Interior Broadleaf Working Group – Pacific Institute for Climate Change

# Aspen & Wildfire in British Columbia

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Abstract

Aspen *Populus Tremuloides* is the most widely distributed Broadleaf in North America, abundant from Alaska to northern Mexico, and California to Ontario and the Eastern States. Known for its adaptability and extensive range, Aspen also plays a role in Wildfire Management practices across the continent due to significantly reduced initial spread and ignition rates in Aspen stands relative to all other dominant tree cover types. Aspen is often credited for reducing the rate of wildfire spread and is commonly utilised as a fuel break or point of defence for suppression teams. Aspen's resiliency characteristics have been noted in the literature since the early 1940s with an increase in focus in the early 70-80s and again in the early 2000s. There exists a large body of research on Aspen Ecology and reproduction, and a smaller anecdotal body regarding Aspen's role in Wildfire. This paper is a preliminary review of the available literature concerning the benefits of Aspen in reducing the intensity and spread of wildfire at the regional and landscape scale, with a focus on Canada and British Columbia. Results indicate that there is sufficient evidence to confirm Aspen as a spread reducing cover type in comparison to all conifer cover types due in large part to species specific water retention, high humidity sub-canopy micro-climates, seasonal leaf out, and disturbance induced propagation by root sprouting. Climatic change and shifting precipitation regimes have a large effect on the moisture content and corresponding fire resilience of affected Aspen stands. Seasonal drought events across British Columbia and southern Canada resulting in the ignition and burning of large stands of Aspen are in part attributed to the effect of intensified seasonal droughts on Aspens longevity with respect to fire.Through a review of published research, wildfire reports and case studies, and a small survey of fire management and prescribed burning personal from western Canada and the Northern states, this paper suggests preliminary strategies for promoting and managing Aspen on the landscape to mitigate future wildfire risk. Considerable knowledge gaps are noted specifically concerning litter fuel loading, decadent stand management, and drought and moisture content identification across Biogeoclimatic subzones.

Contents

*Overview and Findings*

This paper is a summary of findings produced from a literature review of published papers and reports concerning the relationship between Aspen and Wildfire. The objective of the literature review was to discern the Aspen stand conditions which contributed to an increased capacity for the stand to resist ignition and sustained flaming, and reduce fire spread rates. This review is intended to advise future Non-timber management policies and procedures in British Columbia, by gaining a better understanding of Aspen's potential role in Wildfire mitigation and management at the landscape scale. Conclusions from the literature review were nearly entirely anecdotal or situationally specific, but there exists sufficient evidence to confirm Aspen's uniquely low ignition rates, reduced flammability, capacity to reduce fire spread and intensity in almost all circumstances, and characteristic ability to thrive in high frequency fire regimes. Published research clearly delineates an in depth understanding of "why" Aspen is resilient to fire based on its unique characteristics such as water retention and root suckering. The informative findings relevant for guiding strategy development for Aspen and Wildfire resiliency are as follows:

- Aspen roots sucker most after moderate to high intensity fires, rather than low but sucker rates will decline after the second or third high intensity burn if they occur within a time frame of ~8-20 years.

- Aspen grows well on porous loamy soils with high lime content and drainage, root area dependent on adequate soil depth to establish healthy parent root systems, which feed lateral root systems where suckering occurs. If soil is too shallow, lateral root suckers will not effectively sucker.

- A suggested total Canadian Boreal Forest Conifer to Broadleaf conversion rate of 0.3%/year starting in 2020 based on RCP 4.5 and RCP 8.5 by Giardin & Terrier, 2015 to maintain current burn rates.

- Fechner & Barrows 1976 and Martin E. Alexander 2003 support suggestions for Aspen as a landscape level fuel break.

- Comprehensive studies on the potential addition of a "D-2" Summer Green Aspen Fuel Type to the Canadian Forest Fire Behavior Prediction FBP System using fuel moisture guidelines as a predictive measure.

- Extremely variable flammability of Aspen depending on season i.e. Highly flammable and dangerous in spring following snowmelt and in autumn after leaf fall, then exceptionally difficult to burn during summer months during green up. Need for predictive tools to monitor timing and severity of seasonal change.

- Objective preliminary Build Up Index BUI threshold of 70 required for aspen to burn, supported by Beverly & Wotton 2007 study and Zama city fire 2019.

- Wind speed is the most important variable in affecting fire resilience in Aspen.
- A preliminary Build Up Index BUI of 70 has proven an acceptable burning threshold in Aspen.
- Fire Weather Index Values of relevance/having the strongest predictive correlation to sustained flaming – FFMC and BUI. Build Up Index threshold in D-2 Aspen of ~70% for burning considered relatively appropriate with reference cases study Zama city fire 2021. Fuel Moisture % is the most highly correlated variable to accurately predict when aspen will burn.

This paper will discuss Aspen as a species, its unique characteristics related to fire resiliency, consensus opinions from a small survey of Wildfire Management personnel, present and discuss samples of the prominent experimental research and associated findings, and discuss knowledge gaps and future learning.

*Aspen*

Quaking Aspen *Populous tremuloides Michx.* has the largest range of any Broadleaf tree species in North America. Acting as a dominant species from Alaska south throughout Mexico and from British Columbia and California to the eastern United states (Jones, 1985). Aspen is a uniquely adaptive species, reproducing mostly by root suckering of the parent root system following a major disturbance. The parent root system generally must be completely severed, killed or highly damaged through heat in order to promote suckering. For this reason, Aspen is usually the first species to establish following wildfire and is commonly known as the "Phoenix Tree" in the northwestern states (Bartos. 2007). Quaking Aspen in the western mountains typically matures in 70-100 years, and is an important watershed species, occupying southern facing slopes, riparian areas, and is usually the first species to return after mass disturbance (Browns & Simmerman, 1976).

Broadleaf coverage has been reportedly increasing in the past decade in the provinces of Ontario and Quebec due to natural disturbances and increased harvesting and industrial activity (Pinto et al. 2008) Landscape level changes in proportional coverage of Aspen and disturbance stimulated broadleaf species is expected to increase with increasing frequency of disturbances such as wildfire, harvesting and flooding and landslides (Laquerre et al. 2011). Aspen is especially dominant across the US and can be expected to follow the regional warming of northern climates (Iverson and Prasad, 1998). Dominant species in each vegetation cover type require specific edaphic conditions in order to thrive in a given location, without adequate soil moisture, texture and drainage, promoting Aspen on unfavourable sites may not be possible or could result in a lower seasonal regeneration rates, and reduced resilience to fire and drought due to poor establishment and health (Laquerre et al. 2011).

Bartos (2007) suggests that aspen will only be restored to its original extent through aggressive management strategies and continued promotion through fire and disturbance on the landscape. Five major risk factors for managing aspen are 1) Conifer Coverage over 25%, 2) Sagebrush cover greater than 10% 3) Aspen Canopy less than 40% 4) Mature Aspen trees older than 100 years and 5) Aspen regeneration from 5 - 15 meters tall in less than 500 stems/acre. These risk factors were developed specifically for Utah but are parameterized by key ecological thresholds for aspen establishment. More information on Aspen management and reestablishment is detailed in the later part of this Chapter (Chapter 3) on Aspen, for future reference.

Given the broad geographic distribution of aspen, fire regimes in these forests likely co-vary spatially with changing community compositions, landscape setting, and climate, and temporally with land use and climate but relatively few studies have focused on their spatiotemporal variations.

*Aspen in Wildfire Management*

Broadleaf species have been considered a burn resistant species among wildfire fighting personnel in North America for the better part of the last 50 years. When planning approaches for suppression of a wildfire, an overview of the broader forest cover shows locations of clumps or strips of Aspen and other broadleaf species which, depending on size, density, and shape, are then considered for their potential utility as points of defense. Due to the aforementioned high relative moisture content of Aspen, fire suppression teams assume that fire spread rates will decrease through aspen stands. In some cases the fire may reroute around the aspen along pathways of preferred fuel. This consensus does not always apply, and is a generalization of years of practiced assumptions. Spread rates for different cover types vary greatly depending on latitude, elevation, climate, and season. More research is needed to develop a guide for assessing site specific capacity for resistance to burning in Aspen.

Conclusion from a survey of 20 Wildfire mitigation and management personnel from Alberta, British Columbia and Utah support the assertion that Aspen commonly has a considered role in wildfire suppression tactics. The survey focused on accounts of first and second hand experience with Aspen either resisting or permitting wildfire spread, and the associated conditions (location, season, climate, weather, etc). Results were varied, however, the majority of respondents confirmed personal experience with aspen reducing the rate of spread or being avoided by the fire in question, though many had experience working on fires where Aspen did burn. Wildfire events in which Aspen facilitated burning were exclusively in extreme drought conditions, and majority in late fall. Importantly, 90% of respondents raised concerns around increasing frequency and intensities of regional drought conditions being the dominant factor dictating flammability in Aspen stands. Seasonal drought and changing moisture regimes pose a threat to reliable resistance to burning and stand health. Drought conditions allow aspen to burn in extreme cases. The survey collected mixed opinions around a general required depth or size of aspen fuel breaks in order to be effective. Defining a baseline fuel break depth will be highly dependent on local topography and climate, survey respondents suggested a 100-300 meter consensus "safe" zone.

Fire history was additionally noted as an important tool for assessing wildfire risk. As a seral species, mature aspen in British Columbia is seen in congruence with deciduous type species, each with varying predicted rates of spread and ignition. Aspen can also progress in pure clonal stands maturing as a climax species.

Shinneman et al. 2013 completed a literature review of 46 research papers, approximately one quarter of which were considered fire history studies. The review resulted in a classification framework for aspen fire regime types: 1) fire independent, stable aspen 2) fire influenced, stable aspen 3) fire-dependant, seral, subalpine aspen-conifer mix 4) fire dependant, seral, montane aspen- conifer 5) fire-dependant, seral, subalpine aspen-conifer. However, validating these classifications according to Shinneman et al. will require further site specific  studies.

Fire has been shown to be critical to aspen regeneration and persistence in some ecosystems, but not others (Mueggler, 1989). Aspen stands are often scattered among montane and subalpine conifer forests but can form relatively extensive and pure stands, especially in the Southern Rockies and Utah mountain ranges. Aspen stand structures are highly variable, ranging from extensive stands of tall trees on fertile soils and gentle topography, to prostrate trees in alpine landscapes, to dense stands of stunted and twisted trees in wet microsites within otherwise non-forested landscape (Perala, 1990). Aspen communities are primarily found at mid- to high-elevations in the MW, where annual precipitation exceeds evapotranspiration and mean annual temperatures are relatively cool (Perala, 1990).

However, aspen stands do burn when fuel and fire weather conditions are favorable. The International Crown Fire Modelling Experiment ICFME was a research trial conducted in July 1999 in the Northwest Territories, looking at Aspen stands and their interaction with wildfire. A crown fire started in Jack Pine and Black Spruce self distinguished upon entering a leafed out aspen stand with minimal ground vegetation (Alexander and Lanoville, 2004). The Rosie Creek fire which ran into the Bonanza Creek Experimental Forest near Fairbanks, Alaska, in June 1983, burnt through a mature green aspen forest. The fire was wind driven and on a steep slope, with severe burn conditions reported from the nearest weather station.

Important fuel considerations include the overstory composition and understory shrub and forb layer contributions to fuel loads (Brown and Simmerman, 1986). In general, low fuel moisture and fine fuel continuity are required to carry fire in aspen, though downed woody debris may increase the probability of fire spread, and shrubs or conifers in aspen stands can increase torching into the crowns and result in high-severity fire (Brown and Simmerman, 1986; Brown and DeByle, 1987).

*Resiliency Characteristics of Aspen*

The following characteristics have been recognized as prominent features contributing to burn resistance and low spread rates in Aspen stands. Characteristics will not express equally across all aspen stands and therefore will have differing influences on spread rates.

Canopy Closure – Canopy closure creates a microclimate “humidity bubble” in the understory/midstory that in turn influences the understory vegetation, shrub layer, and soil moisture retention.

Leaf Litter/Understory vegetation – Existing understory vegetation significantly influences flammability of Aspen stands, thus community types are important for fire resilience. Effect of shrub coverage percent (greater or lesser than 30%) and community type in understory dependant on subzone and elevation. Aspen leaf litter builds up on the forest floor and decomposes over the lifetime of the stands, leaf litter generally maintains a high moisture content but is susceptible to curing in late fall and for a brief period between snow melt and green up. In seral – mature aspen stands dead and downed organic matter build-up becomes a concern, deteriorating older-mature aspen stands although less flammable than conifers cannot be expected to significantly slow rates of spread, and the physical removal of dead fuel may be mandatory if the stand is not managed before reaching this stage.

Wind reduction – Largely approved consensus on significant effect of wind reduction in dense through mid story in aspen stands, on the scale of 5-15% of open area wind speeds.

Site series/sub zone – Indicates growth capacity/rate, dictates understory community and predicted localized moisture regime. Aspen has proven its capacity to thrive in a range of climatic zones across North America. Planning for long term forest health objectives will require identifying wetter sites where aspen can be expected to flourish in the future (Changing BEC zones and regional scale changes to precipitation patterns. Regeneration/promotion efforts should focus on 1) existing aspen stands who's range can be increased 2) riparian sites or along bodies of water/streams 3) in wet, cool-warm subzones that will presumably be habitable with future climate change.

Drought – compounding factor influencing summer aspen resilience at regional scale. Precipitation regime changes in future mean ecosystem resilience will be key to mitigating fire spread. High level fire in 2019 burnt through summer in Aspen forest cover. Looking at FWI failure points and translating them to other areas with similar conditions. Consideration of 1/50 year drought event effects on Aspen grass/shrub curing, and site moisture retention.

Slope Aspect – Southern facing slopes in warmer climates  have proven to be too dry to support seral aspen stands.

Grass – When aspen regeneration is reduced, or aspen is overly thinned in the Boreal and sub-Boreal forests grass will establish in the understory and will be advantageous summer litter fuel in drier conditions.

Successional stage and Age class – Aspen can in prevailing even aged pure stands hosting shade tolerant conifers through its successional stages. Trembling Aspen is considered a pioneer species and can be a climax species where environmental conditions are suitable, however are most commonly seen in early age classes and early successional stages in British Columbia.  Dense mortality as seen with the Aspen parklands in central Alberta, can lead to intense fires. General dbh of 15 cm required to withstand moderate to high intensity burns without mortality.

*Research and Literature Findings*

Martin P Giardin and Aurelie Terrier in 1986 did a comprehensive study looking into the offsetting potential of increasing broadleaf species representation in conifer-dense forests in Boreal Canada to reduce wildfire spread. They investigated Broadleaf - conifer conversion rates that could stabilize burn rates between 1971-2100 using regional burn rates, mean annual fire weather conditions, and tree type proportions. Vegetation Cover conversion rates were calculated based on the necessary change required to maintain constant burn rates over 1971-2100. Burn rate increases were calculated with respect to the Representative Concentration Pathways (RCP) from the IPCC (RCP 4.5 and RCP 8.5 where 4.5 and 8.5 are predicted radiative forcing values for the year 2100 at a given concentration pathway.

Surprisingly, results suggested many boreal forests will experience a decrease in burn rates and may not require a conversion in forest cover type. In the southern boreal a conversion rate of 0.1 to 0.2% starting in 2020 was suggested, and 0.3 to 0.4% in the northern boreal. Wildfire activity has recently been brought to the attention with the publication of studies demonstrating that past fire risks during post-glacial warm episodes were offset by a higher broadleaf component in landscapes (Girardin et al.2013; Kelly et al.2013; Brown and Giesecke 2014). The burn rate metric considered the proportion of areas burned per year, in a given region. To assess the potential change in burn rate metrics, the Canadian Boreal Forest was divided into fire bioclimatic regions, assigned a burn rate model, and future burn rates were calculated based on altered proportional coverage.

Fire Data was collected from MODIS summer and winter 250x 250 spatial resolution satellite imagery, some data collection was impeded by hazy skies or low cloud cover, insect outbreaks. The Canadian National Fire database CNFDB was used to supplement burn rate modelling. Canadian Fire Weather Index Systems were used to estimate fuel moisture and fire behavior indices, specifically Fine Fuel Moisture code FFMC, duff moisture code, and drought code. Initial spread index ISI and Build up Index BUI were also included. 2714 random sites with adequate relevant metadata were selected across the boreal region in Canada from 3000 original random points. Fire bioclimatic regions were built from fire weather and vegetation zone data resulting in 35 fire bioclimatic zones.

Results

The proportion of Broadleaf species was significantly lower in burned areas than in non burned areas. Increases in the Drought Code DC and Fire Season FS were projected to have a higher effect on the Northern Boreal regions in the RCP 4.5 scenario, but a greater total effect by the 21st century in the RPC8.5 scenario (Giardin & Terrier, 2015). A threefold increase in burn rate was predicted from 36% of the total Boreal Region of Canada under RCP 4.5, and 42% under RCP 8.5.

The Burn Rate model was parameterized using Multivariate Adaptive Regression Splines MARS, which is a non-parametric spline regression approach modelling non-linear relationships between response variables and explanatory variables (Giardin & Terrier, 2015). The explanatory variables are divided into space regions i.e. segmented piecewise regression to show relationships between response and explanatory variables by region.

By examining varying proportions of Aspen the conversion rate $\lambda$ was determined based on projected burn rate increases in each location. Naturally, the higher the climatic change the higher the required $\lambda$ to maintain baseline burn rates. 31% of locations had a $\lambda$ of 0 in RCP 4.5, and 18% in RCP 8.5. A conversion rate $\lambda$ of 0.1-0.2% /year starting in 2020 would maintain burn rates across the southern regions of the Canadian Boreal. For many of the northern regions fire weather conditions are expected to stay low with very little change needed in proportions of Aspen to maintain baseline burn rates (Giardin & Terrier, 2015). Greater $\lambda$ were needed to maintain baseline burn rates across the west to eastern belt on the boreal in 9% of the area in RCP 4.5 and 25% of RCP 8.5, a set $\lambda$ of 0.3 %/year is needed, meaning a 10.4 and 26.4% increase in 2045 and 2085 respectively in Aspen cover. The maximum conversion rate $\lambda$ was 0.6 %/year for the Northwest Boreal regions (Giardin & Terrier, 2015).

The results of the study suggest a significant increase in regions affected by burn rates greater than 0.5% by the end of the century especially near Hudson's Bay and the Northwest extents of the Canadian Boreal Cover (Giardin & Terrier, 2015). This study also shows that dry conditions and extended fires season are not the sole contributors to increasing burn rates, but that burn rates were highest in fire bioclimatic zones defined by Picea spp. and Pinus spp. This statement is supported by the analysis of non-burned to burned areas with the concentration of conifers in burned areas significantly higher than in non-burned areas (Giardin & Terrier, 2015).

The optimal conversion rate varied across Canada, many northern and southern regions would require no conversion to maintain burn rates, and a small incremental conversion rates of 0.2-0.3 %/year could be sufficient to maintain burn rates, a burn rate of 0.3%/ year generally was calculated as the minimum required λ over all areas, with some locations in the northern extent requiring 0.4%/ year.

British Columbia is notably excluded from this study, but comparative research can be done between similar Biogeoclimatic zones and subzones, and corresponding Fire Bioclimatic zones across Canada. The Interior Boreal forests of British Columbia could be estimated to require a conversion rate of 0.3% / year starting in 2020 considering proximity and climatic similarity to Western Alberta and Southwestern Northwest Territories.

### *Fuel Breaks*

In 1976 Barrows and Fechner examined the feasibility of using Aspen stands as wildfire fuel breaks in Colorado state. The objectives of the report were to 1) Determine the needed locations, width, general configuration and vegetative characteristics of fuel breaks 2) Determine fire ignition and, fire spread, general fire behaviour and fire control factors in quaking aspen stands.

The development and consequential resilience of an aspen stand greatly depends on the condition of the soils in which it grows. Barrows and Fechner state it grows best in porous and loamy soils, with high lime content.  Root suckering is also affected by soil conditions. The Shallow rocky soil common in much of British Columbia's Coastal and Interior Mountain ranges acts as a barrier to lateral root spreading, and therefore suckering (Barrows & Fechner, 1976.)

Suckers form on shallow lateral roots, typically within 2-12 inches from the surface (Gifford, 1966.) Because aspen reproduces primarily from root suckering, it is uniquely adapted to respond well following disturbances, specifically fire. Aspen responds well to fire because the parent root systems are not usually damaged by the fire, the heat damage to the shallow root system promotes suckering, and Aspen stands typically decrease the severity and rate of spread in wildfire (Barrows & Fechner, 1976).

The range of Aspen across North America, the condition of the trees in the stand, the quantity of dead and broken material, and flammability of each stand are exceptionally variable. Martin E. Alexander in his 2010 report emphasizes the potential for maintaining large healthy aspen forests by promoting turn over through harvesting mature the aspen, burning the slash, focusing on thinning conifers that reach canopy height and strategically routing into wetter sites. Furthermore, Aspen's flammability changes with the season.

It is common among Fire managers that Aspens stands will have a slower rate of spread than conifer or mixed wood stands, and are therefore an ideal control point for a fire line (Barrows & Fechner, 1976). A considerable portion of Fechner & Barrows 1976 report contains descriptive details concerning sucker formation and propagation of Aspen. Information on environmental conditions best suited to promote suckering formation, and information on promoting aspen can be found from pages 3-13 of the report. Fechner & Barrows use the 1974 Jefferson Lake Fire to demonstrate the potential of aspen stands as fuel breaks. The fire spread ceased within 4 meters of entering the aspen stand, and was brought down to the ground despite crowning at the edge of the aspen break (Barrows & Fechner, 1976.)

Fechner & Barrows (1976) conducted a study looking at the 215 Deciduous type fires from the US Forest Service report of nearly 4590 fires in the National Forests of Colorado between 1960-1973, meaning only 4.7% of all fires recorded occurred in Deciduous stands (Barrows & Fechner, 1976.) A statistical analysis of recorded fires in Colorado National parks shows a significantly reduced rate of spread, reduced area burned, and reduced size of fires in Aspen forests compared to all other cover types. From their results, given some generalizations Barrows & Fechner (1976) outline recommendations and strategies for using Aspen stands as fuel breaks in Colorado. According to these suggestions,

Location

The location should be determined after considering fire ignition potential, proximal major fuel bodies, soil, and climatological factors, topography. Fechner and Borrow (1976) suggest fuel breaks located at or near the base of slopes, along ridge tops, and in low mountain passes.

Fechner and Barrows (1967) assert that the appropriate width of an aspen fuel break will depend completely on regional topography and fire potential Considering recommendations from Fire control officers they recommend generally a width of 20-100 meters (Barrows & Fechner, 1976).

The last section of this report discusses the importance of Fuel Break Management. Fechner & Barrows emphasize the importance of regularly applying fire to aspen stands to limit surface fuel build up and promote propagation and growth of new aspen suckers.

*The D-2 Fuel Type*

In 2010, Martin E. Alexander published a report compiling current evidence and understanding for the D-2 Summer Aspen Fuel type in the Canadian Forest Fire Behaviour Prediction System FBP. Martin suggests a preliminary guideline to use fuel moisture levels as a predictive guide for surface fire spread in the D-2 Fuel type.

DeByle et al.(1987) report that wildfires burning in coniferous and shrubland fuel complexes under extreme weather conditions in the western U.S. seldom penetrate pure aspen stands by more than 30 m. De Groot et al.(2009), for example, have documented the occurrence of wildfire activity in trembling aspen forests in central Saskatchewan in early August 2003 and similarly in the southeastern region of the Yukon Territory in early July 2004. Consider the following changes that occur in the fire environment of a northern hardwood forest stand as the fuel complex transitions from a “cured” state in the spring following snowmelt to full green-up at the start of the summer period:

- A reduction in the effective in-stand wind speed at the ground level which in turn influences fine fuel drying and the direct effects of air flow on the flame front propagation (Marston 1956, Frederick 1961).

- An increase in shading as a result of the leafy canopy and lower vegetation(Kiil et al.1977) and thus a decrease indirect effects of solar radiation on the surface litter leads to lower fuel temperatures and decreased drying in the leaflitter (Byram and Jemison 1943, Van Wagner 1969).

- A decrease in air temperature and an increase in the relative humidity of the in-stand conditions results in decreased drying potential of the fine, surface fuels(Wright and Beall 1934)

-The surface leaf litter becomes matted and more compacted (Van Wagner 1983).

- The reduction in solar radiation at the ground surface coupled with the changes in weather elements leads to substantially less drying in the litter and duff layers (Van Wagner 1970, Wotton and Beverly 2007)

- The “green surface fuel effect” (Van Wagner 1975) resulting from the appearance of the understory vegetation with its very high (>100%) moisture content (Loomis et al.1979, Brown et al.1989) causes a dampening influence on surface fire spread. The crown fuels of the overstory will not support crown fire, presumably in part because of the very high (>140%)moisture content of the foliage (Van Wagner 1967, 1977)and low quantities of fine, dead twigs and branch wood (Loomis and Roussopoulos 1978)

Wright and Beall (1934) sum up the combined consequences of the changes described above: “The results of all these factors in the hardwood stand... is that within a period of about three weeks this forest type is transformed from one of the most hazardous areas” ... to one in which it is almost impossible to start a fire under any circumstances. These changes that occur in the tree canopy and lower vegetation in northern hardwood forests create conditions that reduce the probabilities of fire ignition and spread as evident in the reduction in wildfire occurrences and area burned in areas dominated by such fuel types.

The development of the D-2 Fuel Type

In the FBP System, Rate of Spread ROS is most influenced by Initial Spread Index ISI, which combines the effects of wind and Fine Fuel Moisture Code FFMC. Build Up Index BUI in the FBP System is added to the ISI to account for quantities of available fuel. Combining the BUI, with the duff Moisture Code DMC and Drought Code DC that indicates the total amount of fuel available for combusting. The DMC and DC are numerical ratings of the average moisture content of (i) loosely compacted organic layers of moderate depth, and (ii) deep, compact, organic layers, respectively.

Based on the Rothaermel’s Surface Fire Spread Rate "two fuel model concept" a fire spread rate is determined based on the proportion of hardwood versus coniferous coverage in a stand. p. 204 The FBP System recognizes Mixed wood types primarily Boreal Mixedwood Leafless - M-1 and Boreal Mixedwood Green M-2. The Rate of Spread ROS equations for these cover types are a combination of Boreal Spruce C-2 and Leafless Aspen D-1 weight by different proportions of each. The D-1 component of the ROS equation for Boreal Mixedwood Green is multiplied by a factor of 0.2 to account for the different Rate of spread in Green Aspen compared to Leafless Aspen. This assumes a 20% rate of spread reduction from leafless to green aspen.

By this logic, if the Hardwood component of the ROS equation was set to 100% and the coniferous component 0, a "D-2" Green Aspen cover type ROS can be calculated. However, this cover type is still technically M-2 in FBP System as D-2 has not been officially recognized for a number of reasons. Mainly, because the 0/100 ration in the M-2 ROS equation has not been tested or evaluated and holds no real validity to whether or not it is accurate, 2) Green Aspen as a fuel type has highly variable rates based on age, density, health, climate, moisture level etc. depending on location.

Alexander states that it is likely more important to clarify when D-2 would be applicable than it is to determine a specific rate of spread (Alexander, 2010.) Marty Alexander, the author for this paper and the majority of all papers published out of Canada concerning Aspen and Wildfire, has lived on a trembling aspen acreage in central Alberta for 15 years. Following a dry period in 2002, much of the understory vegetation was yellowing and wilting. Duff Moisture Code at the nearest Weather station was taken at 90, and Drought Code was 625 equating to a BUI of 132.

In order for a D-2 rate of spread to be relevant there must be threshold conditions established delineating the conditions under which Green Summer Aspen would even burn. Alexander evaluates a number of prescribed fires and wildfire case studies for indications of an appropriate BUI threshold for burning a D-2 fuel type.

Otway et al. 2007 assessed sustained smouldering in trembling aspen in Elk Island National Park in Central Alberta. Results suggested a 50% probability of sustain smouldering in the duff layer occurred at a BUI of 44 (Otway et al. 2007.) In order to assure 100% certainty in fire were found to be a DMC of ~70, DC of ~500 and BUI of 104.

Beverly and Wotton 2007 reviewed an experimental study conducted by the Federal Forest Service Fire Research Group between the 1950-1960's. A component of the study included an "Aspen leaf (summer)" site in the Northwest Territories. The Stand was reported as "pure 60 year old even aged" trembling aspen. 131 fires were started in the aspen between June 9 - August 30th, 30 single match ignitions were achieved. Marty Alexander was able to retrieve raw data for the study from personal communications with J. Beverly (Canadian Forest Service, Edmonton, AB, 2009, personal communication). The mean BUI for ignitions was 106 with a low 73 and high of 138. Based on these case studies Alexander M. deduced a minimum BUI threshold could be set at 70 and be generally valid, but could be higher in regions with less forest floor material.

The corresponding details for fuel type D-2 in terms of the fuel type characteristics contained in Table 3 of Forestry Canada Fire Danger Group (1992) are as follows:

- Forest floor and organic layer– Continuous matted leaf litter; shallow, uncompacted organic layer.

- Surface and ladder fuels – Moderately dense, medium total shrubs and herbaceous layers in full "green" state absent-conifer understory; sparse, dead down woody fuels

- Stand structure and composition – Healthy and moderately well-stocked trembling aspen stands; semi mature; leafed out stage (i.e., summer)

Additional information in the form of a relatively few well-documented wildfires and prescribed fires would probably do more to improve our under-standing of fire spread in northern hardwood stands in summer than analyzing a mass of individual fire report data and associated maps. A concerted effort should be made during the next few fire seasons to evaluate the general performance of this equation and the BUI threshold criteria by more closely monitoring wildfire activity during the summer months as the opportunities present themselves (Alexander and Taylor, 2010). Given the inherent spatial variability in summer time rainfall on FWI System components (Lawson and Armitage, 2008), the focus should be on wildfires that are within a very short distance of weather stations (<1 km) in order to avoid any uncertainties with regard to knowing what the rainfall history was at the fire site. There may also be occasions to make similar observations on operational prescribed fires (Alexander 2006). Finally, it may be useful to carefully re-examine particular incidents in the past in order to "mine" useful data and information (Alexander, 2005).

In response to this knowledge gap, Martin E. Alexander and R.W Sando completed a review of six experimental fires conducted in pure trembling Aspen stands and mixed deciduous stands in the U.S Lake States Region in spring and fall leafless stands. Burning conditions were categorized as extreme, most stems under 7.6 cm in diameter at breast height (dbh) were killed while stems over 15 cm dbh prevailed. The results of the study conclude that the most important variable is wind speed in affecting fire resilience in aspen. Another conclusion is that fire or harvesting/cutting of aspen is required to treat aspen before they are mature, burning before an average dbh of 13cm.

The study was carried out at the Mille Lacs Wildlife Management Area in Minnesota, with loamy clay soil rated poor to medium for Aspen. Plot sizes ranged from 4-65 ha, burning took place between April 27th and May 8th, and in late fall October 19th. The stands were between 22-54 years old, 1327-2703 stems/ha with 7.6-25.7m2/ha.

It had been 4-9 days since rainfall when burning occurred, dry-bulb and relative humidity were between 12.7-30.6 degrees Celsius, and 22-49%, with 15-18 km/hr winds. Moisture content of the surface fuels was 8.3-14.8%, although there was significantly less leaf litter than is typical in other Aspen stands in the Mille Lacs Area. The lack of available fuel impacted burning became apparent upon burning. ROS ranged from 1.52-8.84m/min, or slow to moderately fast. The maximum ROS was 15m/min. Due to near closed canopy conditions and reduced fuel loads ROS was only significant when winds exceed 18km/hr. Brown and Simmerman 1986 deduce that frontal fire intensities of 63-98kW/m and flame lengths of at least 0.52-0.64 m are required to kill aspen trees in the Western United States.

Beverly and Wotton (2007) did a comprehensive review of 107 small scale test fires from six sites across British Columbia and the Northwest Territories, testing likelihood of sustained flaming in different ground fuels after exposure to short lived flame source. The Canadian Fire Weather Index (FWI) System components were compared with site specific or regional Weather Variables and Fuel Moisture, to see which were most indicative of smouldering or not in each fire. Results show that FWI system components were not useful for predicting the probability of short-duration flaming in grass on aspen leaf ground fuels during summer conditions but were a highly effective substitute for site specific variables when the data is not available. Fine Fuel Moisture Content was required to be 94 in order for summer grass Aspen to sustain short term flaming.

*Fuel Complexes*

Greg Baxter in 2003 wrote a review of the House River Fire in 2002, which started on May 17th and burnt 248, 243 ha north of Lac La Biche, Alberta. Cutblocks burnt contained Pine, Spruce and Aspen in pure and mixed stands, with Canadian FBP fuel types M-2 Boreal Mixedwood (leafless and green), C-2 Boreal Spruce, and C-3/4, Mature/Immature Jack Pine, and S-2 White Spruce Balsam.

The province had undergone dry conditions in 2001 and in the months before the fire in 2002 with May and June receiving 56.7mm less than their annual average. BUI on May 30th was 84. Historical Precipitation anomalies from this area show similar drought conditions occurring on average once every 6 years back until 1881, and getting drier from 1950 onward. It can likely be expected that this pattern will continue to strengthen.

Baxter deduces that the primary factor influencing fire behaviour in cut blocks in grass, combined with slash fuel. Grass is receptive to embers, has high ignition probability when cured, and facilitates high rates of spread especially when influenced by wind. Baxter states that in Alberta grass can be cured for up to 5 months of the year, from early June to September snow cover.

Perala reported the effects of fire behaviour after an experimental burn of 9 one-hectare plots of clear cut trembling aspen blocks in Minnesota in 1974. Martin E Alexander reviewed the data and from personal communications with Perala, created a supplementary report in 1982. M. E.Alexanders report was a supplementary review of the burning conditions in terms of the Fire Weather Index and Canadian Forest Fire Danger Rating system (CFFDRS).

Stated in Alexander's 1982 report "a total of 101.1 mm of rain fell between April 3 and May 17, 1967. Fire weather observations at 1300 CST on the day of the fires were dry-bulb temperature, 20.6°C; relative humidity, 29%; and wind speed,4 22 km/h. Six days had elapsed since more than 0.6 mm of rain had fallen. The standard CFFDRS fuel moisture codes representing the moisture content of fine surface litter, loosely compact duff of moderate depth, and deep compact organic matter were Fine Fuel Moisture Code (FFMC), 92.6; Duff Moisture Code (DMC), 23; and Drought Code (DC), 63. The relative fire behavior indexes of the CFFDRS representing rate of spread, fuel available for combustion, and frontal fire intensity were Initial Spread Index (lSI), 18; Buildup Index (BUI), 24; and Fire Weather Index (FWI), 23. An FWI value of 23 or greater is considered to be an extreme level of fire danger in Ontario based on the frequency of occurrence (Stocks 1974). In this case, the lSI rather than the BUI contributed to the extreme FWI.

The above conditions would predictably result in extreme, uncontrollable fires in other fuel types but in Aspen resulted in moderate fire intensity (Alexander, 1982). The expected rate of spread in a Jack Pine cover type for the above conditions would be 36.6 m/min, where in Aspen it would be 2.5m/min.

Perala discusses the calculations, assumptions and sources of error in great detail in their 1974 paper. Alexander suggests that this method of conglomerating weather data, moisture codes, vegetation proportions and fuel complexes will ultimately be the process by which we are able to further estimate fire spread rates and intensities of forest fires in different fuel types using the Fire Weather Index system of the CFFDRS (Alexander, 1982).

Foremost, proper fire weather records should be meticulously kept with reference to the CFFDRS codes and indexes where possible, and with applicable weather data from the closest stations. Historical weather data allows for reconstruction of past fire danger conditions, which allows for predictive modelling and forecasting.

*Discussion*

As a result of its extensive range and opportunistic propagation strategies, Aspen's ecological role has been studied and documented in depth. Aspen's relationship with fire lent its hand to a set of assumed behaviours that have been incorporated in practice and policy for many generations. Specifically on Northern south coast of North America, fire has become front and central to both timber management and forest planning activities in an effort to reduce the risk of catastrophic landscape scale fires. In the past decade, California, Washington, British Columbia and Alberta have experienced some of the most devastating wildfire disasters in recorded history displacing thousands, destroying huge swaths of land with hundreds of thousands of dollars needed for repairs and recovery. As the province of BC grapples with these challenges, there exists an opportunity for timber management practices to reorient in preparation for a changing climate. Sufficient evidence exists to confirm Aspen as a fire resistant species with the furthest geographic habitat of any broadleaf species in North America. Unique characteristics contribute to Aspen's capacity to resist burning depending on precipitation and regional moisture regimes, and season. Aspen may be an effective species to propagate in large swaths at the landscape level provided there is a commitment to upkeep. Overmature and decadent aspen stands, especially when dry and leafless in the winter and fall, pose an exaggerated threat acting as a source of fuel. Pure aspen stands will require thinning and brush control, ideally by prescribed burning and physical removal. Mixed wood stands have generally lower rates of spread and minimally lower initial Spread Indexes. General consensus from the aforementioned survey was that some Broadleaves are better than no broadleaves in terms of rate of spread, but will be less instrumental than larger clumps/patches or linear features with regard to fire suppression strategies. There is a limited availability of prescribed burning research in mixed wood with dominant aspen components.

The considerable knowledge gaps in the literature with regard to Aspen capacity to reduce wildfire, specifically in the context of British Columbia, highlights the need for further experimental study and research. Experimental trials of aspen burning in the province accompanied by consistent data collection and monitoring would greatly inform provincial and regional authorities on best practices for integrating Aspen into the forest management plan at a landscape level. As climate change continues to alter precipitation and temperature patterns, drought periods are expected to increase in frequency and intensity across much of southern BC. Non-Timber values are being propelled to the foreground of importance as proactive wildfire management techniques are being developed. Aspen may play an important role in helping reduce the risk of Wildfire.

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