A Visualization and Machine Learning Framework for Understanding Forest Fires in Ontario Using Forestry and Climate Trends

Presentation by: Ontario Geographers

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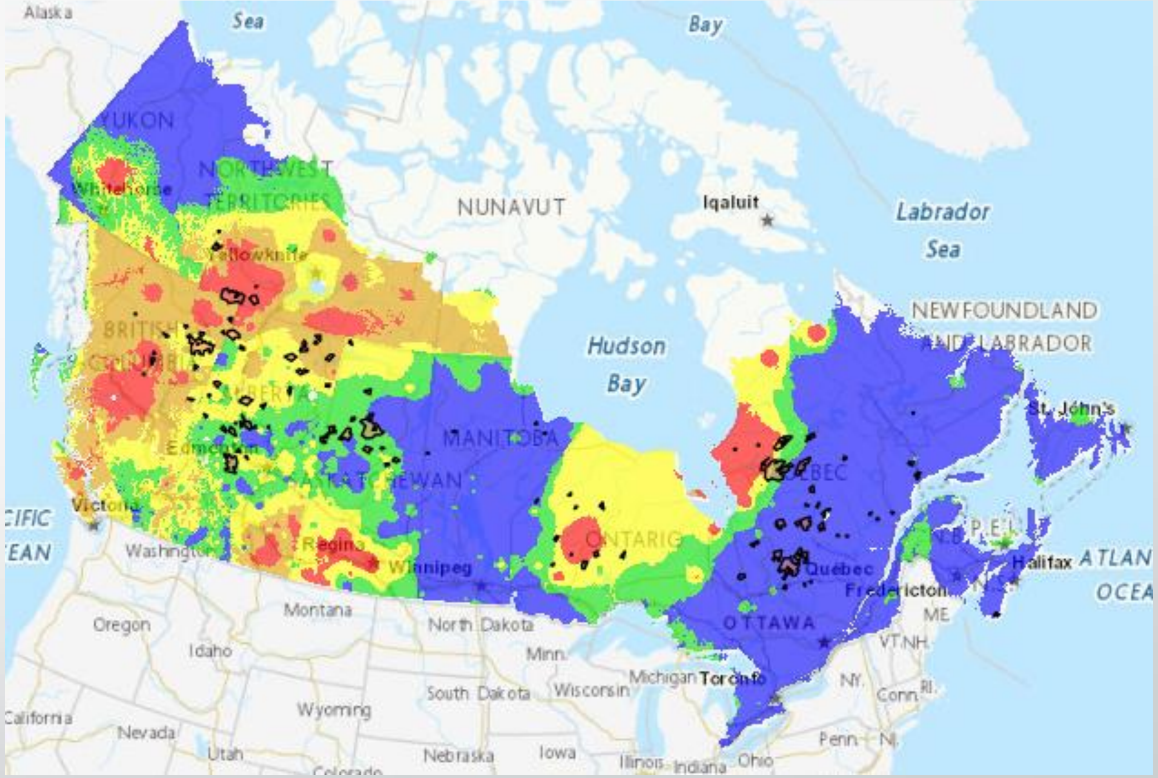
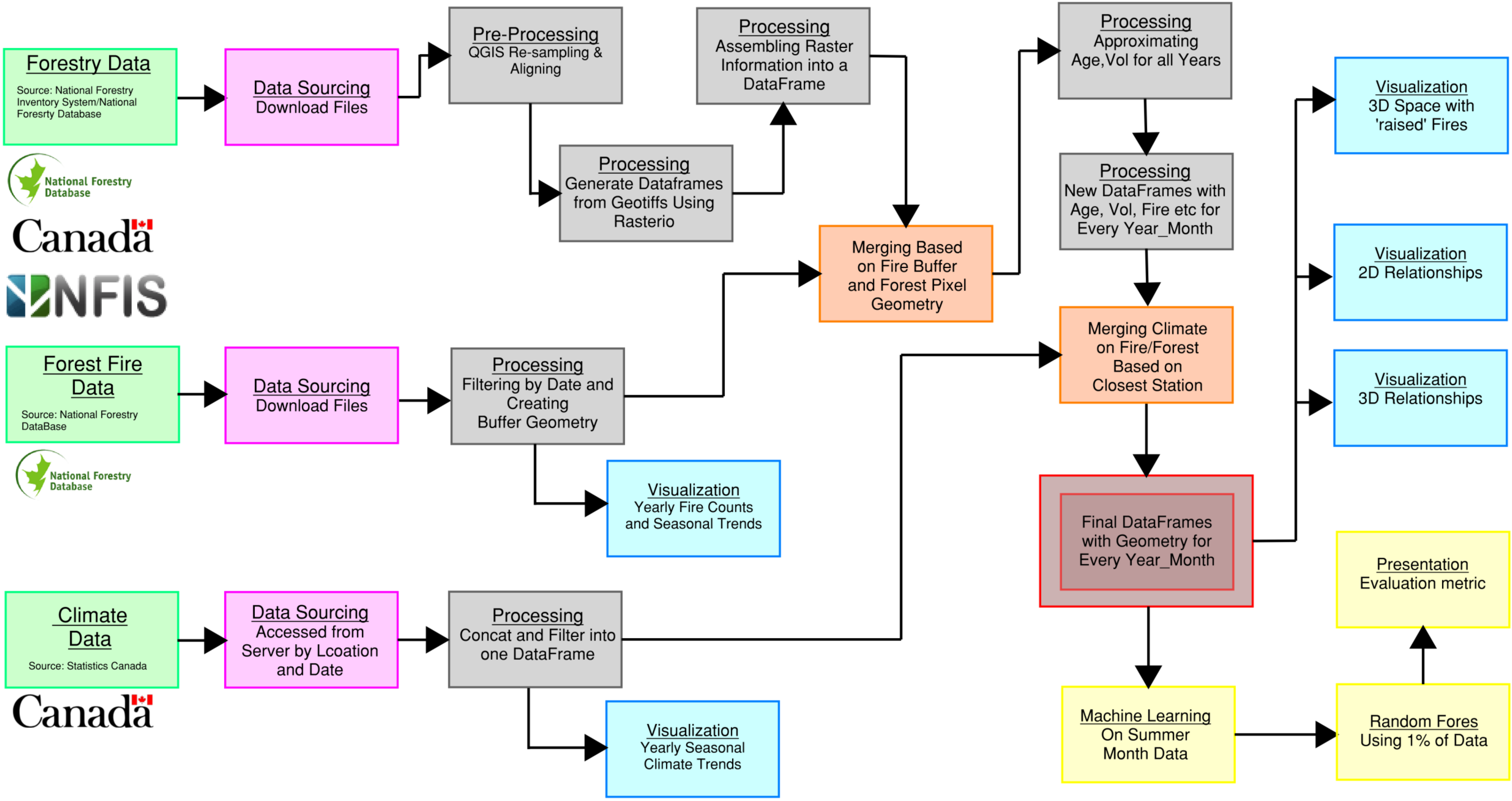
- Problem:
  - Canada reported a record breaking year with 6132 fires, with 16.5 million ha burned, up from an average of 2.5 million hectares (Natural Resources Canada, 2023)
  - Increasing intensity of storms/weather patterns & variation in climate change
- Solution:
  - Build a predictive and visualization framework using typical climate and precipitation variables.
    - Forestry trends (age, vol, harvesting etc.)

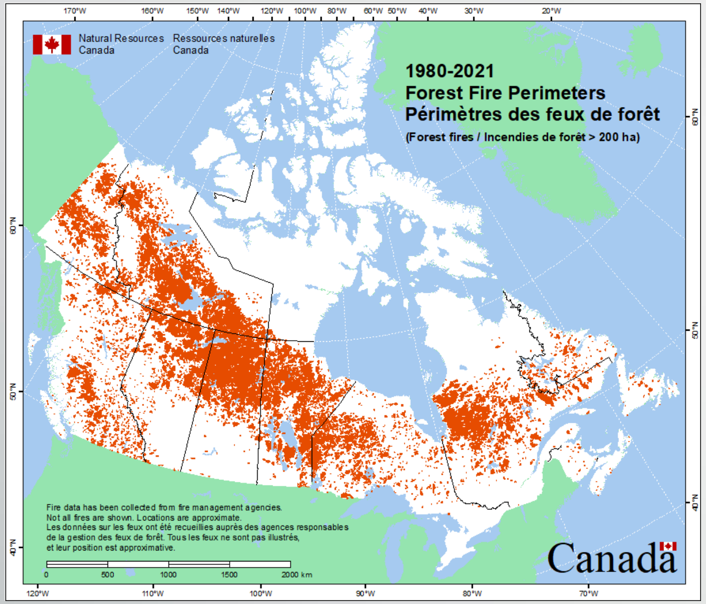


Map of Canada Forest Fires on June 30th 2023 (Source: Adapted from (Canada)

- For simplicity, only look at Ontario fires/data
- What do we want?
  - "If I am looking at a forest, and I know the age, maybe volume, mean temperature, precipitation and other variables that I can quantify based on the previous month, will this forest burn or not?"
- How to do this:
  - 1) Select variables that forest fires might be dependent on
  - 2) Develop some framework to generate an approximation of each variable on a selected geospatial coordinate grid, and based on a timeindex
  - 3) Build visualization tools for selected variables
  - 4) Use machine learning to predict weather or not fires occurred at specific pixel


Forestry Data
Source: National Forestry Inventory System/National Foresrty Database
National Forestry Database
Canada
NFIS
Data Sourcing
Download Files
Pre-Processing
QGIS Re-sampling & Aligning
Processing
Generate Dataframes from Geotiffs Using Rasterio
Processing
Assembling Raster Information into a DataFrame
Merging Based on Fire Buffer and Forest Pixel Geometry
Processing
Approximating Age,Vol for all Years
Processing
New DataFrames with Age, Vol, Fire etc for Every Year_Month
Merging Climate on Fire/Forest Based on Closest Station
Final DataFrames with Geometry for Every Year_Month
Visualization
3D Space with 'raised' Fires
Visualization
2D Relationships
Visualization
3D Relationships
Forest Fire Data
Source: National Forestry DataBase
National Forestry Database
Data Sourcing
Download Files
Processing
Filtering by Date and Creating Buffer Geometry
Visualization
Yearly Fire Counts and Seasonal Trends
Climate Data
Source: Statistics Canada
Canada
Data Sourcing
Accessed from Server by Lcoation and Date
Processing
Concat and Filter into one DataFrame
Visualization
Yearly Seasonal Climate Trends
Machine Learning
On Summer Month Data
Random Fores
Using 1% of Data
Presentation
Evaluation metric

Fire Data – Sourcing and Processing



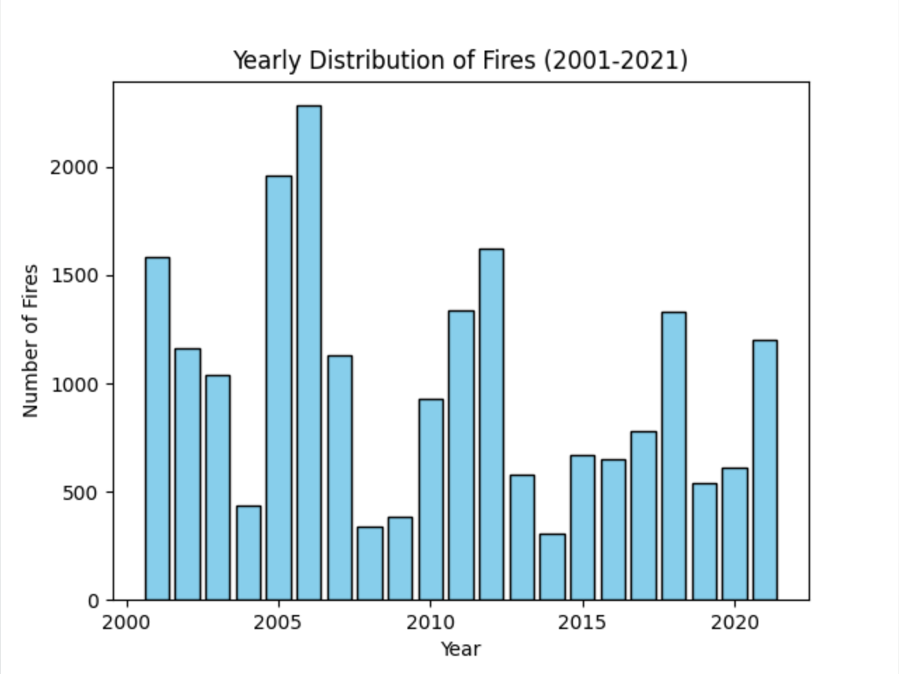
Map of Canada Forest Fires (Source: from Canadian National Fire Database (CNFDB), Natural Resources Canada (2022).

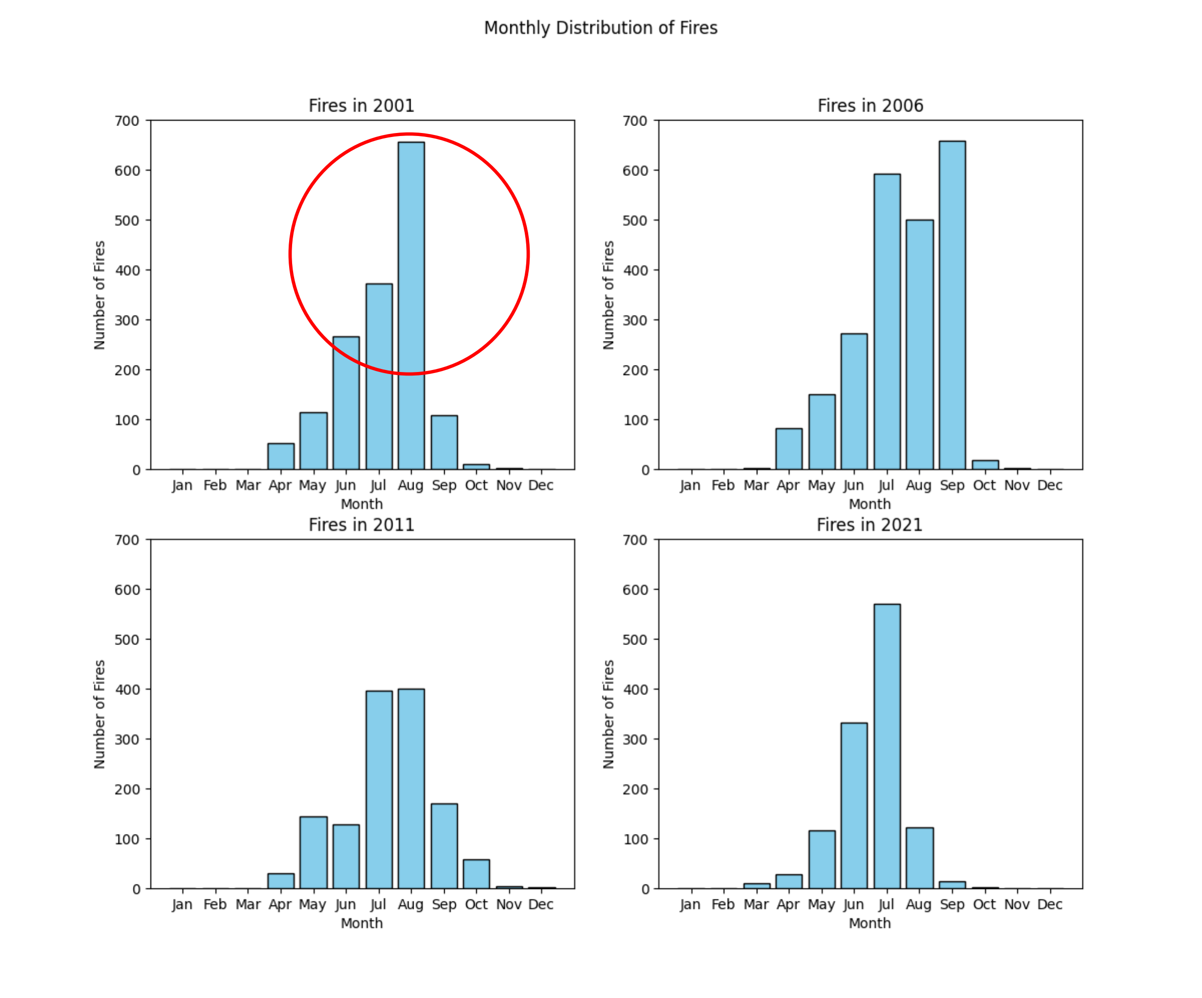
Information on Wildfires in Canada obtained from Canadian National Fire Database

Data Processing

Map of all the wildfires in Ontario from 2001-2021 (Point Geometry)

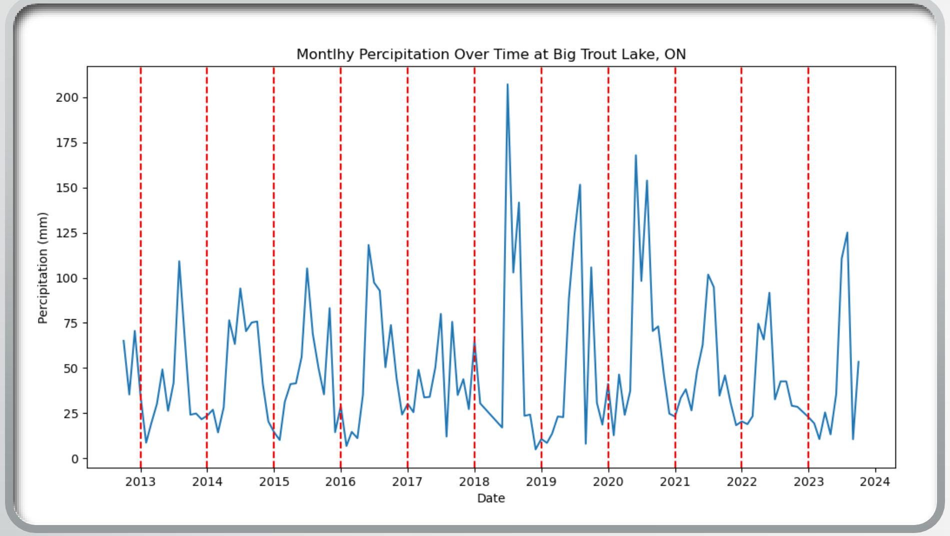
Fire Data - EDA

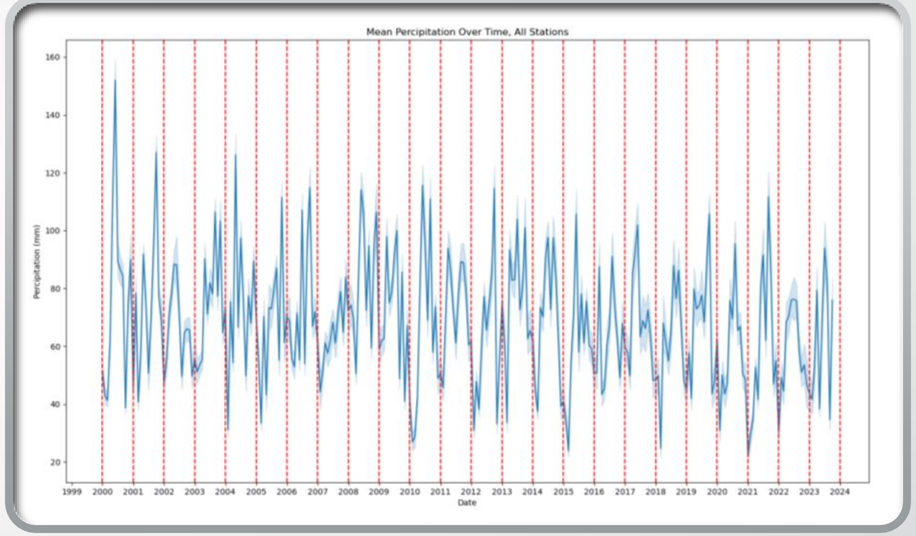


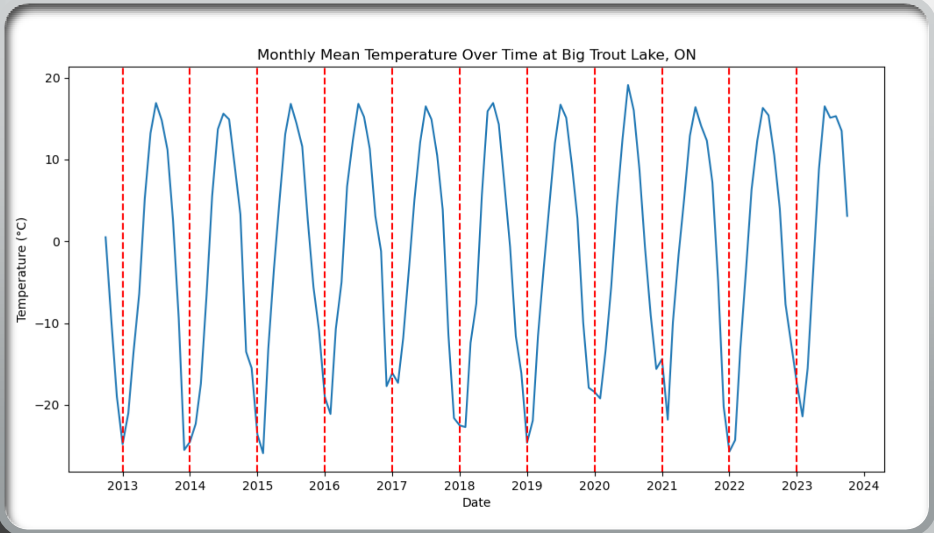


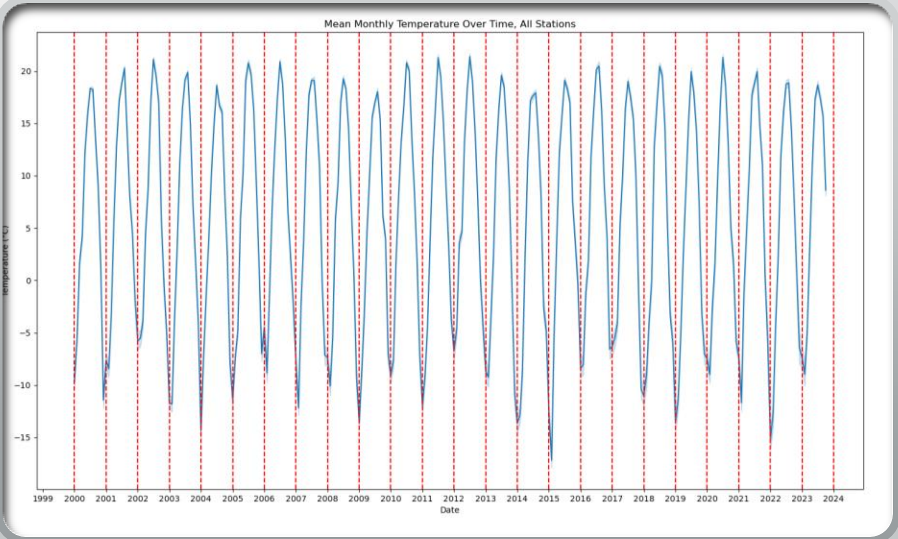
- Highest number of fires occurred in 2006.
- Most of the fires occurred in the summer months.

Climate Data









Forest Data - Sourcing

NFIS National Forestry Database

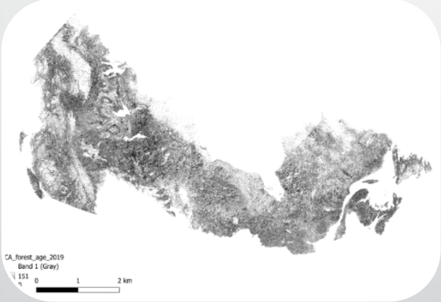
Tree Stand Volume in 2001

Tree Stand Volume in 2011

Tree Stand Age in 2001

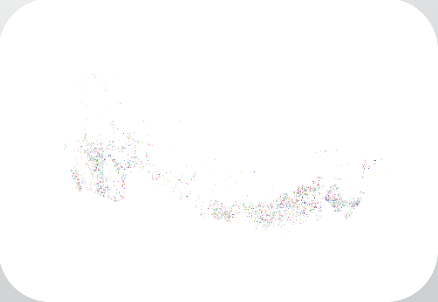
Tree Stand Age in 2011

Canada National Forestry Database



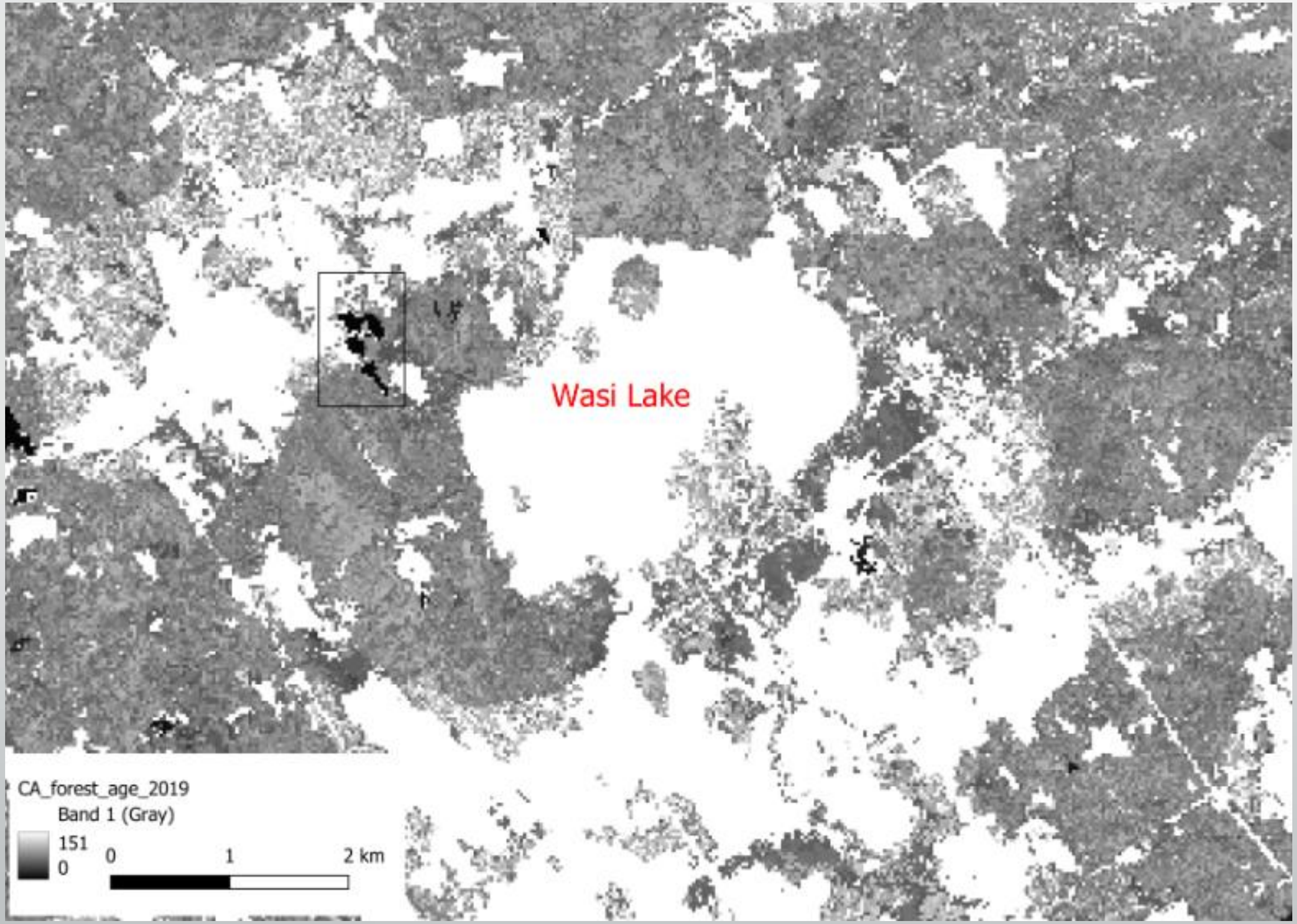
Tree Stand Age in 2019

Gross Stem Volume in 2015

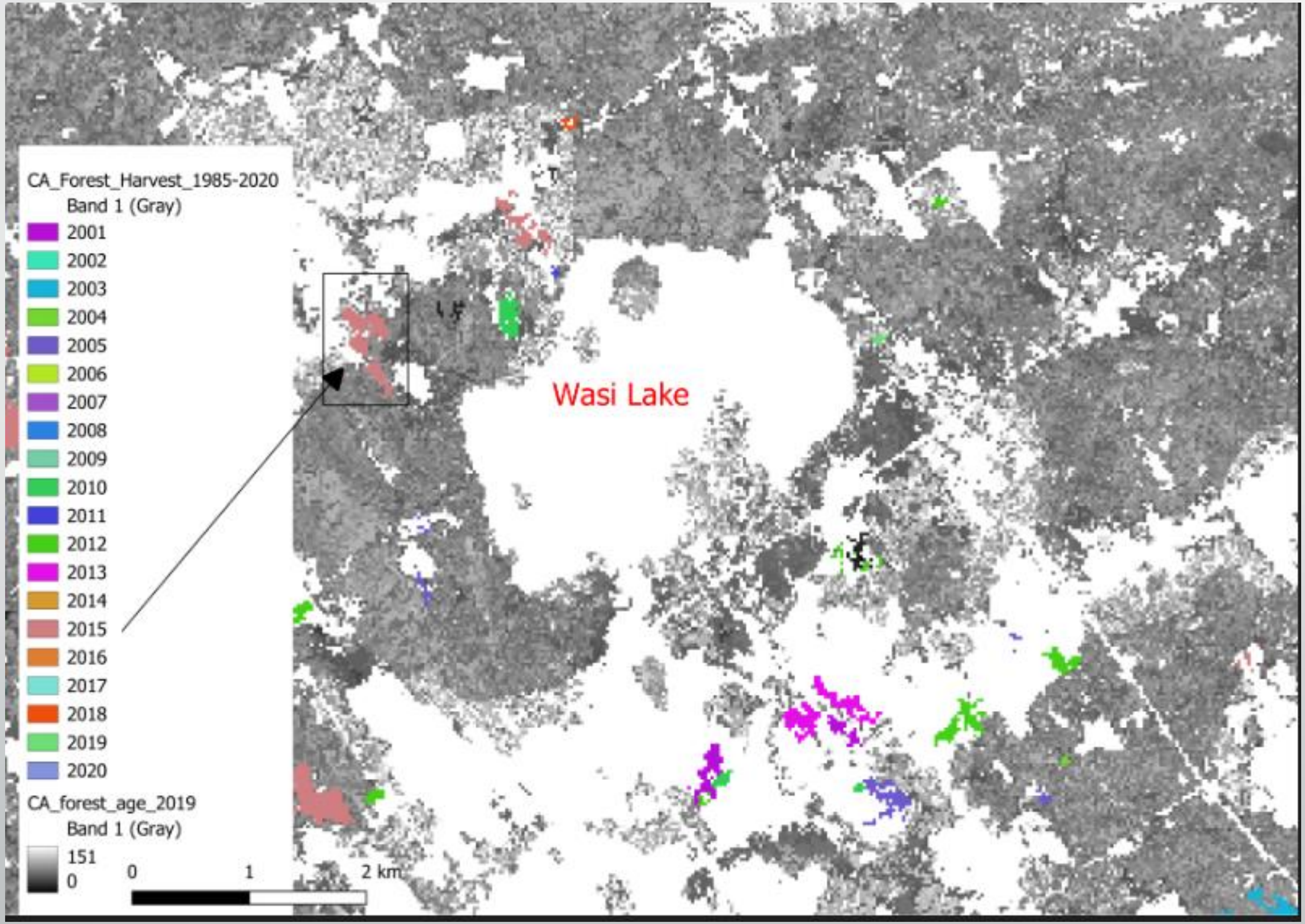


Years Harvested 1985-2020

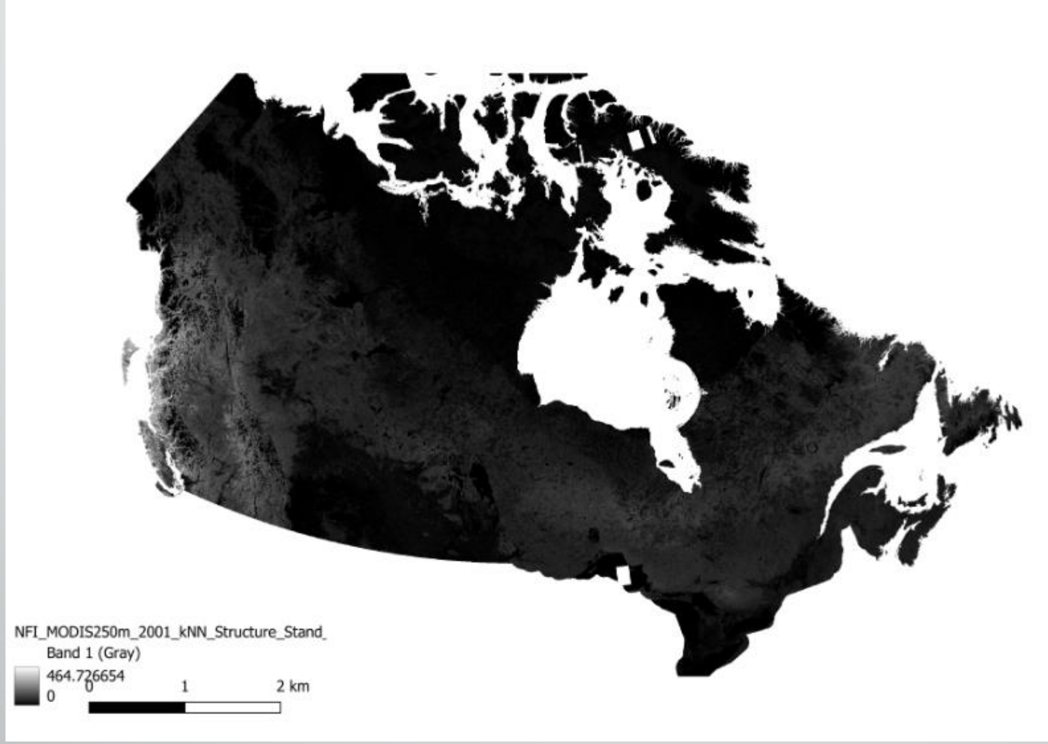
Forest Data – Validation

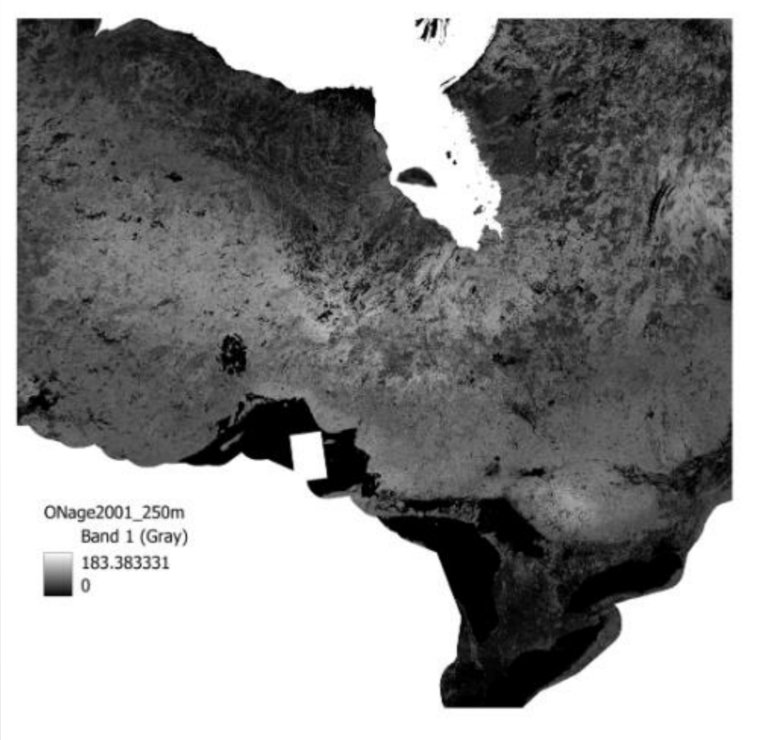


Forest Data – Validation

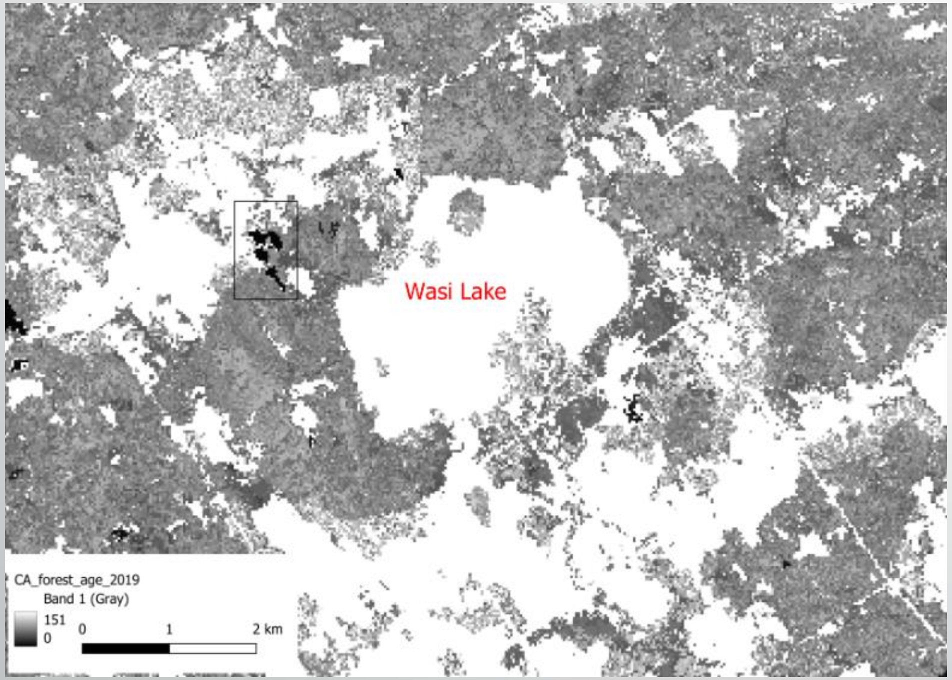


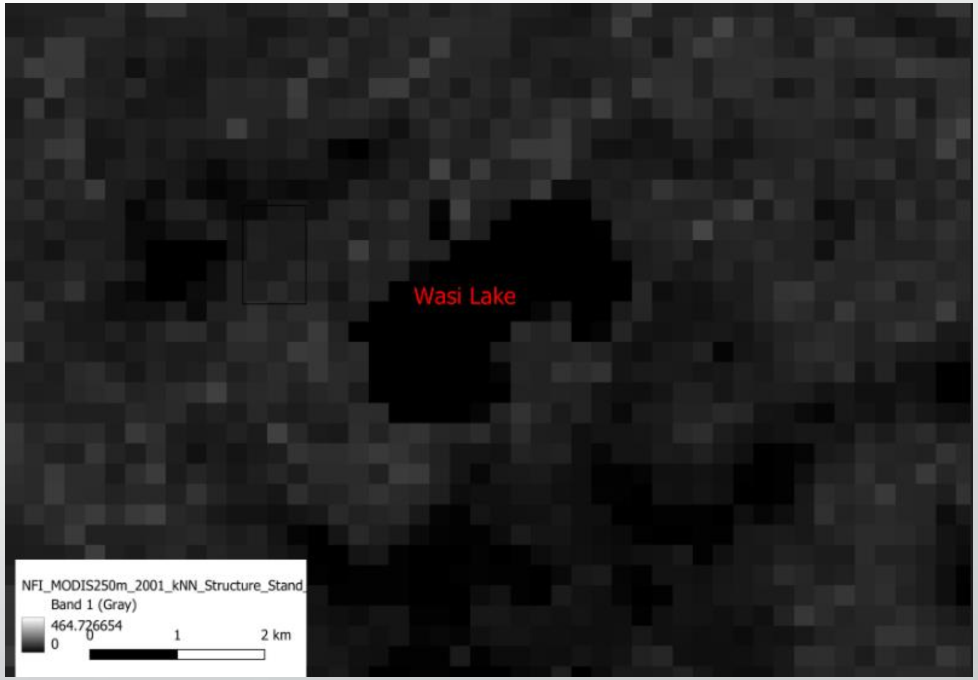
Forest Data – QGIS Alignment/Cropping



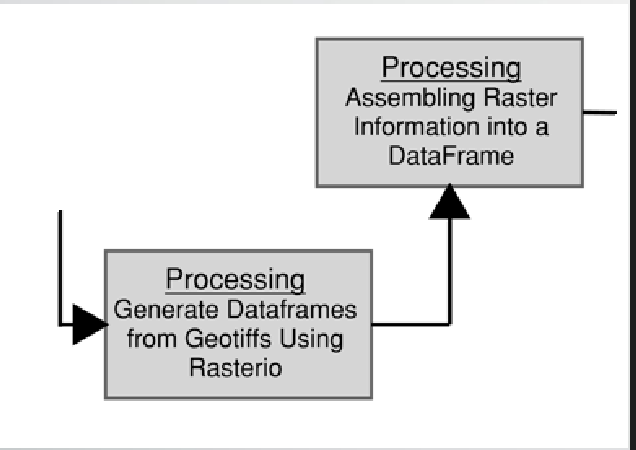


Forest Data – QGIS Resampling



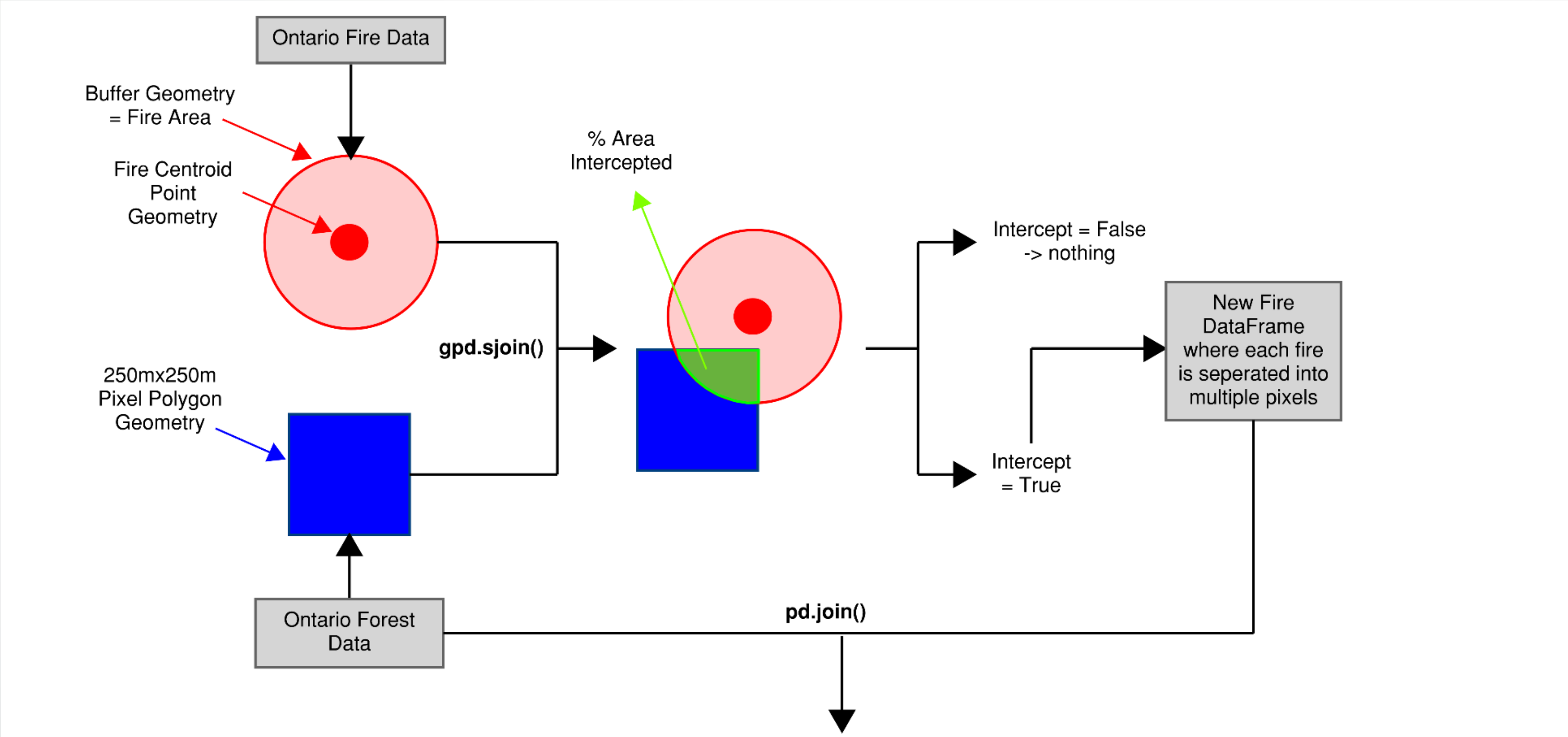


Forest Data – Processing



	age_2001	age_2011	age_2019	year_harvested	vol_2001	vol_2011	vol_2015	lon	lat
37433	58.0	15.0	16.0	2003.0	106.51	18.07	17.5	-84.848203	48.226017
37443	91.0	27.0	47.0	2003.0	168.01	73.06	17.7	-84.851515	48.226373
41341	32.0	25.0	18.0	2001.0	20.62	10.13	133.4	-84.930238	48.266584
41775	70.0	64.0	17.0	2002.0	117.95	24.30	15.8	-84.959025	48.274188
42793	115.0	67.0	110.0	2020.0	198.29	118.21	48.3	-85.016441	48.318860

Forest + Fire Data – Merging



	age_2001	age_2011	age_2019	year_harvested	vol_2001	vol_2011	vol_2015	lon	lat	geometry	year	month	day	area_intersect_perc	number_fires
259347	33.0	32.0	12.0	2007.0	71.10	44.50	NaN	-86.676649	49.235978	POLYGON ((-86.67472180900839 49.23694667154989...	[2006, 2006]	[9, 9]	[7, 7]	[0.1597431028851093, 1.0]	2.0

Forest + Fire Data – Approximation

- Our data, is not congruent!

	age_2001	age_2011	age_2019	year_harvested	vol_2001	vol_2011	vol_2015	lon	lat	geometry	year	month
259347	33.0	32.0	12.0	2007.0	71.10	44.50	NaN	-86.676649	49.235978	POLYGON ((-86.67472180900839 49.23694667154989...	[2006, 2006]	[9, 9]

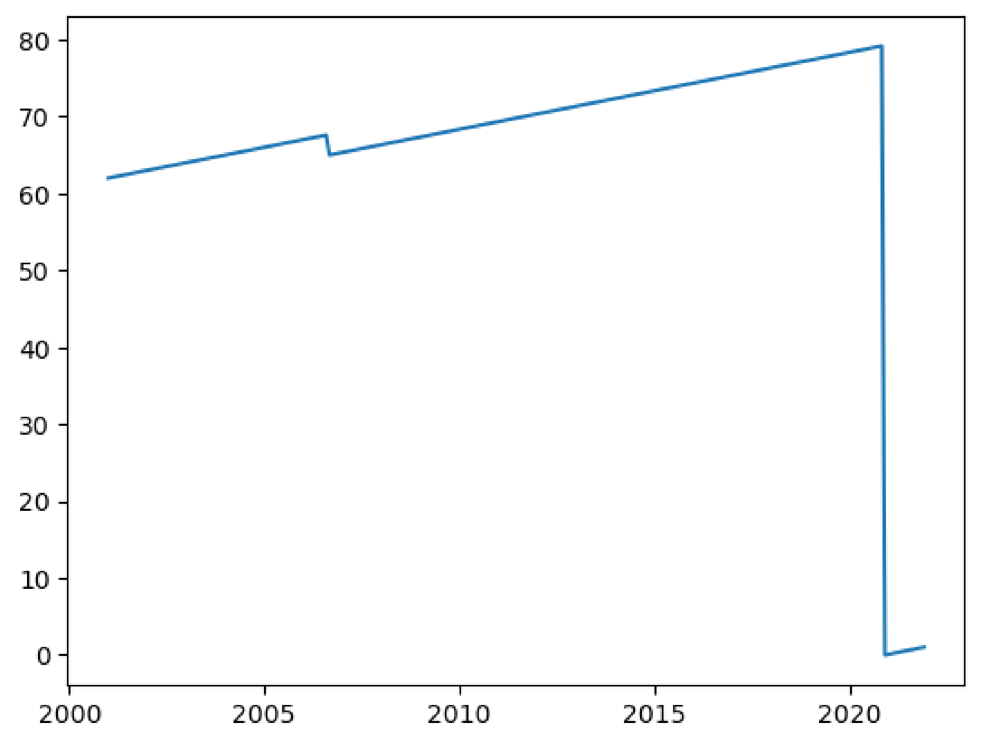
- We want some DataFrame that looks like this at the end so we can append our monthly climate data to:

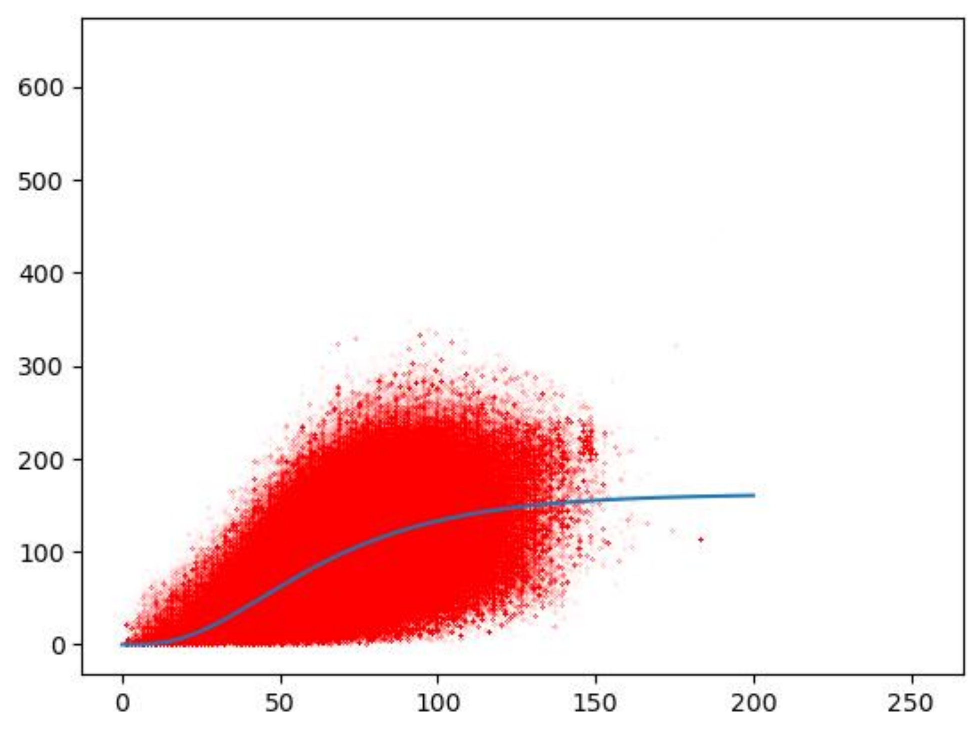
	age	vol	burned	harvested	dist_weight	lon	lat	Tm	Tx	Tn	P	P%N	Pd	BS	BS%
pixel_id															
0	104.5	136.450301	0.0	0.0	NaN	-84.890501	46.906052	17.6	32.0	2.5	33.2	46.0	10.0	NaN	NaN

- We also need data every month year, so let's approximate, we can use the following assumptions:
  - Age approximation – linear with 1 to 1 slope
  - Volume is sigmoidal with Chapmans Richards growth equation [y = a(1-exp(-bx)^m] (Zhao and Feng, 2003)

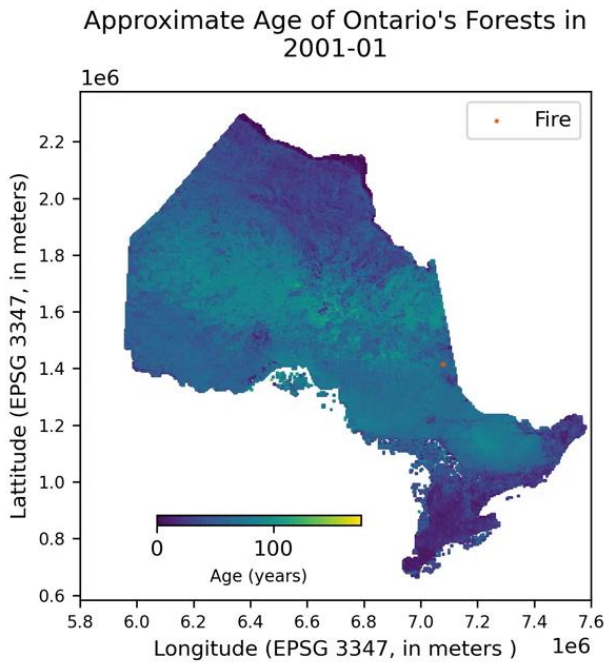
Forest + Fire Data – Approximation

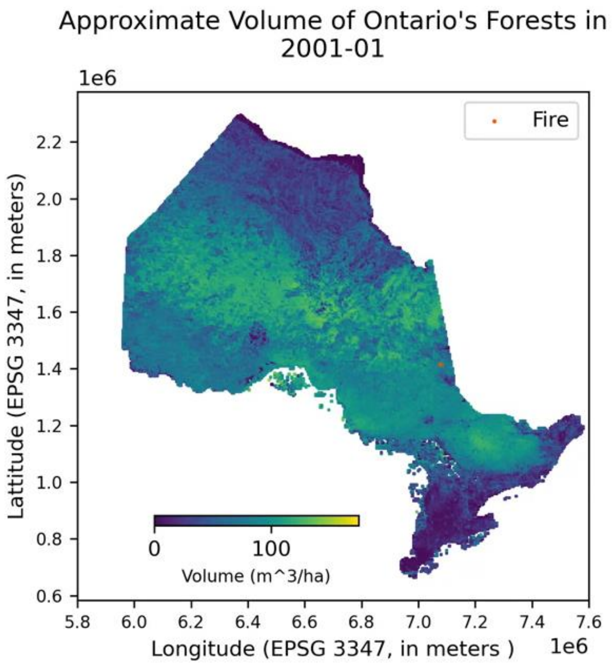
- Age vs. Volume Approximation
  - If encountered fire, age decreased by percent burned. If encountered harvest, decreased to zero age (new forest).

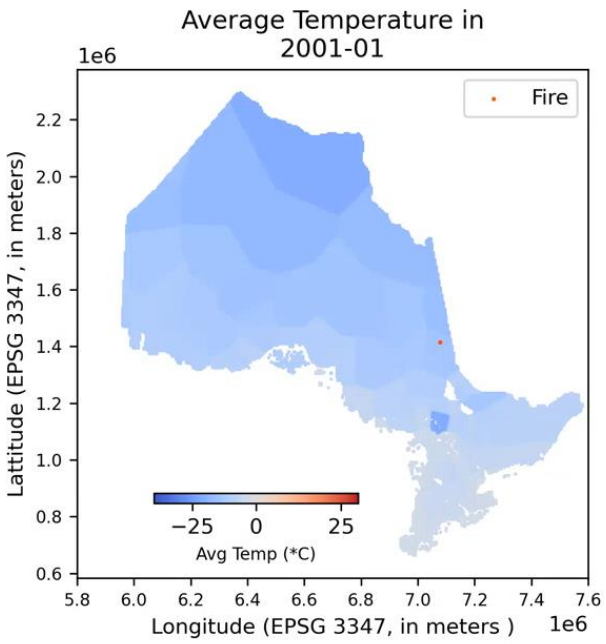


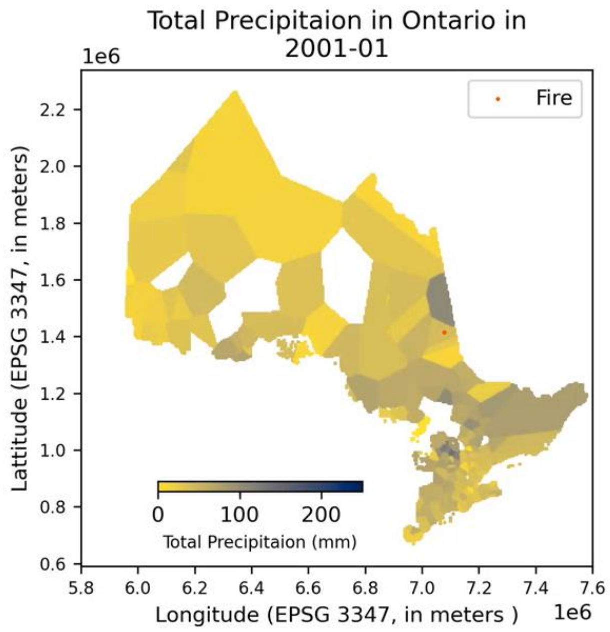


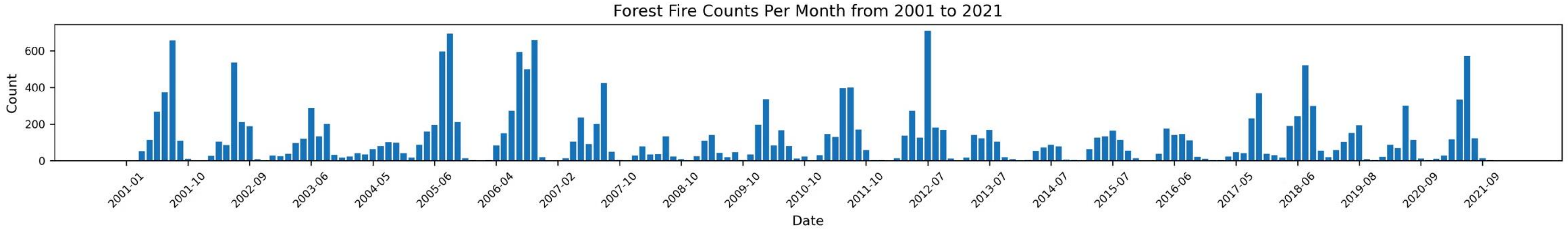
Visualization

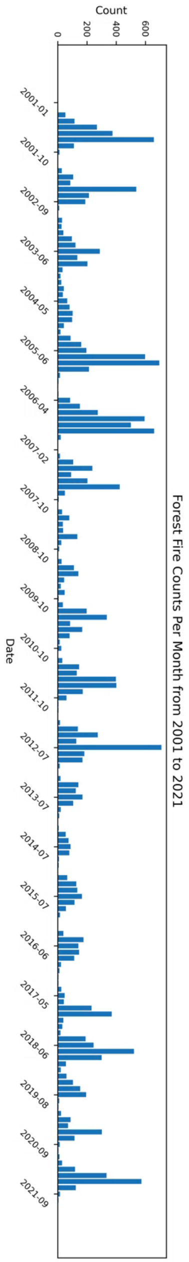

Approximate Age of Ontario's Forests in 2001-01
1e6
Fire
Latitude (EPSG 3347, in meters)
Age (years)
Longitude (EPSG 3347, in meters)
1e6

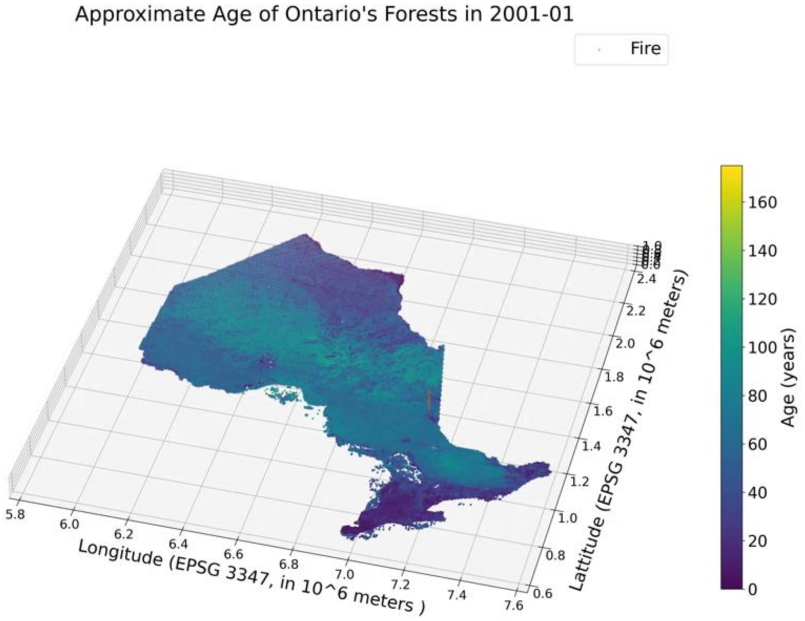

Approximate Volume of Ontario's Forests in 2001-01
1e6
Fire
Latitude (EPSG 3347, in meters)
Volume (m^3/ha)
Longitude (EPSG 3347, in meters)
1e6

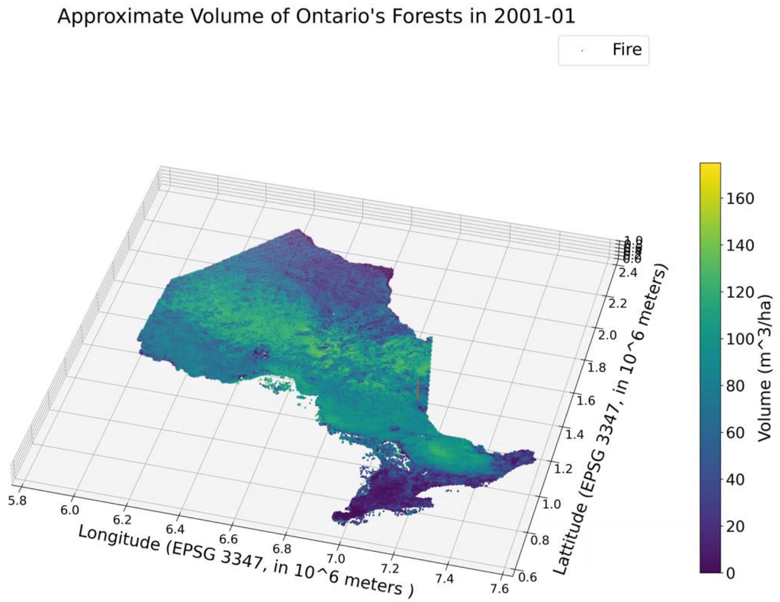

Average Temperature in 2001-01
1e6
Fire
Latitude (EPSG 3347, in meters)
Avg Temp (*C)
Longitude (EPSG 3347, in meters)
1e6

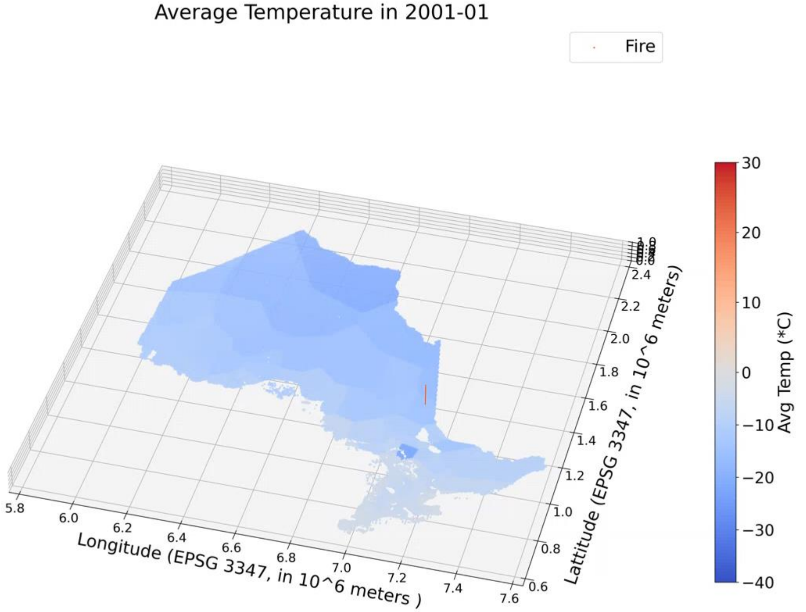

Total Precipitaion in Ontario in 2001-01
1e6
Fire
Latitude (EPSG 3347, in meters)
Total Precipitaion (mm)
Longitude (EPSG 3347, in meters)
1e6

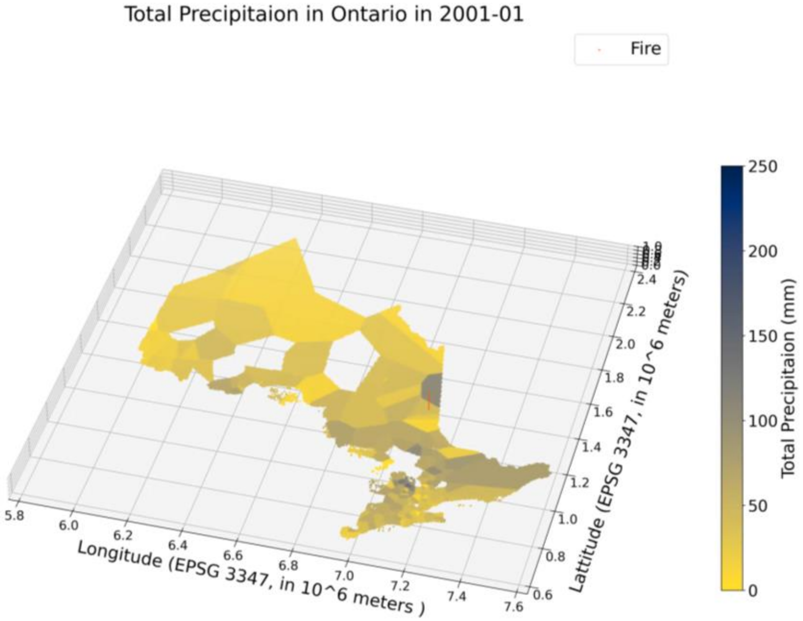

Forest Fire Counts Per Month from 2001 to 2021
Count
Date


Count
Date
Forest Fire Counts Per Month from 2001 to 2021


Approximate Age of Ontario's Forests in 2001-01
Fire
Longitude (EPSG 3347, in 10^6 meters)
Lattitude (EPSG 3347, in 10^6 meters)
Age (years)

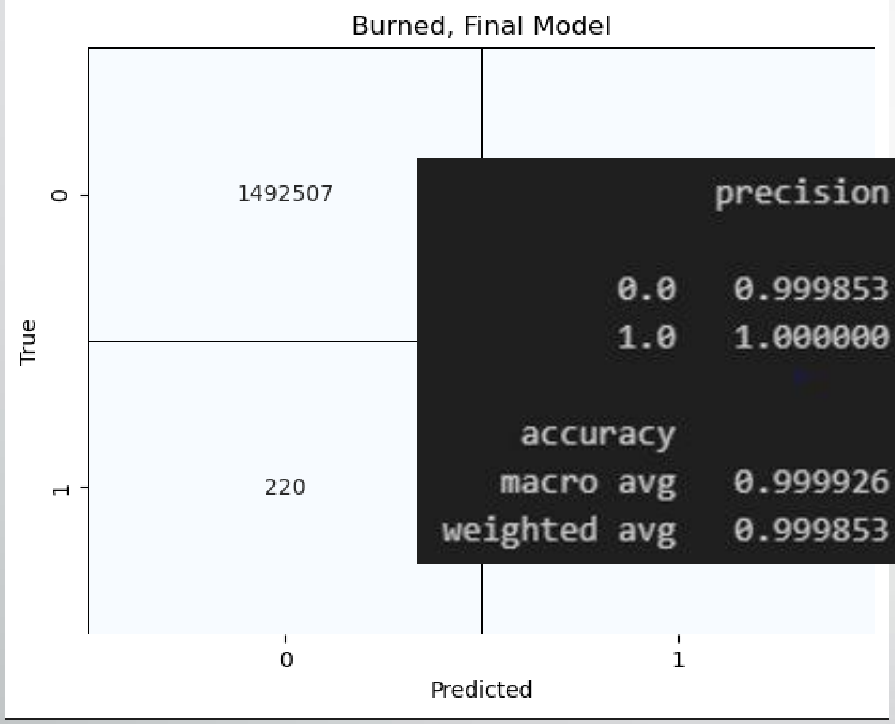

Approximate Volume of Ontario's Forests in 2001-01
Fire
Longitude (EPSG 3347, in 10^6 meters)
Lattitude (EPSG 3347, in 10^6 meters)
Volume (m^3/ha)


Average Temperature in 2001-01
Fire
Longitude (EPSG 3347, in 10^6 meters)
Lattitude (EPSG 3347, in 10^6 meters)
Avg Temp (*C)

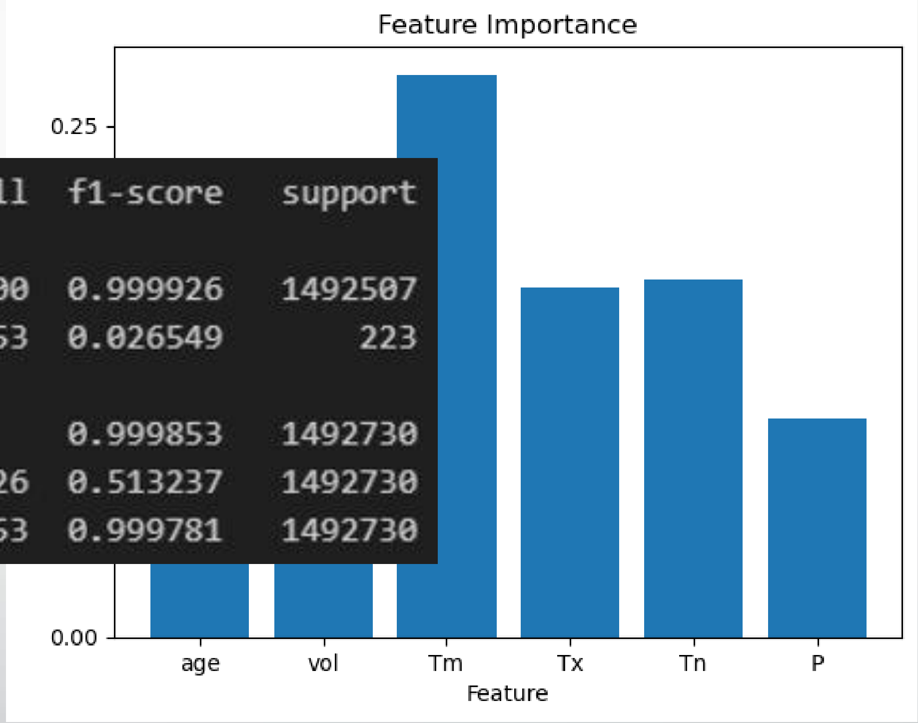

Total Precipitaion in Ontario in 2001-01
Fire
Longitude (EPSG 3347, in 10^6 meters)
Lattitude (EPSG 3347, in 10^6 meters)
Total Precipitaion (mm)

Machine Learning

Machine Learning



	precision	recall	f1-score	support
0.0	0.999853	1.000000	0.999926	1492507
1.0	1.000000	0.013453	0.026549	223
accuracy			0.999853	1492730
macro avg	0.999926	0.506726	0.513237	1492730
weighted avg	0.999853	0.999853	0.999781	1492730



Machine Learning

We are happy with the results, but:

- Are there any limitations?
  - Approximations in Forest Data
  - Reliability in Climate Data
  - What the model really shows

- What are the next steps?
  - Hyperparameter tuning
  - Can we model what causes forest fires?

Conclusion

References:

Beaudoin A, Bernier PY, Villemaire P, Guindon L, Guo XJ. 2017. Species composition, forest properties and land cover types across Canada's forests at 250m resolution for 2001 and 2011. Natural Resources Canada, Canadian Forest Service, Laurentian Forestry Centre, Quebec, Canada. https://doi.org/10.23687/ec9e2659-1c29-4ddb-87a2-6aced147a990

Hermosilla, T., M.A. Wulder, J.C. White, N.C. Coops, G.W. Hobart, L.B. Campbell, 2016. Mass data processing of time series Landsat imagery: pixels to data products for forest monitoring. International Journal of Digital Earth 9(11), 1035-1054

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Natural Resources Canada (n.d.). *Interactive map*. Canadian Wildland Fire Information System. https://cwfis.cfs.nrcan.gc.ca/interactive-map?zoom=0&center=-49014.40575507289%2C798671.2666621353&month=6&day=28&year=2023#iMap

Natural Resources Canada (2023, September 8). *Canada's record-breaking wildfires in 2023: A fiery wake-up call*. Natural Resources Canada. https://natural-resources.canada.ca/simply-science/canadas-record-breaking-wildfires-2023-fiery-wake-call/25303

Zhao-gang, L., & Feng-ri, L. (2003). The generalized Chapman-Richards function and applications to tree and stand growth. *Journal of Forestry Research*, *14*(1), 19–26. https://doi.org/10.1007/bf02856757