STEM Fellowship Big Data Challenge 2016-2017

Effects of Climate Change on Canadian Forest Fires

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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

Canada currently experiences an average of 8000 forest fires per year, burning 0.7 to 7.6 million hectares and amassing $500 million to $1 billion in suppression costs [1]. A 2015 assessment by Natural Resources Canada reported a total of 7068 forest fires burning 3.9 million hectares in that year, resulting in a frequency above the 10-year average and a 50% increase in area burned [2]. More specifically, in 2015, Saskatchewan experienced forest fires 3 times the magnitude of their provincial 10-year average, and Alberta, 2 times [2].Such fires forced the evacuation of 125 communities and resulted in health, environmental, and economic damages particularly in British Columbia, Alberta, and Saskatchewan [2]. This project aims to use data to recommend policies to reduce forest fires' harmful effects, and demonstrate the crucial role of climate change in exacerbating the fires.

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 endeavour. 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].

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

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

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 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, 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. To predict the threat of future forest fires, a linear regression was used to extrapolate the number of fires in the future. Then, an algorithm was used to correlate the types of weather conditions with the size of a forest fire. Then additional methods such as k-means clustering was used to suggest solutions for forest fires.

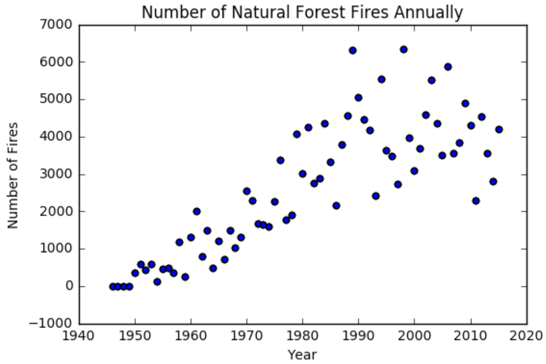

Figure 1: Frequency of forest fires in Canada in the past years

3 Results

Through analyzing data from previous forest fires, an increasing trend in forest fires was evident.

Figure 1 shows occurrences of forest fires in Canada.

Our model clustered locations of forest fires through k-means clustering to optimally place 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.

Figure 2 shows forest fire and wind farm locations based on longitude and latitude.

The study found a positive correlation between wind speed and forest fires, and between temperature and forest fires. The study found a negative correlation between precipitation and forest fires.

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

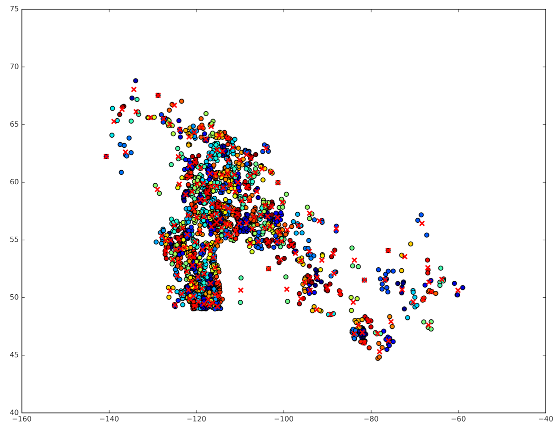

Figure 2: Locations of forest fires (dots) based on latitude and longitude and optimal wind farm locations (x)

potential fuels. Warmer temperatures also allow these fuels to ignite more readily and burn faster, factors which increase the size of forest fires. The positive correlation between wind speed and the frequency and size of forest fires 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.

The negative correlation between precipitation and the frequency and size of forest fires 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.

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].

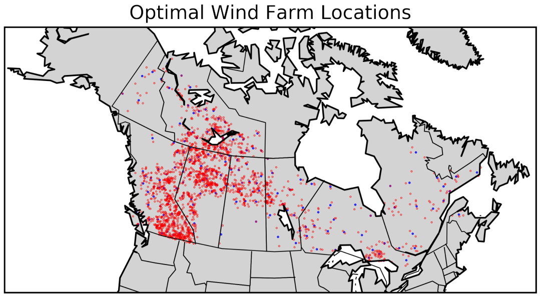

Figure 3: Optimal wind farm (blue) locations with respect to forest fire (red) occurences

Figure 3 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 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.

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