it in others”. It was further concluded that more work needs to be done in regards to edge feathering and that biophysical factors have a greater influence on windfirmness than that of treatments.

Using Models and Windthrow Prediction for Strategic Planning

Windthrow modelling is used to predict the hazard of the occurrence of windthrow through a quantitative approach using computer programs. Two quantitatively based modelling strategies are; Mechanistic, and Empirical. The latter is a global information system (GIS) based modelling program that relates windthrow to qualitative characteristics of the windthrow triangle (Scott & Mitchell, 2005). Regression models are built to relate these attributes with sampling units that measured the presence or magnitude of wind damage (Mitchell et al., 2001). GIS can then be used to predict the most prone sections of the study area to windthrow. This modelling strategy is most suitable for stands with complex structure and composistion compared to mechanistic modelling (Mitchell et al., 2003). Large amounts of sample areas are needed to succesfully construct an accurate empiracle model. Mechanistic modeling uses programs such as WindFIRM or ForestGALES_BC as explained in (Byrne, 2011). To predict windthrow occurrence it uses estimates of critical windspeeds, and the probability that this wind speed would occur in the given location (Mitchell et al, 2003). The critical wind speed is calculated by winching trees to determine their resistence, and by calculating drag on the crowns with the use of wind tunnels (Byrne, 2011). Mechanistic modelling can further use numerical modelling to determine local alterations of the regoinal wind regime (Mitchell et al, 2003). According to Byrne (2011), a limitation of mechanistic models is that they do not account for wind direction.

For these models to accurately work they must data must be collectd from the areas in which they will be used.

Additional Resources

The Internet is a powerful tool with many free and accessible resources one can utilize to increase their ability to successfully manage an area. Two very useful tools that can be overlooked are the historical weather data stored in the Government of Canada's weather office page and the satellite imagery of Google Earth.

Environment Canada can be used to determine historical climate data. Using resources such as this, one can see the variability of wind velocities up to the hour. Figure 5 was compiled using the data presented by Environment Canada of Vancouver collected at the Vancouver International Airport (YVR). This graph suggests that Vancouver receives wind gusts with a velocity greater than 100km/hr an average of every 7.5 years (53 years/7incidents). It must be remembered that the prediction of storm severity is not 100% precise. This data can give a forest manager a basic understanding of the local climate. They can then apply this understanding to practices in the field.

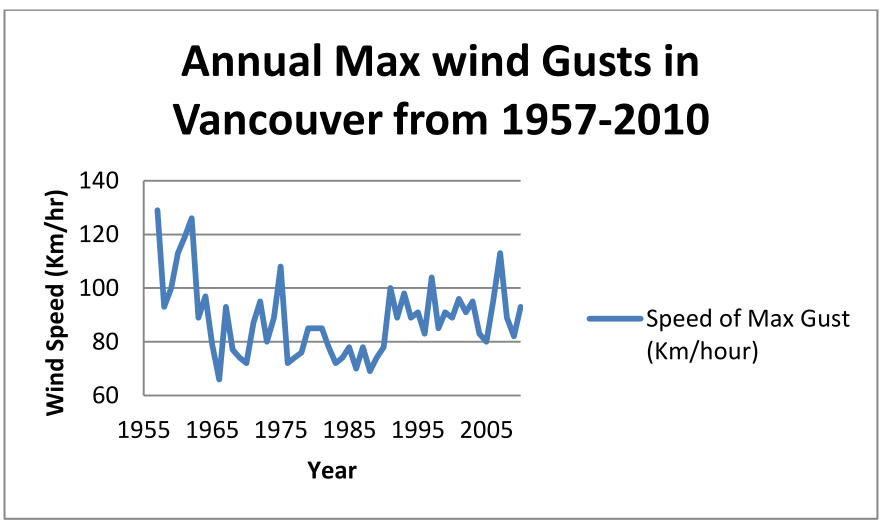

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FIGURE 5: THE ANNUAL MAXIMUM WIND GUST RECORDED AT THE VANCOUVER INTERNATIONAL AIRPORT FROM 1957-2010 (ENVIRONMENT CANADA)

Google Earth© can be utilized as a mapping resource to visualize the proposed area of harvest. In areas where the image resolution allows, windthrow in adjacent cutblocks can be recognized. This can give a manager an idea of the potential windthrow risk before stepping in the field (see Figure 6). The local topography can be studied to find features that may increase wind speeds such as saddles or crests (Alexander, 1987).

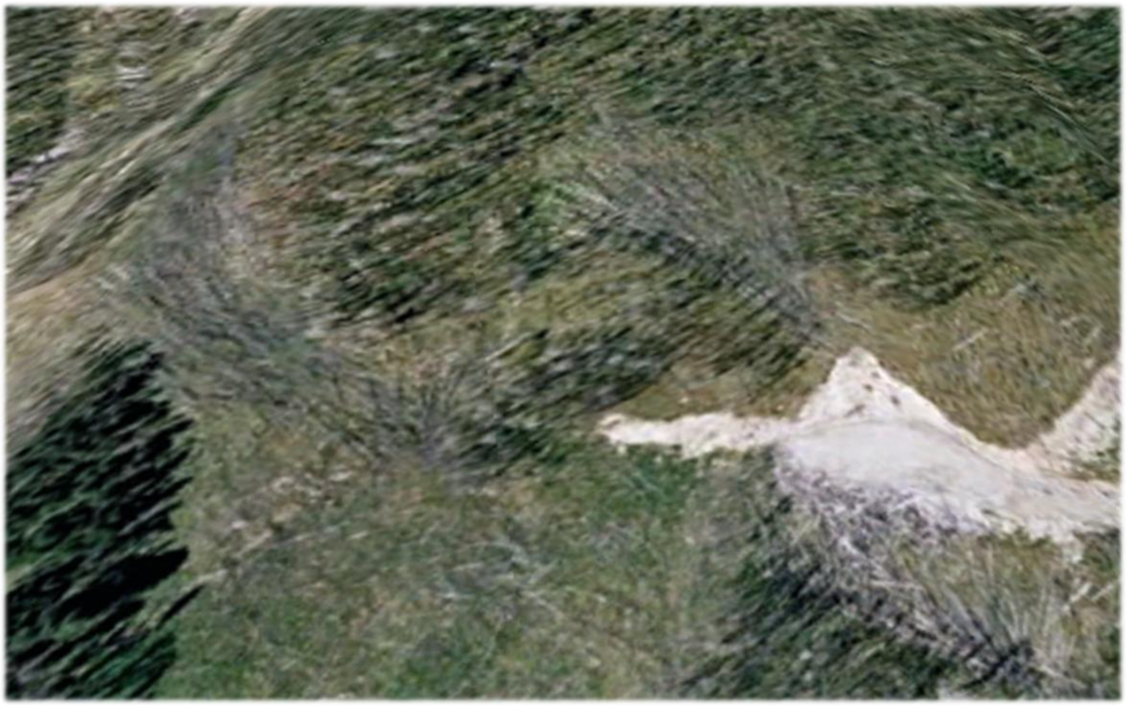

FIGURE 6: IMAGE TAKEN FROM GOOGLE EARTH© OF WINDTHROW IN THE EAST KOOTENAYS

Discussion

Windthrow is a common occurrence in British Columbian forests, with a timber volume equivalent to 4% of the AAC being affected in 1992. This is equivalent to amount affected by wildfire and insect infestation (Mitchell, 1995b). The damaged trees are often salvaged, depending on the feasibility of this practice. Through the history of forest harvesting in British Columbia many of the practices that have resulted in windthrow can be recognized through trial and error. The knowledge and resources of windthrow management strategies and assessment techniques that are available for forest managers to utilize are extensive. Management strategies include treatments aimed at decreasing windthrow hazard while assessment such as block design and edge treatments. While assessment techniques consist of field observations, windthrow risk assessment cards, windthrow handbooks, and the use of models to predict the likelihood of damage occurring risk (Stathers et al., 1994; Mitchell, 1998; Mitchell et al., 2001; Ministry of Forests 2003; Ministry of Forests, 2009; Zielke et al., 2010; Byrne, 2011). Assessment techniques are used to determine which management strategies are appropriate according to the situation. Managers must also actively monitor windthrow in their cutblocks. This should be done to determine the volume affected and if there is an increase in windthrow as the climate changes.

By using the proper assessment and prediction resources, managers can use a pre-emptive approach to reduce the windthrow risk prior to the layout stages. In the office a manager can use the mapping resources to determine factors that may increase risk. This can be done by using company mapping resources as well as programs such as Google Earth© and local climate data provided by Environment Canada. During travel to the proposed area of harvest, observations of windthrow can be made of previously harvested cutblocks. Soil depth along the roadsides can also be indicative of windthrow susceptible conditions. During reconnaissance, the degree of topographic exposure, particularly saturated areas, and stand characteristics can be noted. During this time the forester can observe the history of wind in the area by recognizing windthrow signs and symptoms of the stand (Mitchell, 1998). Root and butt rots, root wads, whether they are relatively new or hidden by the processes of decomposition, bent or broken stems and defoliated or debranched crowns are all symptom of historic presence of windthrow (Mitchell, 2011). As the layout process continues the manager must avoid creating static boundaries perpendicular to the prevailing winds (Mitchell, 1998). The creation of funnel points must be avoided during the layout process (Ministry of Forests, 2009). The same goes for the establishment of riparian reserve zones, and wildlife tree patches. After the completion of cutblock layout the windthrow risk must be assessed using the windthrow field cards, or further assessed by models. If the windthrow level predicted by the hazard assessment appears to threaten management objectives, the cutblock must be altered to meet the objectives. This can be achieved by re-locating boundaries or applying treatments to the edges that reduce windthrow risk.

The resulting windthrow in cutblocks is commonly salvaged. Salvage logging in reserve areas should be minimized particularily in riparian reserve areas. As the affects of removing

LWD from streams is often negative to stream characteristics (Grizzel & Wolff, 1998). These reserve zones have already been set aside, if they are not harvested there will be no loss to the tenure holder. Furthermore some salvage practices that remove green trees can further reduce the windfirmness of the cutblock edge. Although salvaging seems like a productive alternative to make use of windthrown timber, it can detrimental to the structure of the reserve zones.

There is an apparent need for annual statistics regarding the amount of windthrow that occurs in BC. Since the 1992 provincial wide windthrow survey took place, the total area or volume affeted by wind in BC has not been recorded. Through a continuous monitoring program the volume of windthrow occurring at a local level can then be recorded. Data from a local level can be combined to create a provincial wide windthrow database. Through this continuous monitoring, the emergence of patterns may point to better design practices as well as a further understanding of wind in cutblocks. As the climate changes the frequency of windthrow may increase as climate change is thought to produce more severe weather patterns (Toth, 2009). By monitoring the amount of windthrow that occurs annually in an area the increased affects of winds due to climate change could be measured.

Recomendations

Through the research carried out in this literature review, it was found that there are three areas that require further consideration. The following are a series of recommendations that are aimed at reducing the affects of wind on harvested cutblocks and creating a method in which practices can be measured for effectiveness.

- Elimination of salvage logging in reserve zones
- More thorough use of the windthrow risk assessment cards
- Continuous research of windthrow modelling programs to create more site specific predictions
- Implementation of continuous windthrow surveys across the province

Eliminating salvage practices in reserve zones would lead to more effort in the reducing acceptable risk, as the trees will be unavailable for salvage harvesting. An increase in mechanistic and empirical modelling research will lead to pre-emptive management actions resulting from the higher prediction accuracy of wind effects at a site level. The effectiveness of current practices could be measured by implementing an active surveying and mapping program of annual windthrow locally and across the province. By analyzing the collected data simple forest practices may be recognized that could significantly reduce the effects of wind on cutblocks. It may also be a useful indication of a changing climate as more severe weather systems are expected (Toth, 2009). Furthermore, if the current annual volume and area is equal to the survey in 1992, windthrow may become a more upfront issue.

Conclusion

When managing windthrow risk in coastal B.C. cutblocks a multitude of considerations and observations must be made. This literature review has shown that there are many resources available for managers to utilize when it comes to assessing and managing windthrow risk. Successfully designing a cutblock to meet all management objectives can be a challenge. To do this a range of factors must be observed throughout the process from the office to the field and back. This includes the utilization of mapping and modelling tools, local weather knowledge, local topography, and stand, soil, and tree characteristics. By using these tools and understanding the ways in which these factors interact, a forester can successfully design a cutblock to minimize the risk of windthrow while meeting all other management objectives.

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