Alberta Aflame:
A Comprehensive Analysis of Wildfire Impact and Severity

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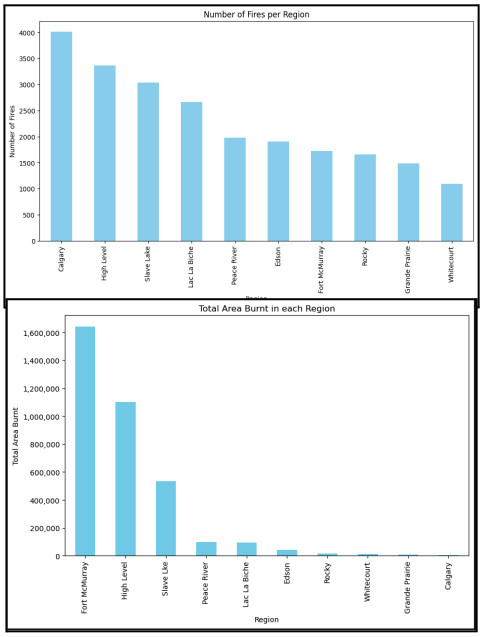
Abstract
The increased intensity and risk of Wildfires are a pressing concern as global temperatures are rising and contributing to a change in overall climate around the world. It not only has economic impacts, but social and health impacts to inhabitants of the region, especially indigenous people. In this report, we present a novel approach to analyzing wildfire data provided by the Government of Alberta in the Historical Wildfire Dataset with logged wildfires in the fire years 2006 - 2021. Our analysis deals with identifying the top FSA regions that are most vulnerable to Wildfires, we find these to be High Level Slave Lake, Fort McMurray. We also look at the main reasons contributing to wildfires in each vulnerable FSA region and find that for all FSA regions the main cause is lightning and then other causes include unsafe fires (including permit related and insufficient buffer) and burning substances. Indigenous peoples have a special connection with their ancestral lands and face profound challenges both during and after wildfire events and we find indigenous people that live in FSA regions that are on Indian reserves are impacted the most. Finally, we develop a machine learning model to predict the size class of wildfires considering variables such as the FSA region and the predominant vegetation that grows in the region which becomes a fuel in wildfires. Our model produces good results giving an accuracy of 88%. This model will provide a means to predict the size area and severity of a wildfire based on initial assessment of the wildfire done by Wildfire Management employees and help to reduce the extreme costs and health risks associated with wildfires

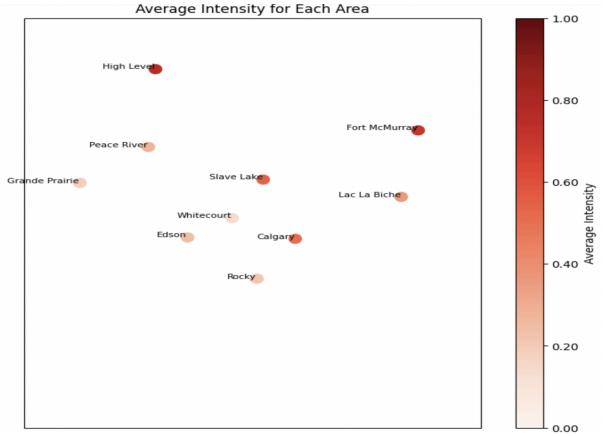
Introduction
Wildfires in Canada's 2023 wildfire season is the worst on record, with more than 5,800 reported fires and over 15 million hectares burned to date. The Alberta government has declared an early start to the 2024 wildfire season in the face of low snowpacks and more dry weather forecasted.This signals the heightened risk that the provincial government perceives, and they plan to lessen the burden by moving firefighters to be ready (The Canadian Press, 2024). The costs of wildfires are astounding with the annual national cost of wildland fire protection exceeding $1 billion for six of the last 10 years and average costs have risen about $150 million per decade since wildfire data collection started in 1970 (Pittis, 2023). The required elements necessary for starting a fire are oxygen, heat and fuel also known as the fire triangle. We look further at these three elements by exploring how they contribute to a heightened risk of fires. Particular regions around the province are filled with different types of vegetation such as coniferous trees, low lying shrubs which increases the likelihood of a fire starting or growing to larger areas. This along with a source of heat (like lightning), high temperatures along with dry and windy conditions can sustain a fire.

Methodology
Most Vulnerable Regions
To identify the top vulnerable regions, we want to look at not only the number of fires, but also the hectares burned, specifically the final area burned, since it is the most representative of the fire's total impact. This is a better approach because if we look at the number of wildfires only, Calgary has the most number of wildfires, however, if we look into them, they are mostly class size A and B, which are very small wildfires. Hence, it is better to assess an area's vulnerability to wildfires based on the impact of fires, not just their number.

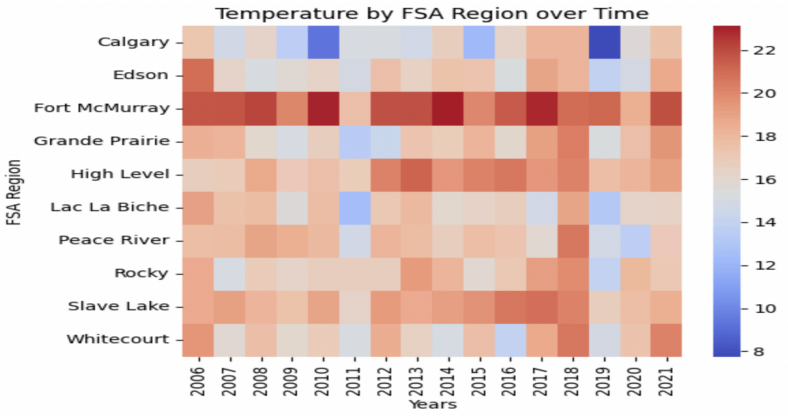


In assessing the vulnerability of regions to wildfires, two critical factors were considered: the extent of hectares burned and the total number of recorded fires per area. To ensure comparability across regions, these factors were normalized by dividing each entry by the maximum value in its respective column.

This normalization process standardized the data, allowing for direct comparison between regions. Subsequently, the normalized values for hectares burned and total number of fires were averaged to derive a composite metric known as intensity. This intensity metric provides a quantifiable measure of the vulnerability of each region to wildfires.Utilizing the coordinates of each Forward Sortation Area (FSA) region, geographical boundaries were delineated on the map. Within each FSA region, the average intensity was computed by aggregating the intensity values of all locations encompassed by that region.
The resulting visualization vividly illustrates the average intensity of each FSA region, with darker hues indicating heightened vulnerability to wildfires. This method facilitates the identification of areas necessitating heightened attention and resource allocation for wildfire prevention and management.



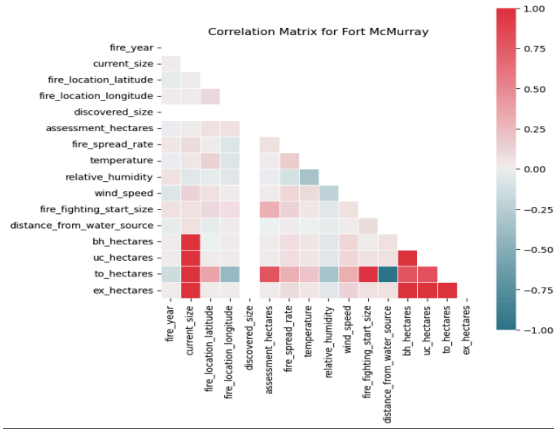
In summary, by amalgamating geographical data with intensity metrics derived from hectares burned and total number of fires, the plot offers actionable insights into the relative vulnerability of diverse regions to wildfires. Notably, it underscores Fort McMurray, High Level, and Slave Lake as the top three most vulnerable areas.



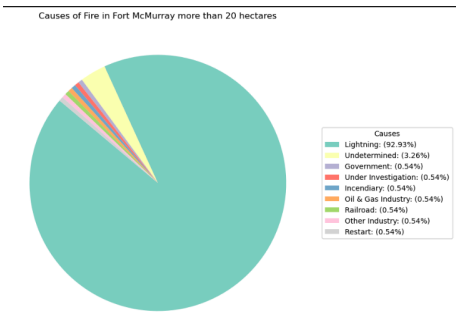
The heat map generated, showcasing the relationship between regions, temperature, and years, vividly illustrates the average temperature trends across various regions over time. Notably, Fort McMurray consistently emerges with the highest temperatures across the years, followed by High Level and Slave Lake. This compelling visualization not only highlights regional temperature disparities but also underscores the significant impact of forest fires on surrounding temperatures. The observed correlation between intense forest fire activity and elevated temperatures reinforces our understanding of the environmental consequences of wildfires. By providing clear insights into spatial and temporal temperature variations, the heat map underscores the urgency of implementing effective wildfire management and mitigation strategies in vulnerable regions.

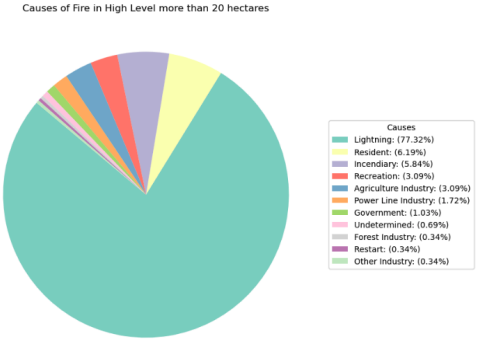
Main Reason Causing The Fires

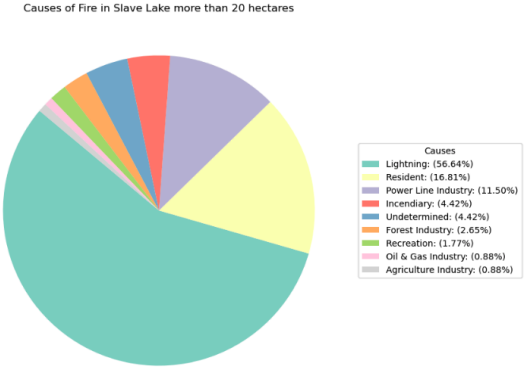
Let's look more into the Fires ignited in the top 3 vulnerable regions. Before looking at the causes of the fire, let's look at some points that may or may not contribute to the fire's size. We can look into variables like temperature, humidity, wind speed and other numerical values. For example, the correlation matrix for the numerical values in Fort McMurray shows that there are not really any strong correlations between the data, other than the values that represent the size in hectares, which makes sense as the size of the fire is usually closely related to the size when it started being handled and became under control.



The correlation matrix for High Level and Slave Lake is not very different to Fort McMurray, it has slight differences in some values that are not particularly interesting to our goals, but the conclusion is that there is not really a specific numerical value found that we can say is highly correlated to the size of fires and so we cannot mention as one of the reasons a region's vulnerability. However, it still could be argued that weather conditions could make it harder to put out a fire and factors like wind could make a fire spread faster.



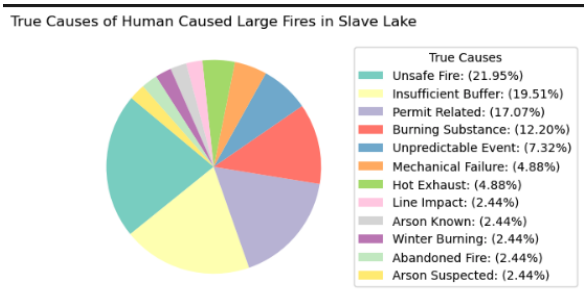




General Cause for Top Regions

We are going to investigate the large and effective fires in the top 3 regions we found earlier, mainly fires that are over 20 hectares in size, as this is a large enough size to be considered a widely harmful fire. The chart for Fort McMurray, that almost all the fires there are caused by Lightning, which is something that cannot really be avoided, but rather dealt with in a better way to avoid them dramatically expanding. Same thing goes for High Level, which has over 77% of fires caused by lighting and the rest caused by several other factors. However, in Slave Lake, Lightning seems to be the highest cause, but there are also other significant causes such as residents and Power Line industry, so let's investigate those.

We can see that in Slave Lake, the top 3 main true causes for large fires that are not caused by lightning are unsafe fires (including permit related and insufficient buffer) and burning substances. With this information, we could come to a few conclusions regarding what could be done to avoid/minimize these fires. The first thing is to spread more awareness on the use of fire and how to handle it in such vulnerable areas. Moreover, there could be increased restrictions as to who can get a permit or handle a fire in these areas so that only individuals who are highly capable could ignite a fire. There could also be more preparations in areas around forest fuels like increasing the buffer areas to avoid fires caused by insufficient buffers. Lastly, applying restrictions to the use and dispensation of burning substances to avoid fires caused by incendiary devices. These are our recommendations to help reduce the number of wildfires that are caused by humans in vulnerable regions.



Integrating Population Data

To have a better understanding of the FSA region's population density and vulnerability to wildfires, we can look at the Alberta Government's census population estimates data between 2016 to 2022.

The chart below highlights the 10 areas in which the FSA region's belong to. Excluding Calgary, the other 9 population figures outline the area to which the FSA region belongs to. For example, Fort McMurray is located within Wood Buffalo.

Census Subdivision (FSA Regions) Population Estimates, July 1, 2016 to 2022, Alberta

Census Subdivision	Area Name	Type	2016	2017	2018	2019	2020	2021	2022	Region Within Subdivision
4806016	Calgary	CY	1278982	1292550	1311699	1337655	1361587	1371575	1413800	Calgary
4816037	Wood Buffalo	SM	73511	71676	72541	73422	73939	73649	74532	Fort McMurray
4814003	Yellowhead County	MD	11236	11332	11319	11360	11314	11297	11438	Edson
4819006	Grande Prairie County No. 1	MD	23099	23351	23714	24186	24491	24734	25928	Grande Prairie
4817093	High Level	T	3256	3246	3196	3244	3263	3254	3293	High Level
4812037	Lac la Biche County	SM	8522	8445	8334	8320	8213	8148	8187	Lac La Bishe
4819038	Peace River	T	7038	6850	6798	6710	6730	6701	6662	Peace River
4809015	Rocky Mountain House	T	6792	6656	6539	6422	6321	6353	6603	Rocky
4817029	Slave Lake	T	6879	6820	6720	6638	6538	6386	6377	Slave Lake
4813030	Whitecourt	T	10543	10341	10311	10147	9997	9760	9586	Whitecourt

We can also look at these figures for Alberta's various Indian Reserves.

Census Subdivision (Indian Reserve) Population Estimates, July 1, 2016 to 2022, Alberta

Census Subdivisio	Area Name	Type	2016	2017	2018	2019	2020	2021	2022
4803802	Blood 148	IRI	4711	4748	4743	4759	4771	4709	4669
4815802	Stoney 142, 143, 144	IRI	3891	3922	3953	3991	4052	4052	4053
4812806	Saddle Lake 125	IRI	4039	4076	4062	4029	4028	3992	4001
4808811	Samson 137	IRI	3473	3518	3536	3560	3587	3590	3577
4805802	Siksika 146	IRI	3578	3572	3563	3596	3590	3558	3559
4806804	Tsuu T'ina Nation 145 (Sarcee 145)	IRI	2331	2388	2366	2385	2609	2710	2719
4817835	Fox Lake 162	IRI	2094	2175	2248	2319	2397	2495	2543
4811801	Ermineskin 138	IRI	2535	2498	2523	2542	2538	2495	2457

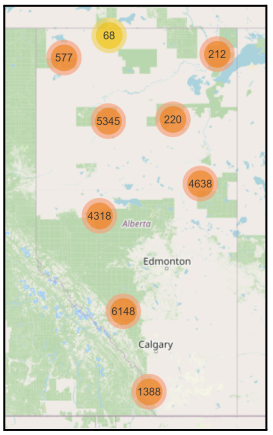
Furthermore, we can analyze the population demographic data provided by Alberta's government to identify the province's vulnerable population based on age.

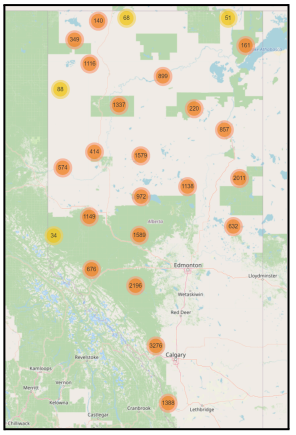
Population by Age and Sex, Canada, Provinces and Territories, 2016-2020

Area Name	Year	Sex	Total Population	Population by 5-Year Age Group																		
				0-4	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95 to 99	100+
Alberta	2016	3	4196061	274112	272631	244641	247030	279676	335867	356151	322538	291601	274583	287289	278838	228871	174507	118335	84111	62106	40055	17474	4928	717
Alberta	2017	3	4241100	274118	275488	252005	247963	274372	329590	355985	331338	295532	277739	279947	281783	239944	179934	128873	87890	63091	41160	18402	5183	763
Alberta	2018	3	4298275	273078	276431	260466	251141	273625	325500	354921	341605	302205	281249	272724	284370	250016	187561	138542	92769	64458	42271	19176	5355	812
Alberta	2019	3	4361694	271515	277057	268369	254468	275421	320638	355048	351505	310526	284865	267723	286095	258072	198535	147813	98075	66281	43214	19994	5570	910
Alberta	2020	3	4421876	269163	277785	276328	256742	277328	314507	356226	359301	319889	288546	266489	284259	264339	210073	157657	102977	68565	44033	20921	5746	1002

Plotting Wildfire Clusters By Location

By using the data provided, we plotted the wildfires based on their starting location and through zooming in on the map, we can identify which areas have a greater number of clusters. When looking at specific towns and cities, such as the Dene Tha' First Nation, we are able to pinpoint the exact locations that are historically susceptible to fires.



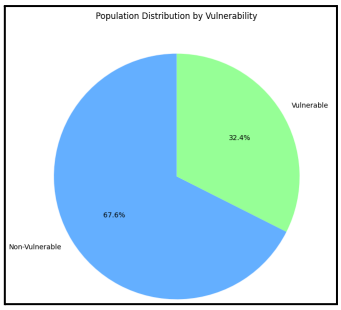


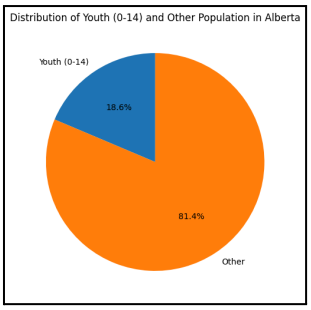
Experiments and Results Vulnerable Populations In FSA Regions

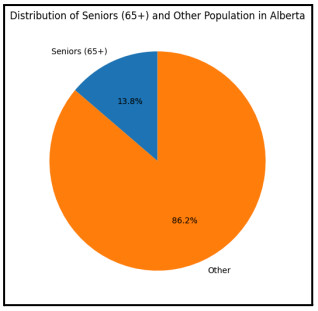
Each region of Alberta is faced with different socio-economic and demographic intricacies that contribute to its population's vulnerability to wildfires.

According to a report from the University of Fraser Valley, "seniors are between 2 and 8 times more likely to die in fires relative to other age groups. Nonetheless, the likelihood of getting injured at fires for seniors is similar to that of youth with 2.8 injuries per 100,000 population" (Garis and Biantoro, 2019).

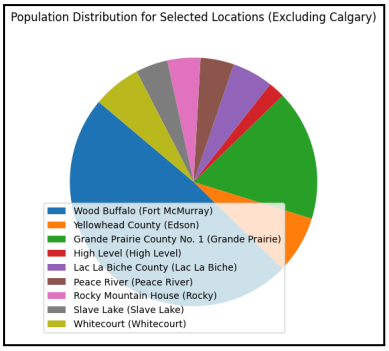
By grouping youth (0-14) and seniors (65+) as Alberta's vulnerable population, we can see that this group accounts for nearly one third of the province's total population in 2020.

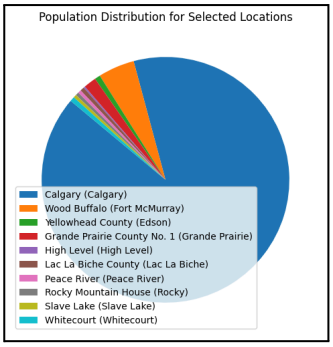


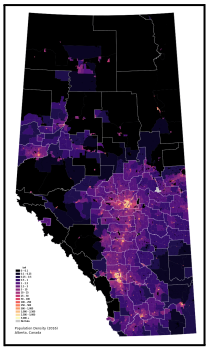




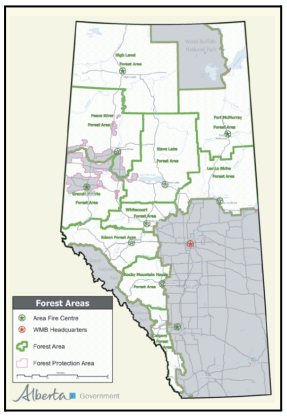
In assessing the population size and density for each region, we can see that of the top three most vulnerable regions we discussed previously (High Level, Fort McMurray, Slave Lake), two of them are amongst the province's smaller regions in population size. These three regions are also among the province's least dense regions in regards to population.

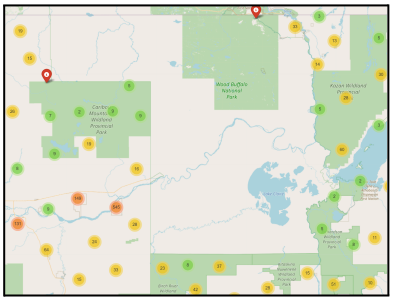






FireSmart is a Canada-wide initiative that focuses on helping individuals, communities, and organizations reduce the potential impact of wildfires. The FireSmart program in Alberta is adapted to the specific conditions and challenges faced by the province.





By looking at the fire clusters that we have mapped, we can confirm that for the regions that FireSmart is not active, such as Wood Buffalo National Park, there is little threat of wildfires emerging in such areas.

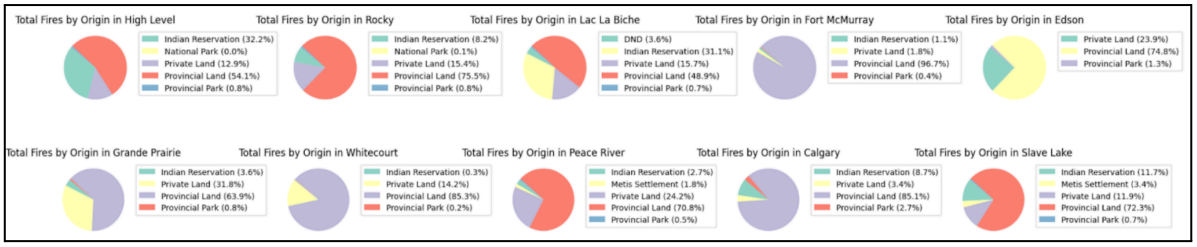
Wildfires & Climate Change's Impact on The Indigenous Peoples

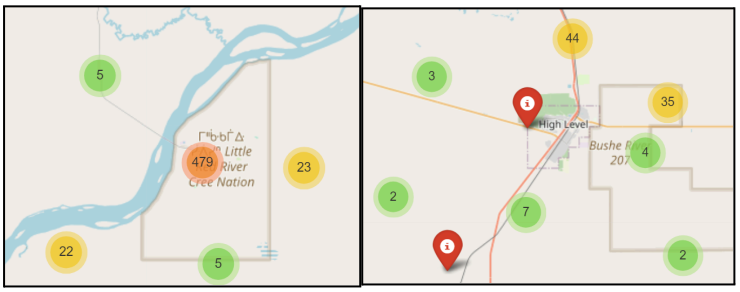
The effects of Alberta's wildfires go well beyond the mere ecological impacts it has on the environment. Indigenous peoples have a special connection with their ancestral lands and face profound challenges both during and after wildfire events.

Indigenous peoples make up approximately 6.8% of Alberta's total population, with just under one third currently living on reserves. 27.6% of the Indigenous population is between the ages of 0-14, a significant increase to the 18.6% that constitute the Non-Indigenous population in the age bracket.

We can determine that over 63% of the fires that take place on an Indian Reservation will take place in one of these two regions: High level and Lac La Biche.

		%				
		Indigenous	First Nations	Métis	Inuit	Non-Indigenous
2021	0-14	27.6	30.1	24.5	31.0	18.6
	15-24	16.9	17.4	16.4	16.3	11.4
	25-44	28.4	28.2	28.6	30.0	29.5
	45-64	20.4	18.7	22.5	19.0	25.9
	65+	6.7	5.6	8.0	3.6	14.5
	Avg. Age (yrs)	31.3	29.6	33.2	29.1	39.1
2016	0-14	29.1	32.2	25.3	30.6	18.7
	15-24	17.7	18.1	17.3	15.6	12.1
	25-44	28.4	27.7	29.0	33.2	30.7
	45-64	19.7	17.6	22.3	17.2	26.6
	65+	5.2	4.4	6.1	3.4	11.8
	Avg. Age (yrs)	29.8	28.1	31.8	28.5	37.8

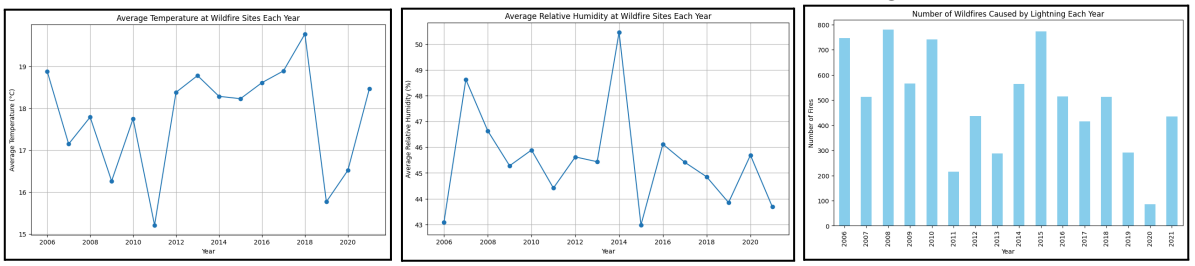




Fox Lake is the most populated Indian reserve outside the Calgary region (2543 people in 2022) and is located in High Level. This reserve has seen over 500 fires since 2006 which is significantly more than the town of High Level, which has a population of over 3000 people but an area less than one third of Fox Lake.

Scientists agree that Canada's wildfires are continuing to grow in number and size as a result of climate change and this has and will continue to have significant consequences on Indigenous peoples.

Climate change has directly resulted in increased temperature, decreased humidity, and an increase in the number of lightning strikes. This is clearly evident in the charts shown below and we must note the impact that the COVID-19 pandemic had during 2020 on the data.



"Most wildland fire-related evacuations occur in sparsely populated boreal regions, where wildland fires are the most active" (Beverly and Bothwell, 2011). "Many First Nations reserves are located in forests prone to wildland fire. They are often particularly vulnerable to wildland fire emergencies due to their remoteness and limited access" (Christianson, 2015).

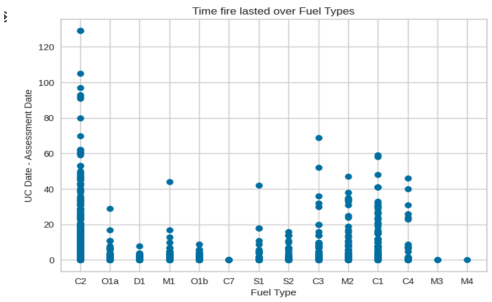
The smoke that arises from wildfires is especially harmful to Indigenous peoples as they have a higher rate of contracting chronic respiratory diseases (Koleade et al, 2018). Both the quality and availability of freshwater on Indigenous reserves are impacted by wildfires on top of the pre-existing issues that these people face with getting clean drinking water (Office of the Auditor General of Canada, 2021). The land of the Indigenous peoples is often deemed to be sacred, whether it may be used as a fishing area, burial grounds, or another means to live out their culture and spirituality. However, wildfires have the potential to destroy this very foundation of their lives (Lamberink, 2023).

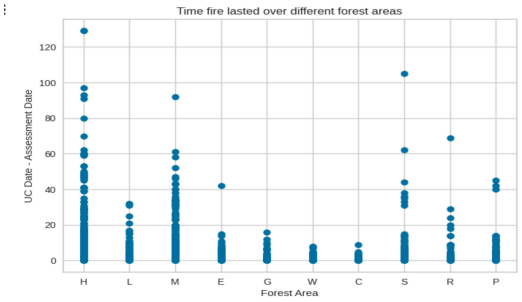
"The blame for these conflicts can also be shared with those managing Alberta's wildfire responses and resources. Wildfire management agencies in Canada devolved from colonial government systems; therefore, they monopolize power in terms of wildfire management decision-making" (Hoffman et al 2022).

There are very few Indigenous-led fire management initiatives in the province and little being done to utilize Indigenous knowledge and experience to further help these communities and

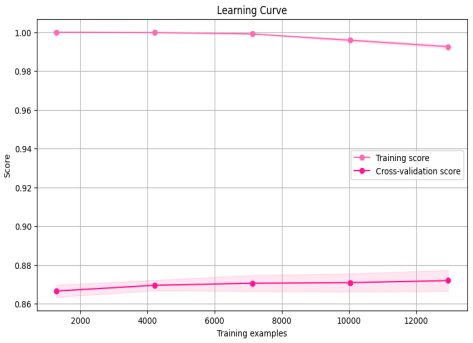
their surrounding areas. The most common Indigenous practice is controlled burning, which has been proven to be effective. However, Alberta's government has chosen to ignore the potential of practices like this.

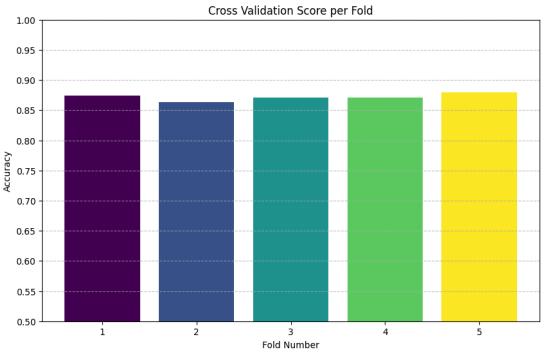
Models and Analysis





As can be seen from the plot, the Coniferous (Cx) type of fuels have a longer lasting fire. This is because Coniferous trees have a large amount of sap in their branches. This sap burns very quickly, and supports fast-moving wildfires. Also different regions have longer lasting fires as seen on the right diagram.
For the model development we decided to use a classification model to predict the size class of wildfires based on various input variables such as 'fire_year', 'forest_area', 'assessment_hectares', 'fire_origin', 'general_cause_desc', 'fire_spread_rate', 'fire_type', 'fire_position_on_slope', 'weather_conditions_over_fire', 'temperature', 'relative_humidity', 'wind_speed', 'fuel_type'. We decided to use the random forest classifier model and the XGBoost classifier. The random forest classifier is better than the decision tree classifier preventing overfitting if the depth is too large. The XGBoost classifier was chosen to also use the gradient boosting technique essentially taking the errors of previous models and correcting them.





The XGBoost classifier performs better than the Random Forest classifier. Different hyperparameters were used such as altering the num_estimators which is the number of trees that are being used. The increase in the number of trees did lead to an increase in recall for XGBoost, having more trees reduces the variance of the model. The model gives Accuracy of 0.87 , Precision of 0.63, Recall of 0.55, F1 Score of 0.57.

Conclusion

Lightning fires with burn size greater than 20 hectares (90%) are the most common forest areas are High Level, Fort McMurray, Slave Lake. Another factor contributing to the higher risk of fires is low wind speed, high temperature, and low humidity. These forest areas also account for the highest total area burned and among the highest regions in terms of number of fires. They also account for high severity of wildfires with the longest time of burn from the initial assessment date to the declaration of the under control date.

Despite Alberta’s contributions to the growing number and severity of wildfires through climate change and industrialisation, the province does not provide ample support or consideration towards the Indigenous communities and culture that they are significantly impacting. The Indigenous peoples’ have the experience and expertise to deal with wildfires on their own, but with the recent external implications towards climate change and their ability to utilize their own methods and resources, they will continue to be put at a greater risk against wildfires.

Future Steps

We plan to look further into how the government is acting on indigenous practices like cultural burns, are indigenous people getting enough resources to support their living in their lands, and if indigenous people can return to their reserves after the wildfire. Also, we want to further look at cost data and how particularly severe and large area wildfires contribute to federal and provincial spending on prevention of wildfires. Look further into the effect of how different regions, different fuel types, and various weather changes affect how long a fire lasts. This will also aid firefighters and government personnel to understand how to fight fires to reduce overall negative impact on costs and people's health.

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