Wildfire Prediction

Data Visualization

MPCS 2024

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I. Introduction to this project

This project explores wildfires in Canada from 2006 to 2023, utilizing weather data and NASA FIRMS satellite scan data. The dataset includes information on wind, temperature, precipitation, sunlight, location, wildfire dates, and more. Our work involved data analysis and machine learning techniques. In this report, we present the results and insights from the analysis phase.

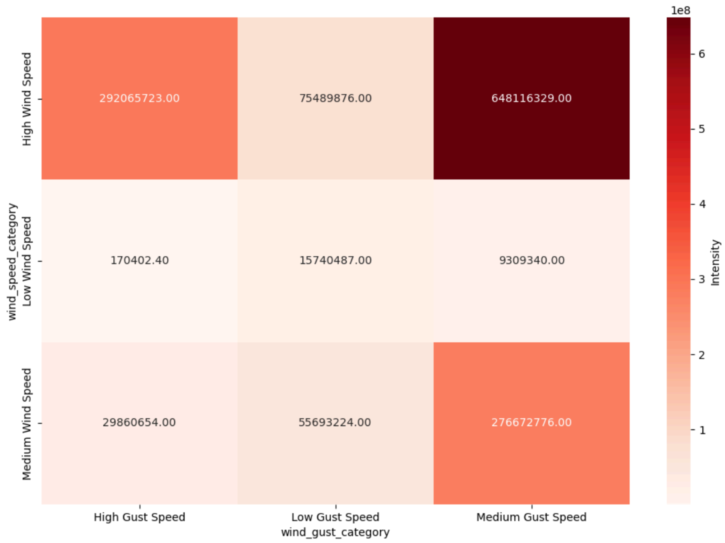
II. Data Schema

By combining weather data from Open Meteo with NASA FIRMS data, we obtained detailed information about daily weather conditions, wildfire occurrences, their locations, and intensity. We performed a left join on the Open Meteo data using NASA FIRMS data, matching by date and location. Furthermore, we derived new features from the existing ones using relevant theories and formulas.

The dataset includes a variety of features, such as date, city, and geographical coordinates (latitude and longitude). Weather-related attributes include maximum, minimum, and mean temperatures, apparent temperatures, daylight duration, sunshine duration, precipitation (rain, snowfall, and cumulative), precipitation hours, and wind-related metrics such as maximum speed, gusts, and dominant direction. Additional attributes cover shortwave radiation, evapotranspiration, and satellite-specific information like brightness, scan, track, satellite type, instrument, confidence, version, brightness temperature, fire radiative power (FRP), and day/night classification. Derived features include temperature range, relative humidity, cumulative precipitation, dryness index, fire intensity, daylight fraction, wind vector components (x and y), fire risk, soil moisture, and the precipitation-to-radiation ratio.

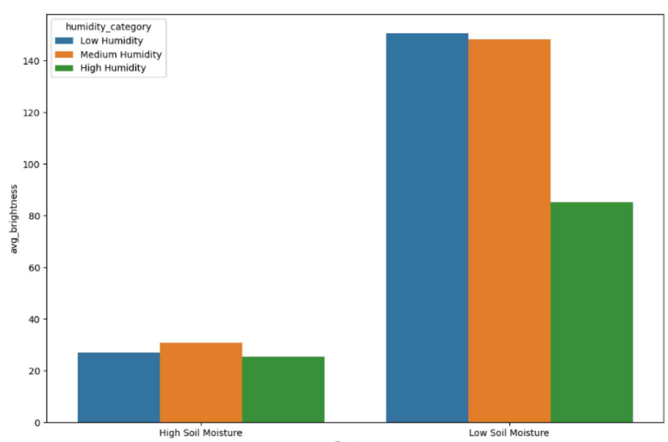
III. Analysis

IV. Wind Analysis



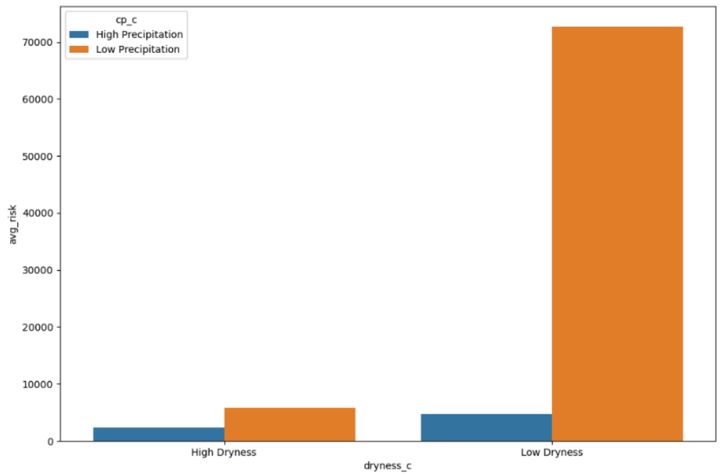
The analysis above shows how gust speed and wind speed contribute to a higher fire intensity using a heatmap. A higher intensity is more likely with medium gust speed and high wind speed and the lowest intensity is correlated with high gust speed and low wind speed. This indicates that wind speed has more of an effect on fire intensity than wind gust.

V. Soil Analysis



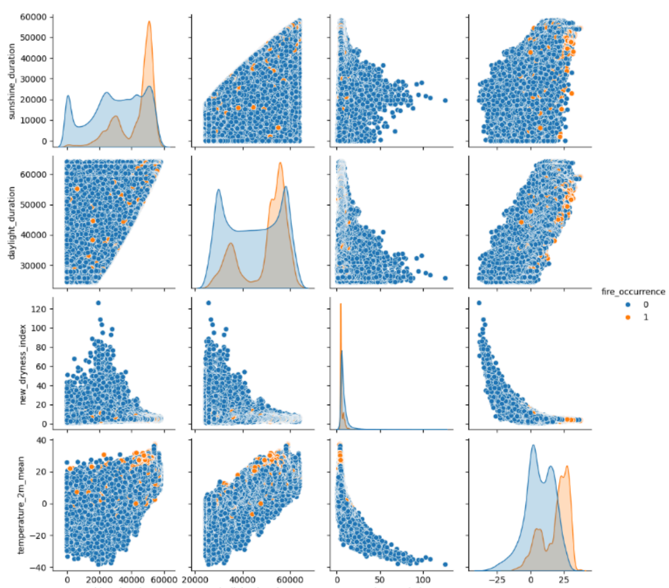
The soil analysis focuses on how soil moisture and humidity levels contribute to average brightness. As the graph indicates, low soil moisture dictates more brightness but when paired with low and medium humidity, the average brightness increases.

VI. Fire Risk (precipitation and dryness)



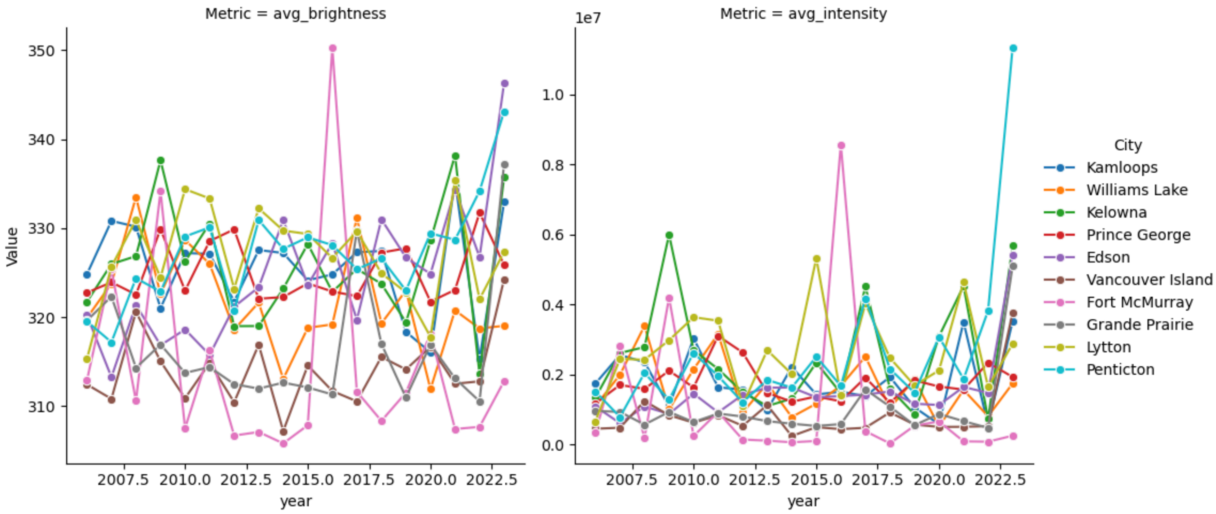
The graph above implies how dryness and precipitation relate to average fire risk. Low precipitation levels and low dryness imply a higher average fire risk. The graph also shows that dryness seems to be the dictating feature as high dryness with low precipitation has a lower fire risk.

VII. Feature Correlation (sunshine_duration, daylight_duration, dryness, temperature)



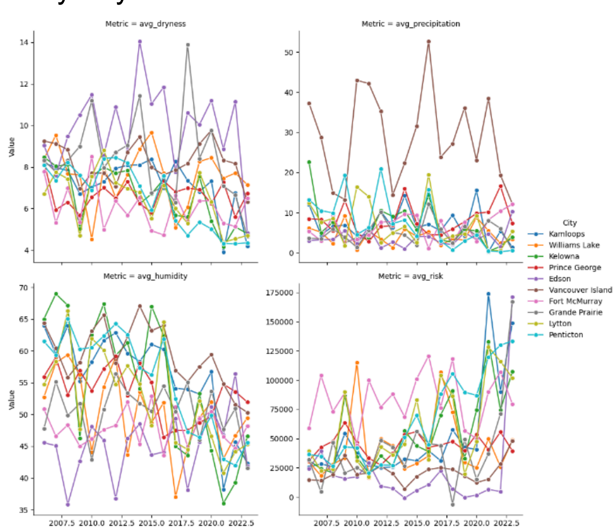
The graph above explains how the values for the following features: (sunshine_duration, daylight_duration, dryness, temperature), relate to a fire occurrence. So as the graph shows, higher temperatures and higher daylight and sunshine duration imply a fire occurrence. Meaning, higher values for all these features paired with higher temperature values imply a fire is present.

VIII. Average intensity and brightness per city by year



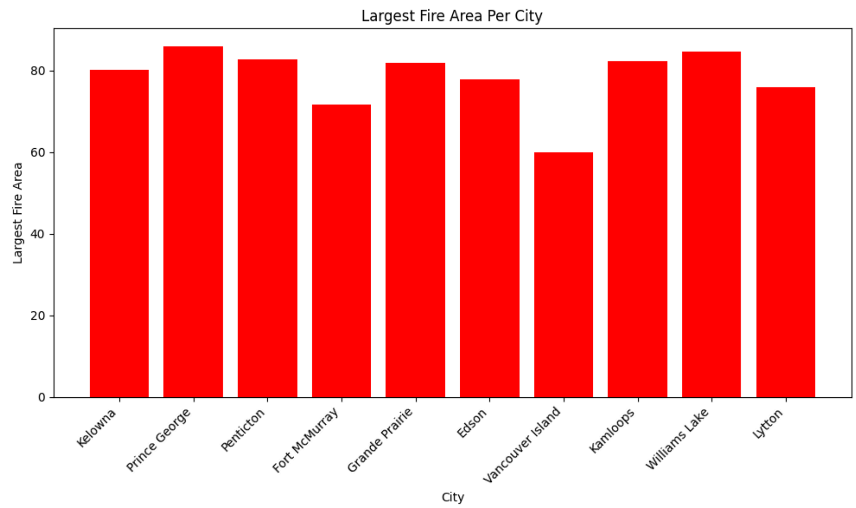
The graph above shows how average intensity and brightness changes over the years per city. Intensity: intensity seems to be normal for the most part, but some cities show a spike in certain years such as Penticton (2024), Fort McMurray (2016), and Kelowna (2010). Brightness: brightness also has the same trend as intensity, the spikes include Fort McMurray (2016), Edson (2024), and Penticton (2024). From this graph, we can see that there were significant wildfire activities in 2024 for Penticton and 2016 for Fort McMurray.

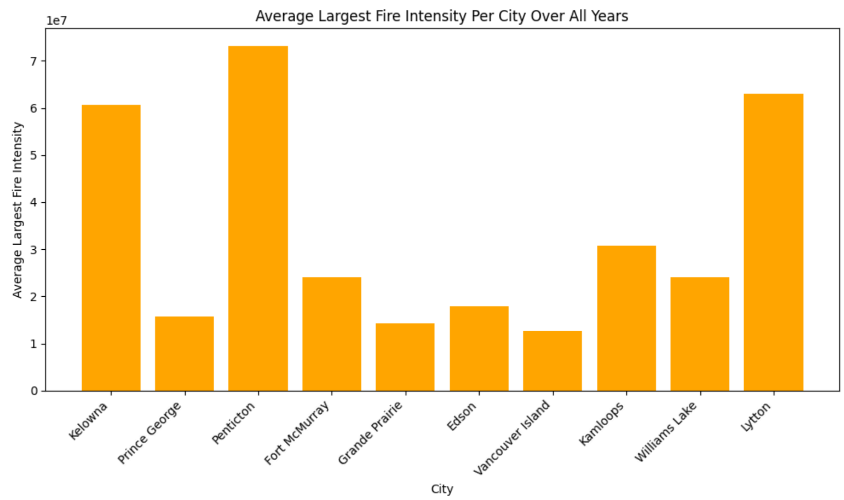
IX. Yearly City Trends



The graph above displays the trends for features: dryness, humidity, risk, and precipitation per city. Excluding risk, we can see how the 3 other features influence fire risk. As average humidity lowers over the years, the fire risk increases for each city. Cities with higher precipitation values also show lower levels of fire risk.

X. Largest Fire Intensity Per City

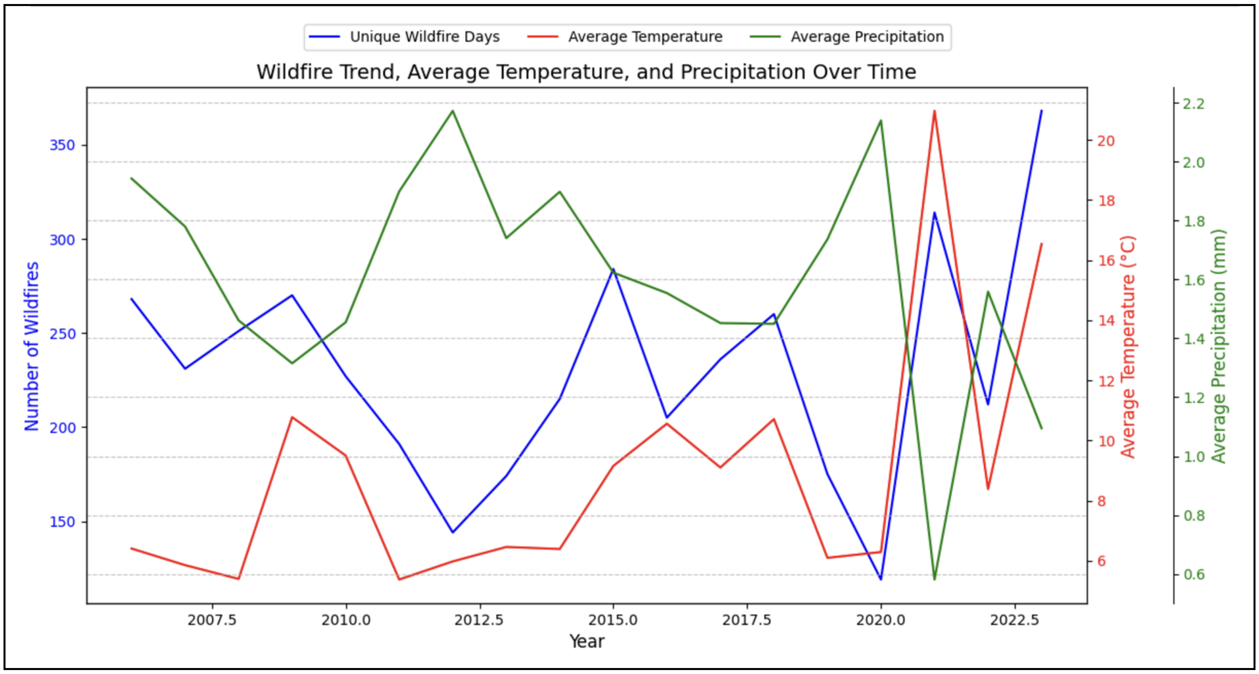




The graph above displays the largest fire happening in each city in terms of intensity and area. The area is calculated as the area of the smallest matrix covering all the locations in one city. For area, all the cities perform similarly excluding Vancouver Island and Fort Mcmurray. For intensity, Kelowna, Penticton and Lytton are the top three cities with the highest forest fire intensity. With VIII and X analysis combined, we can conclude that people live in these three cities need to pay more attention to the possibility of forest fire happening in summer times.

Wildfire Day Counts, Temperature And Dryness Index Trend Analysis

One of the hypotheses is that the number of wildfires is associated with temperature and dryness, as wildfires are likely to occur in an environment that is hot and dry. The following graph described those three factors over the time period from 2006 to 2023.

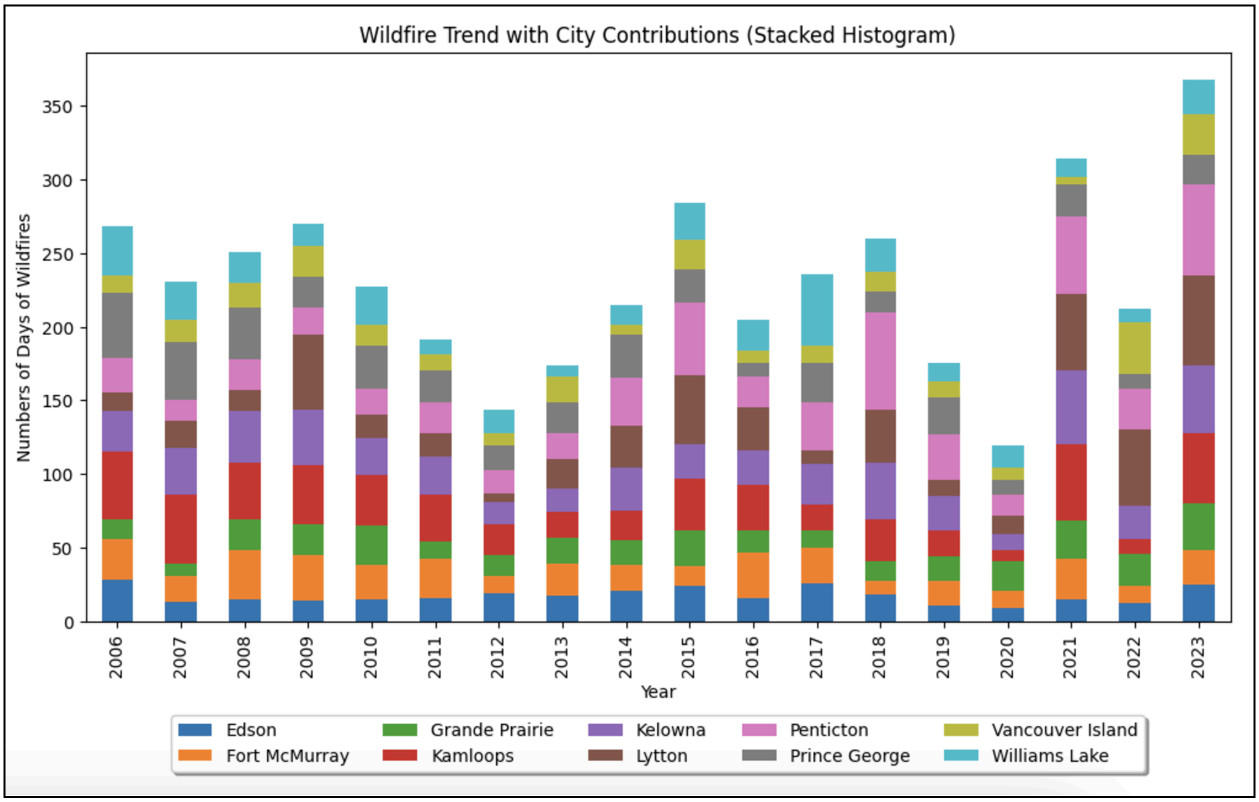


Key observations include the correlation between temperature, precipitation, and wildfire activity. The blue line represents wildfire count, the red line indicates average temperature, and the green line corresponds to average precipitation.

In years with higher average temperatures, such as 2016 and 2021, there is a noticeable increase in wildfire count, suggesting a potential link between temperature and wildfire activity. Conversely, years with higher average precipitation generally show lower wildfire counts, indicating precipitation may act as a mitigating factor for wildfires. The interplay between these variables highlights how climatic factors like temperature and precipitation contribute to wildfire dynamics, underscoring the importance of understanding environmental influences for better wildfire management.

Geographical Wildfire Day Counts Analysis

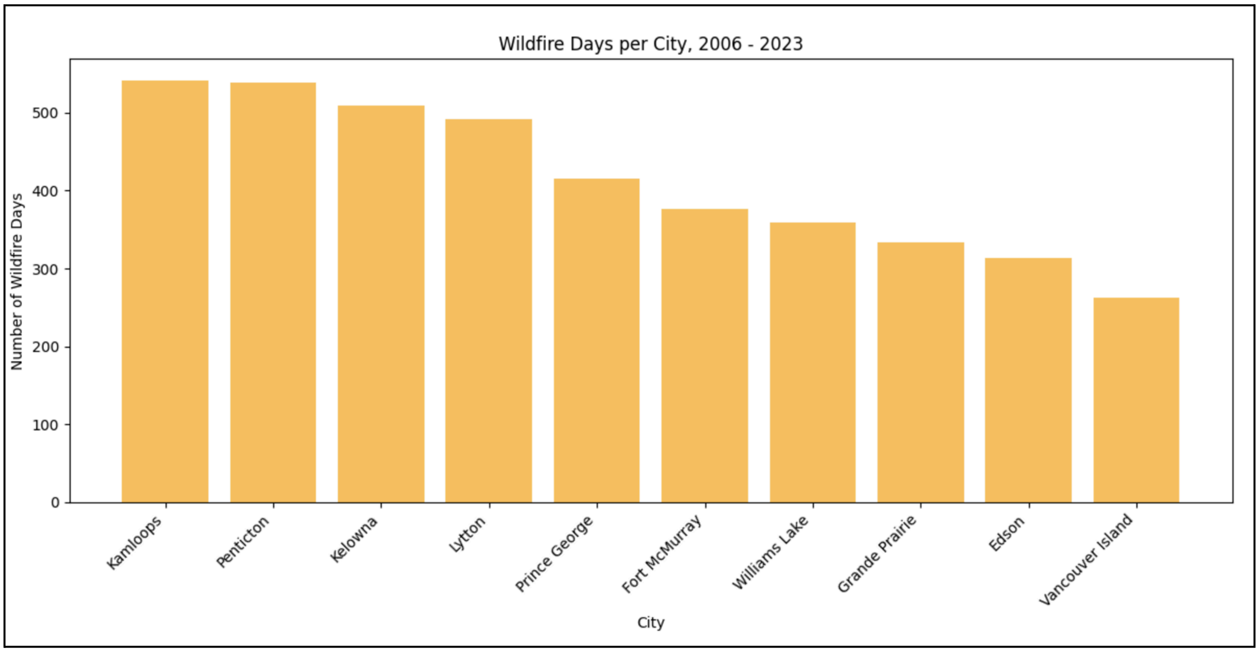
This stacked histogram visualizes the annual trend of wildfires across various cities from 2006 to 2023, with contributions from specific cities represented by different colors. The y-axis shows the total number of wildfires, while the x-axis represents the years. Each segment in a bar corresponds to the number of wildfires reported in a particular city, allowing for a clear comparison of contributions by location over time.



Key observations include a noticeable spike in wildfire occurrences in 2015 and 2023, indicating potentially extreme conditions during those years. Conversely, years like 2012 and 2020 exhibit relatively lower wildfire counts. Among the cities, locations such as Prince George, Kamloops, and Penticton seem to consistently contribute a significant portion to the total wildfire count, reflecting areas of high fire activity. This trend suggests that wildfire management efforts might need to prioritize these cities due to their recurrent vulnerability.

From 2020 to 2021, there is a significant leap in the total number of wildfires, as illustrated by the marked increase in the bar height. This sharp rise suggests a drastic shift in environmental conditions or other contributing factors, such as prolonged droughts, higher temperatures, or increased human activities during this period. The cities of **Kamloops, Penticton, Kelowna** and **Lytton** appear to play a prominent role in this increase, with larger segments in 2021 compared to 2020. This jump highlights the need to investigate and address the underlying causes of such spikes to mitigate future wildfire risks.

This bar chart shows the total number of wildfire days recorded for each city. Kamloops and Penticton lead with the highest numbers of wildfire days, both exceeding 500 days, indicating that these cities experience prolonged and frequent wildfire activity compared to others. This trend highlights them as high-risk areas requiring more focused wildfire prevention and mitigation strategies.

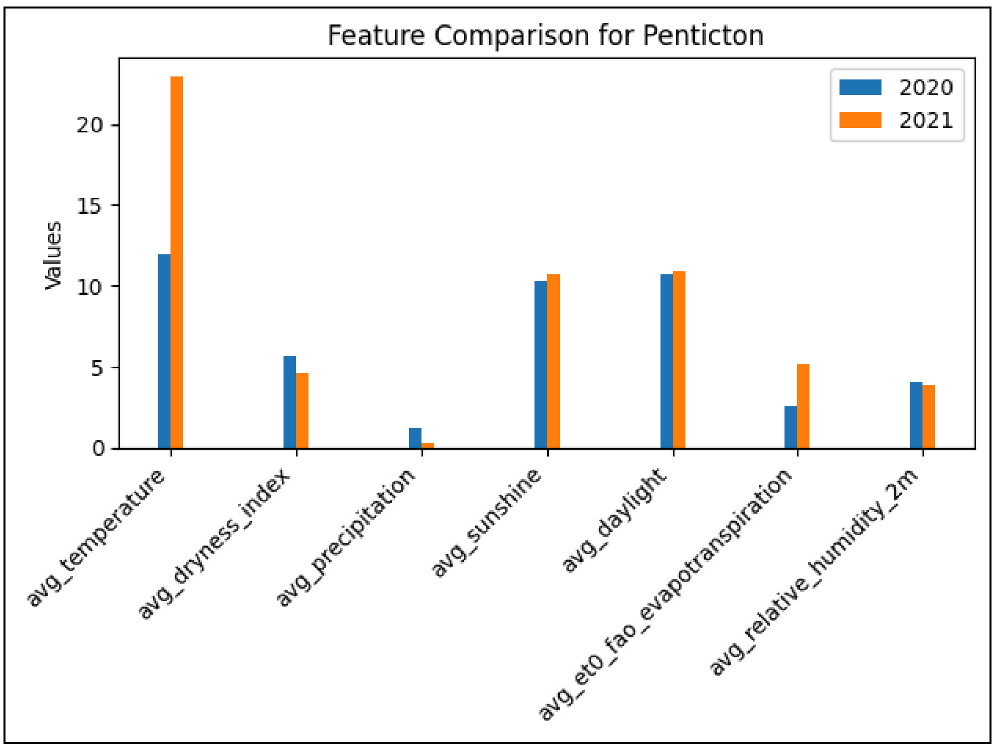


Cities like Vancouver Island and Edson are at the lower end of the spectrum, with fewer wildfire days, suggesting they face relatively less frequent or severe wildfire conditions. However, even these cities are not immune to wildfires, emphasizing the need for consistent monitoring and preparedness across all regions. Overall, the distribution suggests significant geographic variability in wildfire patterns, influenced by local climate, vegetation, and possibly human activities.

2020 - 2021, A Gigantic Increase in the Number of Wildfire Days

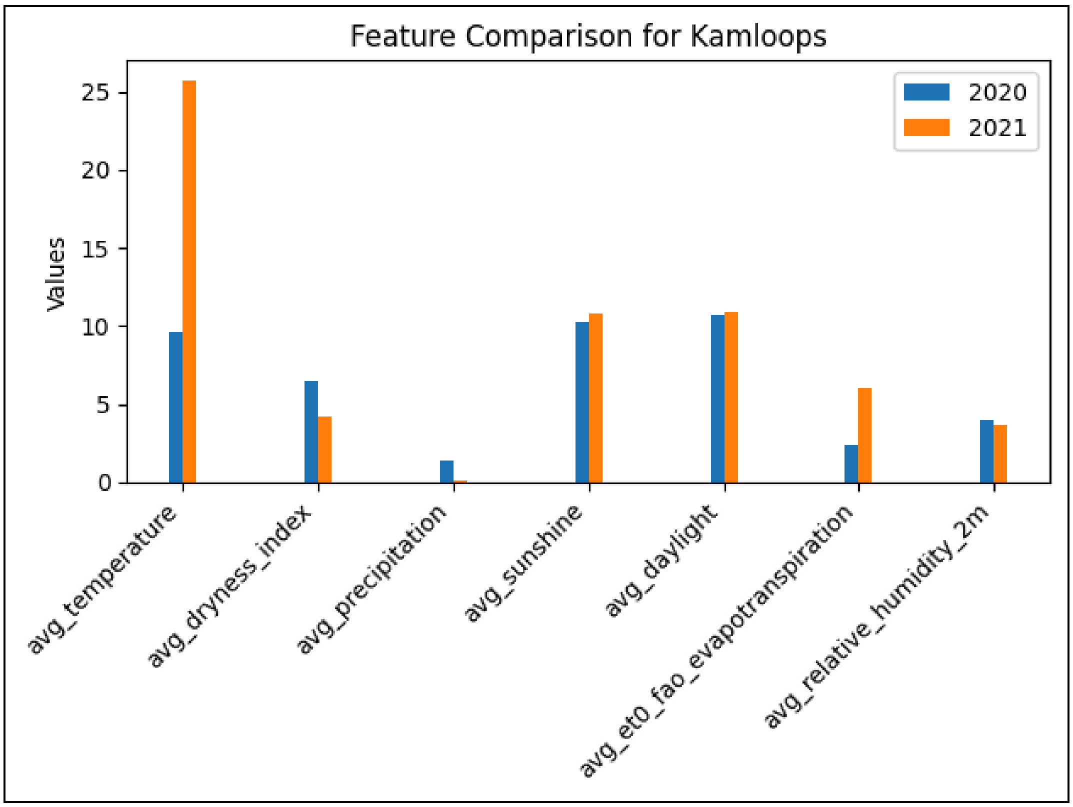
As mentioned in the previous analysis, we observe a large increase in the number of days of wildfire occurring during 2020 - 2021 mainly in the following cities: Kamloops, Penticton, Kelowna and Lytton. In this section, we will take a look at those four cities in terms of their average values during this time period.

- **Penticton**



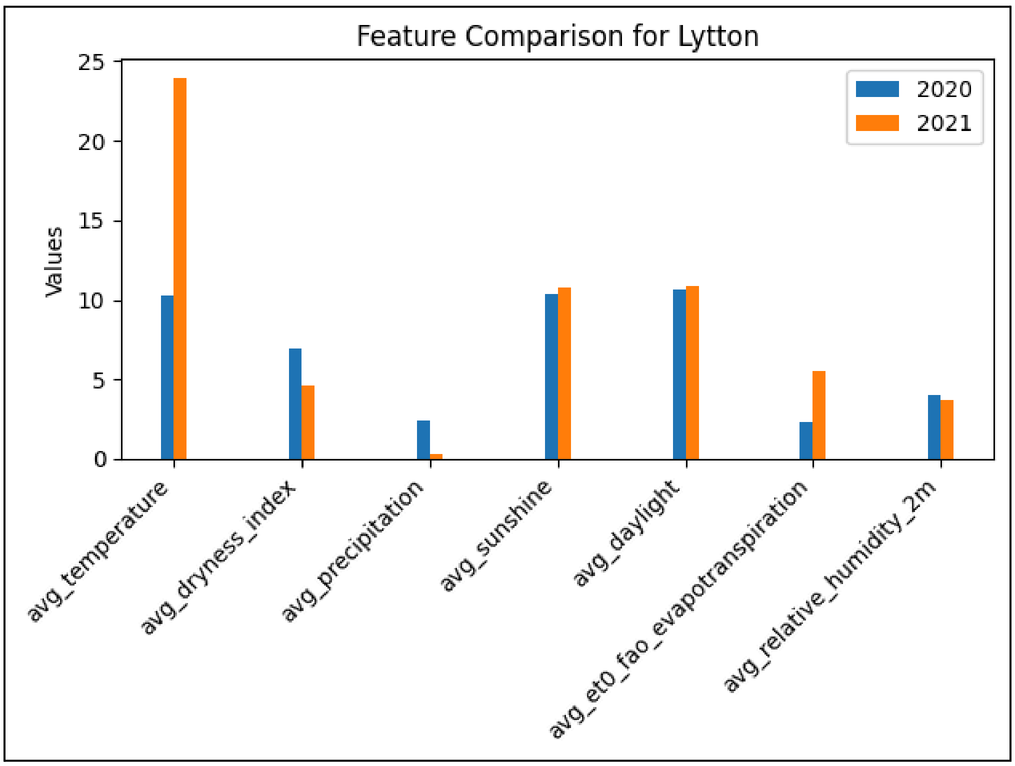
Penticton saw an average temperature increase from 11.99°C in 2020 to 22.93°C in 2021. The dryness index declined from 5.72 to 4.67, while precipitation dropped from 1.29 mm to 0.32 mm. Sunshine duration rose modestly from ~31,632 hours to ~44,301 hours, and daylight increased from ~44,237 hours to ~52,502 hours. Evapotranspiration also increased, rising from 2.61 to 5.25. Relative humidity decreased from 54.77% to 45.33%, contributing to the overall arid conditions.

- **Kamloops**



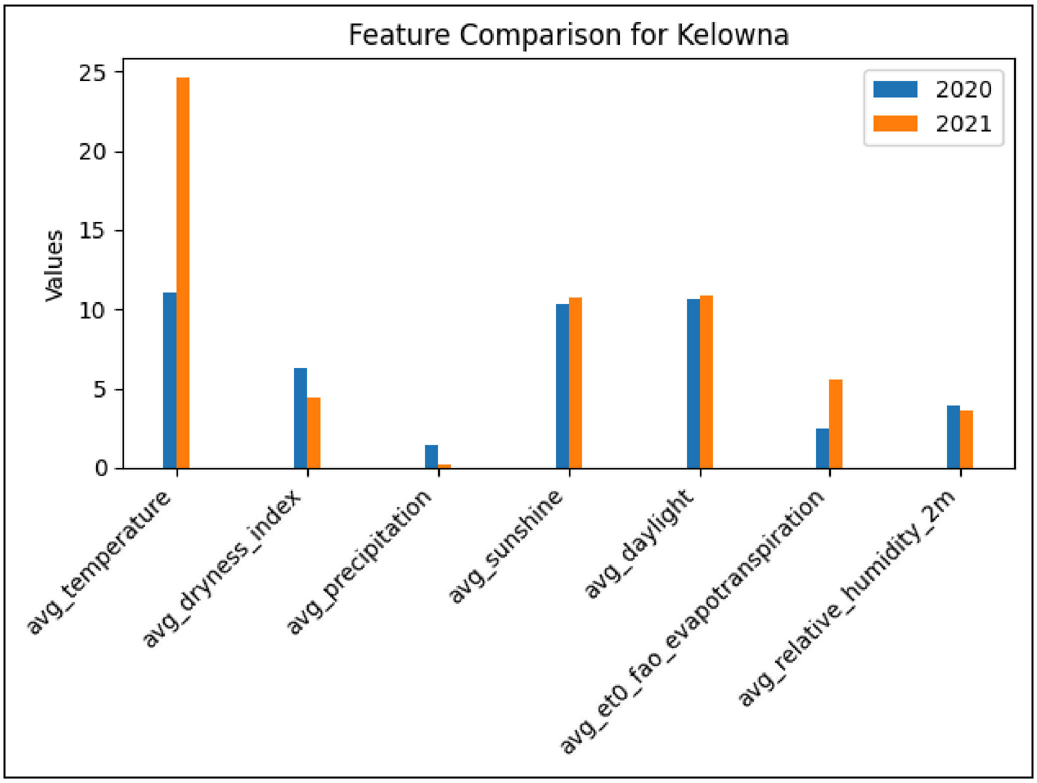
In 2021, Kamloops experienced a dramatic rise in average temperature from 9.65°C to 25.71°C, coupled with a significant drop in the dryness index from 6.44 to 4.20. Precipitation decreased drastically, from 1.39 mm to just 0.15 mm, highlighting much drier conditions. Sunshine and daylight durations increased substantially, with sunshine rising from ~30,060 hours to ~47,062 hours and daylight from ~43,975 hours to ~54,161 hours. Evapotranspiration more than doubled from 2.35 to 6.11, indicating higher water loss due to increased heat and sunshine. Relative humidity dropped from 51.59% to 39.33%, further emphasizing the arid conditions.

- **Lytton**



In Lytton, the average temperature rose significantly from 10.25°C to 23.91°C in 2021. The dryness index saw a marked decrease from 6.96 to 4.64, while average precipitation dropped from 2.42 mm to 0.34 mm, reflecting notably drier conditions. Sunshine duration increased dramatically from ~31,427 hours to ~47,262 hours, with daylight rising from ~44,271 hours to ~54,490 hours. Evapotranspiration rose from 2.33 to 5.55, indicating greater water loss, and relative humidity decreased from 52.20% to 41.87%, further emphasizing the dry conditions.

- **Kelowna**



Kelowna experienced a significant temperature increase in 2021, with the average rising from 11.04°C to 24.59°C. The dryness index fell from 6.27 to 4.45, indicating drier conditions, and precipitation levels dropped from 1.40 mm to 0.18 mm. Sunshine duration rose sharply from ~30,837 hours to ~45,928 hours, while daylight duration increased from ~44,325 hours to ~52,429 hours. Evapotranspiration also more than doubled, increasing from 2.52 to 5.60. Relative humidity dropped from 49.11% to 37.59%, making the atmosphere much drier overall.

- **In Summary**

  In 2021, all four cities—Kamloops, Kelowna, Lytton, and Penticton—experienced significant increases in temperature and dryness compared to 2020. Average temperatures rose sharply, with increases of around 14°C to 15°C across the board, accompanied by a notable drop in the dryness index. For instance, Kamloops' dryness index dropped from 6.44 to 4.20, while similar patterns were observed in the other cities. Precipitation levels plummeted, with most cities experiencing reductions of over 80%. Kamloops and Kelowna saw their average precipitation fall from around 1.4 mm to below 0.2 mm, while Lytton and Penticton faced similarly steep declines. These reductions in precipitation were paired with significant increases in sunshine and daylight hours, which rose by roughly 15,000 and 10,000 hours, respectively, across all locations.

  Evapotranspiration levels more than doubled, reflecting heightened water loss from the soil due to elevated temperatures and prolonged sunlight exposure. Kamloops saw a rise from 2.35 to 6.11, with other cities following similar trends. At the same time, relative humidity dropped significantly, indicating much drier atmospheric conditions. For example, Kamloops' relative humidity decreased by over 12%, while other cities saw comparable declines. These combined changes suggest that 2021 was considerably hotter, drier, and more prone to extreme conditions, raising concerns about the increasing risk of wildfires and the broader impacts of climate change in these regions.