Effects of Climate Change on Canadian Forest Fires

Curtis Chong, Emily Huang, Leon Chen

Pierre Elliott Trudeau High School

March 13, 2017

Abstract

This study aimed to determine the effects of climate change on forest fire trends in Canada by measuring correlations between weather conditions and the frequency and size of forest fires. Upon identifying the correlations, a model was created to understand future forest fire trends. The purpose of this study was to prevent the increasing trend of forest fires and devise solutions to reduce their damages.

The data obtained from the Canadian National Fire Database underwent a linear regression and a machine learning algorithm to respectively predict and correlate weather conditions with future forest fire trends. It was concluded that temperature and wind speed experienced a positive correlation with forest fire frequency and size and precipitation experienced a negative correlation.

To reduce the harmful effects of forest fires, cloud seeding can be used to create more precipitation and wind farms can be built to lower wind speed and attract lightning. However, more research and stricter policies directly targeting climate change are necessary for long term stability or decrease in forest fire trends.

Keywords
Forest Fire, Climate Change, Canada, Big Data

1 Introduction

The 2015 Fort McMurray Fire in Alberta exemplifies the extent of damages caused by forest fires. The incident destroyed 2400 buildings and 1600 private residences, with the total cost of damages estimated by the Conference Board of Canada to be between \$4 billion and \$9 billion [3]. The Alberta government also spent \$160 million for evacuation procedures, disbursing \$1250 to each adult and \$500 to each dependent [3]. The event also forced 14 days of lost oil production averaging around 1.2 million barrels per day, equating to around \$985 million in lost real GPD [3]. The fire also allowed contaminants deposited on trees and soils such as mercury, heavy metals, and polycyclic aromatic hydrocarbons to be released into the air, thereby creating a more toxic smoke than that of regular forest fires [4]. In burning the buildings, houses, cars, furniture, etc., the fire further released a wide range of toxins and small particles potentially dangerous for the lungs [4]. A rainfall will also cause a toxic surge into the water systems, including the Athabasca river, and adding to the aquatic pollution already caused by contaminants from oil sand production [4].

Given its evident harms, preventing the increase of forest fires appears to be an important endeavor. In fact, the Ecological Institute at Northern Arizona University found prevention efforts can reduce the cost of rehabilitating/treating an area to 30%, resulting in an cost between \$200 to \$400 per hectare [5]. While the differences in region and climate does not allow a direct comparison between Canadian forest fires and those studied by at NAU, the consistently heavy burden of forest fire relief on taxpayers provokes a re-evaluation of policies surrounding the fires. For the past decade, British Columbia, which experienced around 900 forest fires between April and July 2015, has overspent their wildfire fighting budget almost every fiscal year [6].

Table 1 depicts discrepancies in the British Columbia wildfire management budget and spending

Evidently, as the economic and environmental toll of forest fires are consistently greater than expectations. In developing a model analyzing climate conditions affecting the fires, our

Fiscal Year	Budget	Spending
2014/15	63	297
2013/14	63	122
2012/13	62	133
2011/12	63	53
2010/11	52	212
2009/10*	409	382
2008/09	56	82
2007/08	56	98
2006/07	56	159
2005/06	55	47
2003/04	55	371

*Election Year

Table 1: Table to depicts British Columbia wildfire management budget vs. spending per fiscal year in $ millions

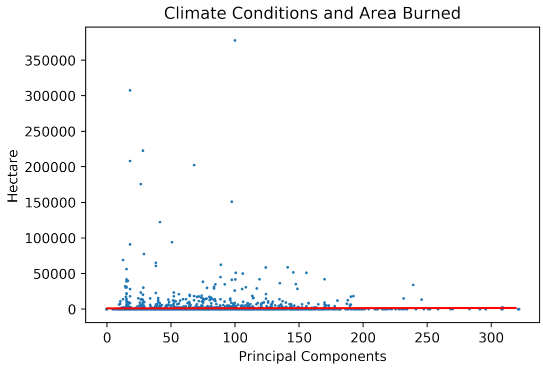

Figure 1: Relation between principal components and area Burned

project aims to assist the targeting of government funds to more efficient and long-term productive uses. For instance, through understanding the atmospheric conditions that cause more frequent and intense forest fires, we can implement solutions which directly target those conditions. On a grander scale, in demonstrating the extent to which climate change intensify forest fires, our model may provide further concrete support for the urgent need for stronger policies against overall climate change.

2 Materials & Methods

To understand the effects of climate change on forest fire trends, historic fire data was extracted from the Canadian National Fire Database. Each fire incident was matched with the nearest weather station to determine weather conditions at the time of the fire; namely, precipitation, temperature, and wind. The model also considered burn rate, measured from 1 -3, based on different types of trees in the area. A Principal Component Analysis (PCA) was first conducted to determine key features and reduce the dimensionality of the dataset. Then, a linear regression algorithm was applied to the simplified dataset to predict the size of forest burned using atmospheric conditions. Next, this model was used to predict and compare the size of forest fires in 2050 using current projections of atmospheric conditions and those satisfying the Paris Climate Change Agreement goals. The difference between the two shows hectares of forests saved if CO_2. The number of forest fires at the year 2050 was then multiplied by the average area of forest saved to determine the forest area that would be protected under global climate reform. Additionally, a k-means clustering was used to determine optimal placements of wind farms around Canada and specifically the Northern-Albertan region. These wind farms are to be placed in the centroids of previous forest fire areas to achieve maximum impact.

3 Results

The linear model received the following sets of variables to predict the size of Hectares burned:

PCA	Temp	Month	Burn_rate	Prec
Not met	5.8	2	1	10.3
Met	4.5	2	1	11.0

Table 2: Table outlines the two sets of variables, without and with the success of the Paris Climate Agreement goals, used to predict size of forest fires in 2050 which include average temperature, the month of data, burn rate, average precipitation.

The linear regression yielded an r-value of 0.024192099753, a p-value of 0.0829027260742, and a standard deviation of 2.93742495196.

The first model projected a annual burn area of around 1300 hectares while the second model projected a burn area of 1600 hectares, yielding a difference of 306.

Based on the frequency of forest fires in the National Fire Database, the 2050 fire frequency is projected to be 6280 natural wildfires. When multiplied by the amount of hectares saved from the Paris Climate Agreements, 1,921,680 hectares of forest can be saved annually.

Figure 1 shows the correlation between prominent features and hectare burned

Figure 2 shows occurrences of forest fires in Canada.

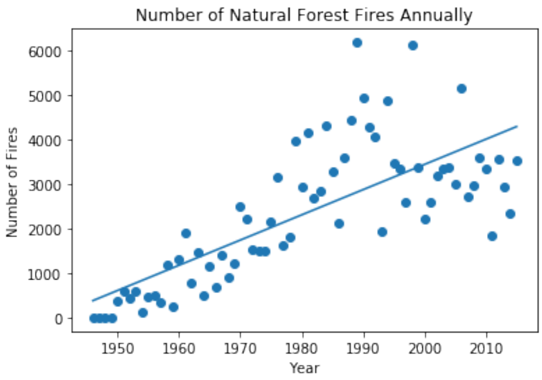

Figure 2: Frequency of forest fires in Canada in the past years

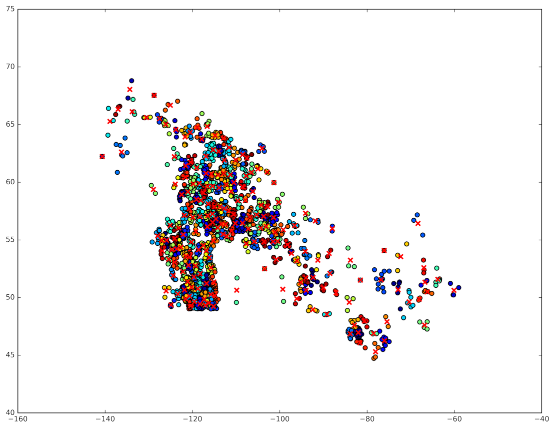

Figure 3: Locations of forest fires (dots) based on latitude and longitude and optimal wind farm locations (x)
shows forest fire and wind farm locations based on longitude and latitude.

The k-means clustering model placed windmills in the centroid of those clusters based on an input of the number of desired windmills. The model currently displays an input value of 200 wind farms, a reasonable goal for the next 5-10 years given the recent upward trend of Canadian wind energy investments.

4 Discussion

The positive correlation between temperature and frequency and size of forest fires is intuitive as heat is one element of the combustion triangle. The radiation from the sun heats and dries shrubbery and sticks on the ground to become potential fuels. Warmer temperatures also allow these fuels to ignite more readily and burn faster, factors which increase the size of forest fires.

The principal components revealed a positive correlation between wind speed and the frequency and size of forest fires which can be attributed to the role of wind in supplying the fire with fresh oxygen, drying potential fuel, and increasing the rate at which the fire progresses across the terrain. Furthermore, we revealed a negative correlation between precipitation and the frequency and size of forest fires which demonstrates the role of moisture in lowering the likelihood of forest fires igniting. As water has a very high heat capacity, moisture – existing as precipitation and humidity – can slow the rate of forest fires and decrease their intensity by absorbing the fire's heat.

As the climate data used for each forest fire was attained from the nearest fire station rather than the direct site of the fire, there may exist discrepancies in weather conditions that slightly distort the result.

It is also evident that climate action is required to steer Canada's forests away from oncoming fires. To mitigate the affects of climate change, the province of Alberta must diversity its workforce and build wind farms in its northern regions. Such political action will only direct the province towards clean energy and will protect the Boreal Forest.

Conclusions

As indicated by the study, high wind speeds intensify forest fires by supplying fresh oxygen and tilting the flames forward to dry and preheat surrounding vegetation. As a result, we recommend building wind farms. Currently, our model suggests building 200 wind farms each at the centroid of clusters of forest fires. The wind farms would effectively remove kinetic energy from the air and reduce wind speed in the region. These wind farms can also attract lightning strikes and reduce the frequency of forest fires incited by lightning, which account for 81% of total area burnt [1]. Furthermore, wind farms should specifically be built in regions of high-risk for forest fires such as Northern Alberta instead of primarily in Ontario as previous wind energy investment trends have indicated [10].

Figure 4 shows optimal wind farm locations in Canada.

A method frequently employed by other nations including the U.S., China, and Thailand to prevent and put out forest fires is cloud seeding, a weather modification mechanism which shoots seeding agents such as silver iodide or salt into clouds to form precipitation and add moisture to the environment [7]. Cloud seeding efforts can reduce the strength of forest fires or temporarily delay them to allow time for creating

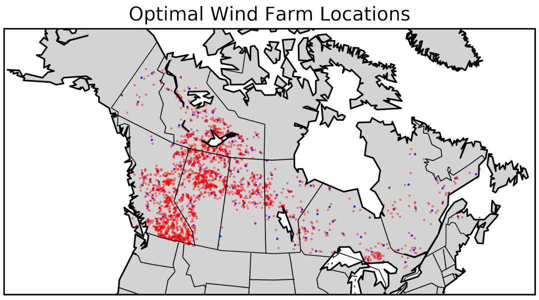

Figure 4: Optimal wind farm (blue) locations with respect to forest fire (red) occurences

evacuation and preparation policies to minimize damage. Using the model from this study, we can allocate cloud seeding projects to areas that will most benefit.

Though our study focuses on the impact of climate change on forest fires, man made forest fires account for around 43% of forest fires exceeding four hectares [8]. As many man made forest fires are caused by ignited exhaust pipes covered by clumps and mud and grass or irresponsible practices by the oil and gas industry, increased awareness of safe practices should be encouraged by municipalities and poor industry practices should be penalized. Such measures will prevent unnecessary forest fires and reduce the negative impacts while other policies are devised to reduce the increasing occurrence and magnitude of forest fires due to climate change.

In addition to the aforementioned measures, climate change is the most significant issue to be addressed. To tackle climate change and meet the goals of the Paris Agreement, we first advocate for reducing and eventually doing away with the $3.3 billion fossil fuel subsidies which effectively pay polluters $19 for each tonne of carbon dioxide emitted and, if the subsidy is not removed, will increase to $50 per tonne by 2022 [9]. The government should instead subsidize the research, development, and growth of green energy technologies and businesses. These efforts will also help domestic green energy businesses become more competitive in meeting the expanding global need for green energy.

Further models can be built to more precisely predict the intensity and location of imminent forest fires, rather than merely determining overall trend, to assist in directing prevention and suppression efforts. This model would likely require understanding greater in scope and depth of the weather conditions that cause and worsen forest fires.

To more stringently target climate change, further research can be conducted comparing the greenhouse gases output and economic contribution of various industries to determine which industries should be phased out or reformed to be efficient.

Acknowledgments

First, we want to thank our mentor Ching Pan for finalizing our plan. We also want to thank the Canadian National Fire Database for providing us with the data set and Environment Canada for compiling the historic weather data. Lastly, we thank Dr. Sacha Noukhovitch for the ongoing support.

References

[1] Lightning and Forest Fires. (2016). Environment and Climate Change Canada. Retrieved 10 January 2017, from https://www.ec.gc.ca/foudre-lightning/default.asp?lang=En&n=48337EAE-1

[2] Cheadle, B. (2016). Climate change bringing larger forest fires, more bugs, diseases, Natural Resources Canada warns | Toronto Star. The Star. Retrieved 10 January 2017, from https://www.thestar.com/news/canada/2016/09/28/climate-change-bringing-larger-forest-fires-more-bugs-diseases-natural-resources-canada-warns.html

[3] Economic Impacts of the Fort McMurray Wildfires. (2016). The Conference Board of Canada. Retrieved 10 January 2017, from http://www.conferenceboard.ca/press/newsrelease/16-05-17/economic_impacts_of_the_fort_mcmurray_wildfires

[4] Leahy, S. (2016). Canada wildfire - what are the environmental impacts?. the Guardian. Retrieved 10 January 2017, from https://www.theguardian.com/environment/2016/may/11/cana wildfire-environmental-impacts-fort-mcmurray

[5] Peterson, J. (2014). Wildfire Prevention Costs Far Less Than Fires. Live Science. Retrieved 10 January 2017, from http://www.livescience.com/47894-wildfire-prevention-costs-less-than-cleanup.html

[6] Talmazan, Y. & Dunn, T. (2015). The cost of B.C. wildfires over the last decade. Global News. Retrieved 10 January 2017, from http://globalnews.ca/news/2101720/interactive-the-cost-of-b-c-wildfires-over-the-last-decade/

[7] Vanderklipe, N. (2016). Could cloud seeding have saved FortMcMurray? Does it even work?. The Globe and Mail. Retrieved 10 January 2017, from http://www.theglobeandmail.com/news/alberta/could-cloud-seeding-have-save-fortmcmurray/article29957745/

[8] Markusoff, J. (2015). What's to blame for Western Canada's forest fire outbreak?. Macleans. Retrieved 10 January 2017, from http://www.macleans.ca/news/canada/whats-behind-western-canadas-forest-fire-outbreak/

[9] Milman, O. (2016). Canada gives $3.3bn subsidies to fossil fuel producers despite climate pledge. The Guardian. Retrieved 10 January 2017, from https://www.theguardian.com/world/2016/nov/15/climate-change-canada-fossil-fuel-subsidies-carbon-trudeau

[10] Installed Capacity. (2017). Canadian Wind Energy Association. Retrieved 11 December 2016, from http://canwea.ca/wind-energy/installed-capacity/