STRATEGIC ASSESSMENT OF CURRENT AND FUTURE EXPOSURE OF WILDLAND HUMAN INTERFACE AND COMMUNITIES TO WILDFIRE IN CANADA

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Abstract: In the wildland-human interface (WHI, including the wildland urban interface [WUI], the wildland industrial interface [WII] and the wildland infrastructure interface [INF]), the imperative is to protect life and property from destructive fires, while also conserving biodiversity. Under climate change, fire-prone conditions are predicted to increase by 1.5 to 4 times before the end of the century across Canada. Currently, there are no comprehensive Canadian-wide fire exposure assessment for the WHI, nor for the quantification of the population exposed to different fire return intervals under current and future fire regimes. We assessed the current and future area of each type of WHI exposed to high fire return intervals, as well as the current and future population facing high fire return intervals in boreal Canada. Slightly more than 10%, 20% and 15% of the WUI, INF and WII are respectively currently experiencing short (< 250 yrs) fire return intervals. These proportions would increase to 28%, 42% and 41% respectively after 2071 under RCP 8.5. Currently, about 12.3% of the Canadian population (4.1M) reside within the WUI with First Nations being overrepresented. About 5% of the Canadian population currently live in landscapes with short (< 250 yrs) fire return intervals, including >15% of First Nation population. These numbers would surge to >17% and >37% respectively in 2100 under RCP 8.5. Our study should greatly help communities, agencies, industries and First Nations to know where the risks currently are and will be in the future and which mitigation measures are to be implemented.

1. INTRODUCTION

Wildland fires and humans maintain a dynamic relationship driven by the successive interferences with one another. On one hand, fires are a necessary disturbance to preserve the health and biodiversity of the boreal forests of Canada, determining their physical and biological attributes as well as their spatial configuration. On the other hand, out-of-control wildfires represent a direct threat to human life and infrastructures. Within the last decade, Canada has experienced dramatic evacuation events (e.g., Saskatchewan in 2015) whereas single fires have resulted in catastrophic infrastructure losses (e.g., Slave Lake in 2011, Fort McMurray in 2016). Characterizing regional and local factors affecting human's fire exposure is therefore paramount in order to increase awareness, protection and develop efficient management strategies.

Landscape-level interactions between human activities and natural fire dynamics tend to be spatially concentrated at the Wildland Human Interface (WHI), where residential structures and other human

development (i.e., industry and infrastructures) meet or intermingle with undeveloped vegetation, creating an environment in which fire can move readily between structural and vegetation fuels (Johnston and Flannigan, 2018).

Diversity in land occupancy and in forested cover implies diversity in the profiles of WHI communities in terms of fire exposure. Nevertheless, all communities in or near the WHI face a common problematic: what are their current level of fire exposure and how can they protect their living environment in a fire-prone landscape? Up to now, fire exposure within the WHI is totally unknown for virtually all Canada. Identifying areas of high fire exposure will help fire agencies to enhance community resilience by aiding in the development of risk reduction strategies, and serving as a valuable tool for prioritizing mitigation and preparedness activities (McGee et al. 2009, McFarlane et al. 2012).

The WHI fire exposure is expected to worsen during the 21st century, as fire activity increases in severity and variability with climate change, particularly in the Boreal forest (Flannigan et al. 2009, Price et al. 2013, Gauthier et al. 2015a). The cumulative effects of expanding interface areas, population density, and climate warming converge to create an expectation of more frequent interface disasters and increasing losses (i.e., environmental, social, and economic) during the upcoming decades, with an ongoing pressure on fire management. This study provides an overview of the current and future fire exposure of WHI and communities in Canada, whether in terms of area and population, to create a baseline for assessing regions which are, or will be, potentially affected by wildfires. We confronted the spatial distribution of communities and human-built values to the spatial distribution of forest flammability, by using new Canadian Forest Service databases, included the pan-Canadian interface maps. Our objectives were to (1) assess the area of each type of WHI exposed to short fire return intervals; (2) stratify the WUI into WUInterface and WUIntermix to evaluate the proportion of population exposed to short FRI, with a distinction for Indigenous people on reserves; (3) portray the changes in high FRI under future climate change projections, in terms of both areas within each WHI types and WUInterface population.

2. MATERIAL AND METHODS

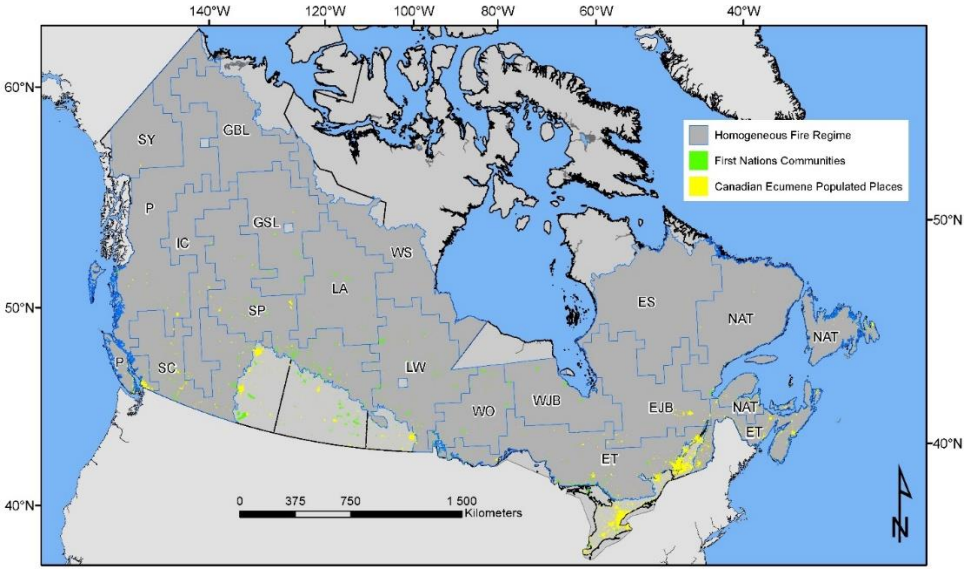
The fire exposure of communities, infrastructures, and industries has been assessed through the combination of census data and spatial products, recently developed by the Canadian Forest Service. The study area encompassed the forested regions of Canada, as represented by the Homogeneous Fire Regime (HFR) zones of Boulanger et al. (2014) (Fig. 1A). Local current annual fire return intervals were obtained at 250 m resolution from the map of Bernier et al. (2016), which resulted from the combination of regional burn rates by HFR zone (1959-1999, Canadian National Fire Database (NFBD)) and the fire selectivity by forest property (age and composition; Beaudoin et al., 2016) (Fig. 2A).

Future trends in regional fire activity were considered through the climate projections of three Representative Concentration Pathways (RCP) scenarios, namely RCP 2.6, RCP 4.5, and RCP 8.5 (Fig. 2 B, C, D for RCP 8.5). The future trends were computed for each HFR for the 3 different pathways using the equations defined in Boulanger et al. (2014), and this for three periods of time over the next century (2011-2040, 2041-2070, and 2071-2100). The projected local fire return intervals were computed as for the current conditions' one using the vegetation of 2011 (Beaudoin et al. 2017) and the regional fire projections (Fig. 2 B, C and D for the RCP 8.5).

The Wildland Human Interface (WHI, Fig. 1B) characterized areas of wildland fuels surrounding human-built structures, making them potentially vulnerable to forest fires (Johnston and Flannigan, 2018). The generic term of WHI interface referred actually to three distinct types of interfaces: the wildland-urban interface (WUI; considers all homes, public, and commercial structures), the wildland-industrial interface (WII; considers electric power, oil, and gas facilities), and the wildland-infrastructure interface (INF; considers roads, transmission lines, bridges).

The WHI covered 13.8% of the total land area of Canada (116.5 M ha, including overlapping between the three interface types), the majority of which were located in the southern part of the country (Johnston and Flannigan, 2018). Individually, WUI, WII and INF represented 3.8% (32.3 M ha), 1.2% (10.5 M ha), and 13% (109.8 M ha) of land area, respectively.

A)



B)

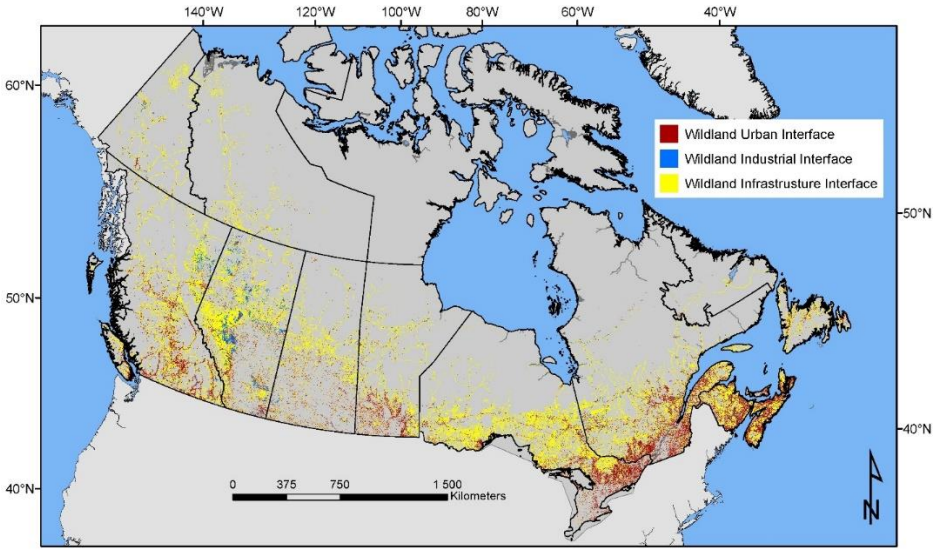


Figure 1. Location of the study area and of A) the Homogeneous fire regime zones of Boulanger et al. (2014) and the Ecumene presenting the native and non native communities (Natural Resources Canada 2018), B) the Wildland Human Interface in three categories (Johnston and Flannigan 2018).

The stratification between Interface (WUInterface) and Intermix (WUIntermix) was not yet available in the current WUI stratification (Johnston and Flannigan 2018). We therefore proceeded to a simple quantification of the Intermix and Interface areas by intersecting the WUI layer with the Canadian Ecumene GIS database, a polygon dataset created through the linkage of satellite night light images, official place names, and population data (Natural Resources Canada 2018).

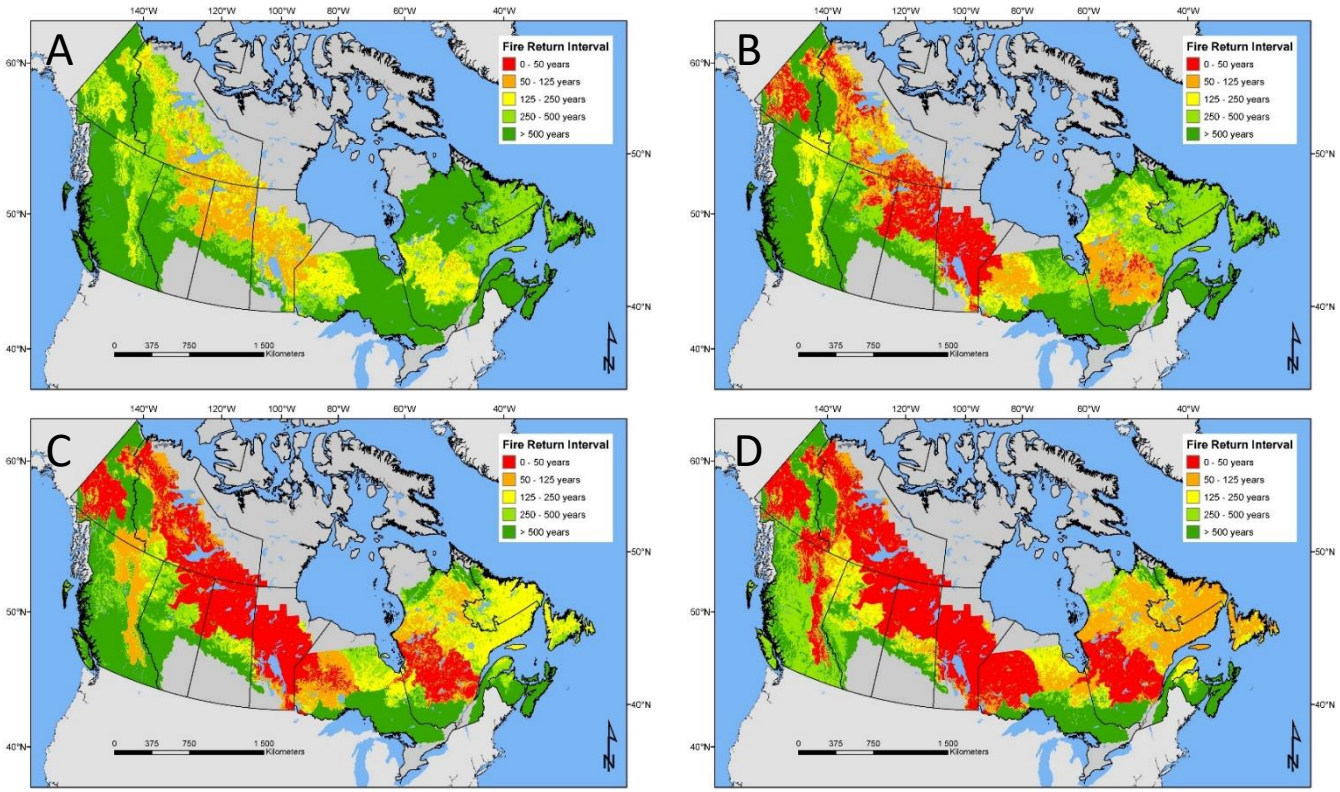


Figure 2. Projection of the current and future localised fire exposure (fire return intervals) accounting for fire selectivity under the RCP 8.5 as defined by Bernier et al. 2016. A) current regime; B) 2011-2041, C) 2041-2070 D) 2070-2100.

The Canadian Ecumene GIS database spatially identified populated places as “human habitats”, without administrative boundaries constraints. The localised fire exposure of WHI areas was assessed by overlaying the aforementioned fire return interval maps (2.1) and each of the four wildland interface maps (WUInterface, WUIntermix, WII, and INF interfaces), after that all the maps were referenced to the same grid size. We compiled the pixels of the WHI interfaces comprised in the same 5-years classes of fire return intervals, and reported the values as cumulative area distributions (1 pixel = 6.25 ha). The analyses were performed for the current and future time period, as depicted by the RCP projection scenarios (2.6, 4.5, and 8.5).

We assigned to each community polygon of the Canadian Ecumene database the number of inhabitants compiled from 2011 census data (Statistics Canada, 2012). The Ecumene database comprised 99.4% of the total Canadian population. The gridded population density of communities was then obtained by dividing the total number of inhabitants, by the total number of 250m-pixels composing the polygon. We restricted the scope to populations exposed to wildland fires by subsampling only the pixels that were located inside the WUInterface. Considering the particular exposure of Indigenous peoples to wildland fires, we refined the Canadian Ecumene GIS database by distinguishing First Nations reserves from other communities.

3 RESULTS

3.1 Areas exposure to wildland fires: the Wildland Human Interface

The Wildland Urban, Industrial, and Infrastructures Interfaces cover 4.35%, 1.53%, and 16.5% of our study area, respectively (Table 1). As some interfaces do overlay, a total of 17.32% of the study area is considered to be in the Wildland Human Interface. The larger areas in WHI are located in the Southern HFR zones (SC, ET, and SP zones), which have long Fire Return Intervals (FRI), even in the projection of 2100 (Figure 2). The HFR zones under the shortest FRI (≤ 125 years) cover the Northern regions (GBL, GSL, LA, and LW zones). Although less built up than Southern regions, they are however covered by 3.65 to 11.73% of WHI, mostly in the INF Interface (3.49 to 11.31%), and are projected to be more exposed to wildfires during the next century.

Slightly more than 10% of the WUI area is currently experiencing a fire return interval of less than 250 years, 14.6% for the WII, and almost 20% of the INF (Fig. 3). The proportion of WHI area under short fire return interval is expected to increase under projected future fire exposure. The WUI area currently submitted to very short FRIs (≤ 125 years) would increase from 2.1% currently to 12.2-24.3% in 2100, under the scenario RCP 2.6 and 8.5 respectively. In the same way, the WII area would increase from 4% to 14.6–33.6%, while for the INF would increase from 6.4% to 20.7–37.5% (Fig. 3).

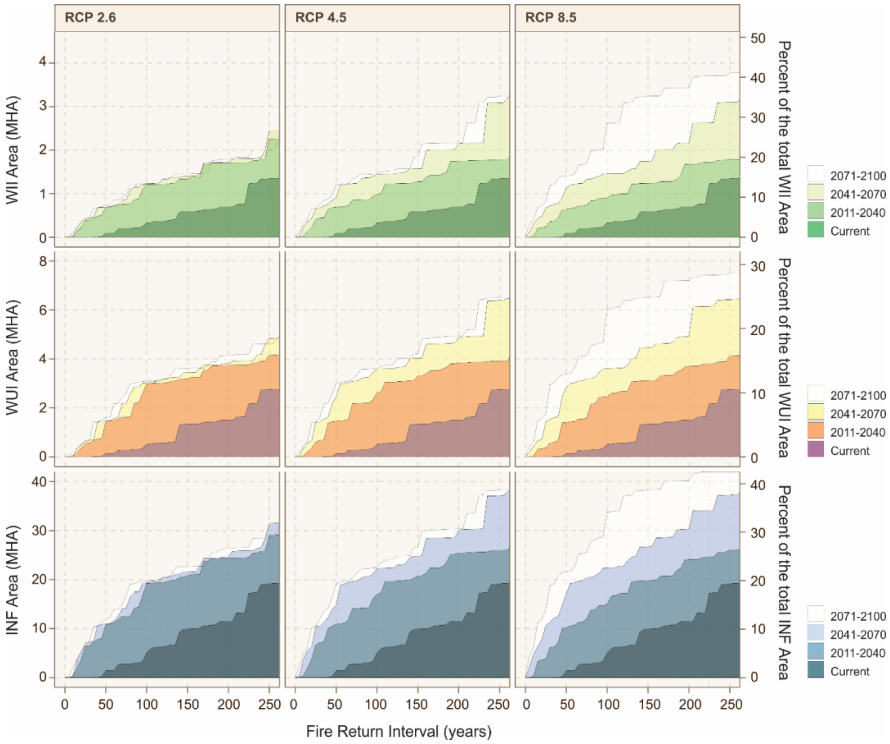


Figure 3. WHI interfaces areas under different fire return intervals if submitted to current and future fire regimes

Only 6 % of the broad WUI area is assigned as WUInterface, whereas 94% of the area is assigned as WUIntermix. Future projections of fire activity show similar trends both in the WUIntermix and WUInterface. The WUIntermix area currently submitted to very short FRIs (≤ 125 years) would increase from 2.2% currently to 12.5-24.4% (i.e., RCP 2.6-RCP 8.5) in 2100, while WUInterface would increase from 1.4% to 7.7–22.5%.

3.2 Current exposure of populations

The population evaluation was conducted only for the WUInterface area. When looking at the Canadian population from the 2011 census, we estimate that around 12% of the Canadian population reside in the WInterface (4.1 millions of people), i.e. in or near lands prone to wildland fires (Figure 4). With regards to

First Nations reserves, they appears to be more exposed to fire risk than the other communities: they are only 1.1% of the Canadian population while they represent 2.9% of the total population in the WUInterface.

We observe that slightly less than 5% of the communities live in landscapes under a Fire Return Interval inferior to 250 years and less than 2% are under a FRI inferior to 150 years (Figure 4). First Nations communities located in reserves are more numerous to be exposed to short fire intervals as 9.8% and 16.7% of their total population are under FRI < 150 and < 250 years, respectively.

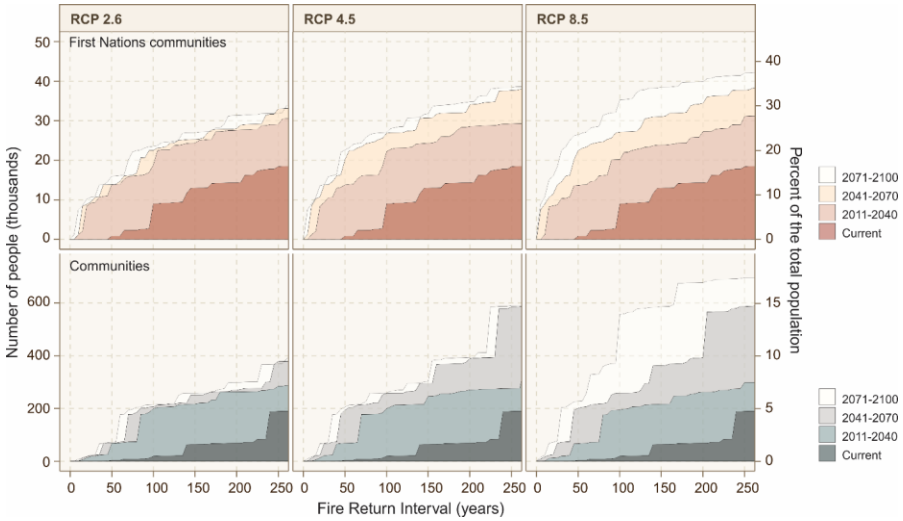


Figure 4. First Nations and non-First Nations population distribution (2011 census) depending on the different layers of the landbase.

In terms of future exposure, if we consider a FRI of 100 years, it would progress from ca 8% under the current conditions to around 30% under RCP 8.5 for the First Nation reserves (Figure 4). More than 20% of these people would even face fire return intervals below 50 years. For the other communities, close to 15% of the current population would see fire return interval of less than 100 years under RCP 8.5 in 2100.

4 DISCUSSION

To our knowledge this study is the first assessment of current and future fire exposure to fire of WHI areas, and population. This work should help in raising awareness of potential impacts of the forecasted change in future area burned in Canada. The area of the WHI exposed to short fire return interval will increase considerably between now and 2100, notably with more or less 30% of each of the WHI types being affected by return intervals below 100 years, a many-fold increase from today. The current exposure of the INF and the WII witness the fact that so far, in Canada there has been little consideration of fire exposure in the planning of infrastructure or industry. Our result also suggest that the areas of these types of WHI under short fire return interval would increase considerably in the future.

Our work also highlight the importance of the WUI that is in the intermix areas which covers more than 94 % of the WUI area. Our results also suggest that the areas of the WUI-intermix submitted to short return interval would increase more rapidly in the near future indicating that the population living in these conditions will need to be made aware of the fire risk.

Our analysis provide very rough estimate of the population located in the WUI-Interface areas, as it leaves out the majority of WUI area, i.e. those mostly intermix areas on the fringes of communities which are located even more into the forests. On the other hand, high population density in cities being defined as WUI-interface are likely to over estimating the real population in the WUI. With regards to the First Nation data, we used the census data available on First Nation reserves which of course do not cover the entirety of Indigenous populations in the country.

Our results also suggest that First Nation communities on reserves are already located in areas where short fire return intervals are more likely, and that they would see an increase in future fire risk as they would be submitted to shorter fire return interval sooner that what is observed for the other communities.

Our results are derived from static information on forest types, location of the different type of WHI areas, and population density. As there are several initiatives to expend management in the currently unmanaged forest and in region already submitted to high fire activity, and with a high rate of growing population notably for First Nations communities. This information is timely. We trust that it can be use by land planner, municipalities, communities, etc. to start considering the fire risk in their regions and to develop action either to reduce the risk, or to face it when it will occur. It can also be used to help raising awareness of fire exposure in communities that are already or that will be exposed to higher risk in the future.

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