Population, Population Density and Active Fire Events Worldwide

Big Data Analysis in Extreme Environments Final Project

Tyler Bull, Spring 2021

Abstract – This project has sought to analyze the relationships between instances of active fire events and how population density and changes in population of various countries around the world affect the quantity of active fire incidences as recorded in the NASA VIIRS I-Band 375 m Active Fire Data [1]. It was hypothesized at the onset of the project that human population would increase fire instances due to human activities. Using Python Numpy and Cartopy modules to analyze and visualize the data revealed correlations and regressions within this data when compared with the human population over the time range under consideration (2003-2019). From this analysis it was found that increasing population density tends to have a negative relationship with active fire instances across the world. The shape of this relationship was not found to be clear enough from the data to determine the non-linear regression, however a linear and quadratic relationship were attempted on the worldwide dataset.

Author Disclaimer: All code written in Python is my own and is not owing to another source for large sections or routines. Though many resources were used in the development of the code, and small functions and methods borrowed from a variety of resources, no large sections of code can be credited to any other. Code, datasets used, report and presentation may be found in the GitHub repository at the following address:

https://github.com/BigDataCourseBhaganagar/Human-Impacts-on-Fire-Instances

Introduction

Beginning in 2000, NASA has recorded and compiled data which records active fire instances worldwide vie satellite detection. The Visible Infrared Radiometer Suite (VIIRS) 375 m Active Fire dataset is compiled from regular readings of the VIIRS package which is aboard the joint NASA/NOAA Suomi National Polar-Orbiting Partnership and NOAA-20 satellites. The sensor package records the infrared (IR) spectrum data and reports pixel of size 375 x 375 m which detect brightness levels according to the instance of an active fire.

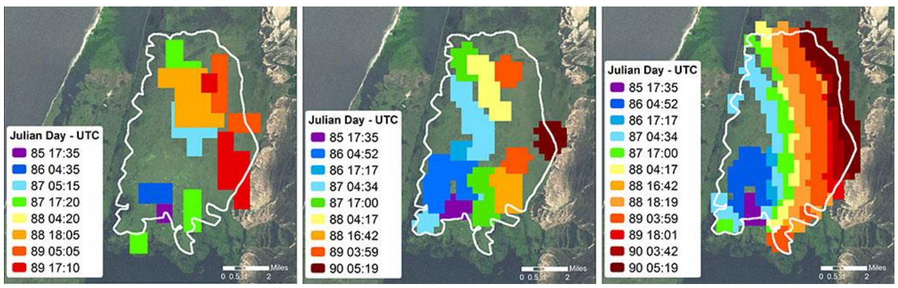


Figure 1: A time study of a large wildfire at the Taim Ecological Reserve in southern Brazil in March 2013 using the 375 m VIIRS data (right). (*credit, NASA Earth-data*)

The dataset includes a number of useful attributes for analysis of various types:

- Latitude
- Longitude
- I-4 Channel Brightness
- Pixel Size (typically 375m)
- Acquisition Date and Time
- Confidence Level
- I-5 Channel Brightness
- Day vs. Night

For the purposes of this analysis, select year in the range 2000-2020 are analyzed. At the onset of the analysis the years 2000, 2005, 2010, 2015, and 2019 were selected, but after initial review it was found that the year 2000 was only a partial set of data with initial recording beginning in October of 2020. Consecutive years 2001, 2002 also had marked the beginning of the collection period with limited satellite coverage and were rejected due to limited data. For this reason, the year 2003 replaced the year 2000 in the selection. The total number of active fires registered worldwide in this set of years was 15,113,806. To investigate further the impact of population specifically, the countries considered for analysis is reduced to a useful subset of these. Further analysis would use the full dataset later to analyze trends associated with population density.

Furthermore, it was intended that durations of fires be resolved from the data, but it quickly became apparent from looking at fires which occur near each other, that the data would only support analyzing the durations of fires if the fires are sufficiently large to cover several 375m pixels. If the fire does not leave its initial pixel that it was found in, it does not get recorded again in subsequent data. Due to this discovery, the duration of fires in a specific pixel could not be resolved from the data and this analysis was abandoned.

Population Gradient Analysis

At the beginning of the analysis, population data was imported from *The World Bank* datasets for all countries in the range of years outlined for analysis. To look at the effect of population change on the active fire instances, two categories of analysis were considered. Countries with a large *increase* in population (greater than 30%) from 2003-2019 were determined from the population data and recorded as Group A. To further analyze any trends found in Group A, a second group is identified of five countries which saw the highest *decrease* in population during the data range. **(Table 1).**

Table 1: A listing of 10 countries, along with their populations, which saw a growth of greater than 30% would serve as Group A. (Left) And 7 countries with the highest reduction in population served as Group B (Right).

Country	Code	2003	2005	2010	2015	2019	Pct
Qatar	QAT	681788.0	865416.0	1856327.0	2565710.0	2832067.0	75.926135
Oman	OMN	2386166.0	2511251.0	3041434.0	4267348.0	4974986.0	52.036729
Kuwait	KWT	2161626.0	2270198.0	2991884.0	3835591.0	4207083.0	48.619364
Jordan	JOR	5434030.0	5765635.0	7261539.0	9266575.0	10101694.0	46.206745
Niger	NER	12647984.0	13624467.0	16464025.0	20001663.0	23310715.0	45.741759
Uganda	UGA	25980552.0	27684585.0	32428167.0	38225453.0	44269594.0	41.312875
Chad	TCD	9373916.0	10096633.0	11952136.0	14110975.0	15946876.0	41.217854
Burundi	BDI	6909154.0	7364862.0	8675602.0	10160030.0	11530580.0	40.079736
Gabon	GAB	1319953.0	1390549.0	1624140.0	1947686.0	2172579.0	39.244879
Mali	MLI	11982695.0	12775516.0	15049353.0	17438778.0	19658031.0	39.044277

Country	Code	2003	2005	2010	2015	2019	Pct
Bulgaria	BGR	7775327.0	7658972.0	7395599.0	7177991.0	6975761.0	-11.462061
Romania	ROU	21574326.0	21319685.0	20246871.0	19815616.0	19356544.0	-11.457531
Moldova	MDA	2902320.0	2888111.0	2861487.0	2834530.0	2657637.0	-9.206788
Ukraine	UKR	47812949.0	47105171.0	45870741.0	45154036.0	44385155.0	-7.722839
Serbia	SRB	7480591.0	7440769.0	7291436.0	7095383.0	6944975.0	-7.712281
Georgia	GEO	3951736.0	3902469.0	3786695.0	3725276.0	3720382.0	-6.218555
Croatia	HRV	4303399.0	4310145.0	4295427.0	4203604.0	4067500.0	-5.799607

Because each of the entries of the data represents a 375m pixel of area which has registered on the VIIRS sensors, the length of these datasets is an initial indicator of the effect of this data on Group A and Group B. **(Figure 2)**

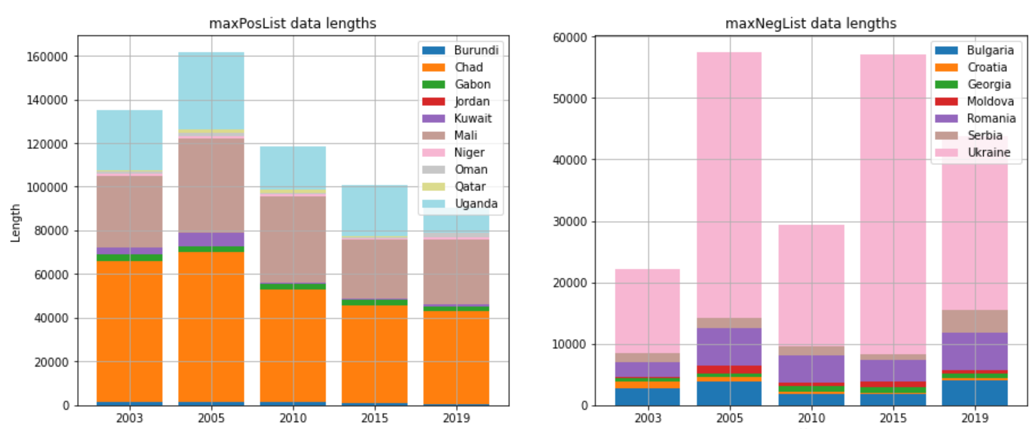


Figure 2: The lengths of the datasets for Group A (left) and Group B (right).

Initial analysis of the length of data reveals what is likely a negative trend associated with population change within a country and active fires in the region. This is indicated by the negative relationship seen in Group A, and the positive relationship visible in Group B data lengths. This trend will be analyzed for each country in the dataset to identify if this trend is true most often for each of the countries or if a few countries in the data have caused this phenomenon.

Furthermore, on the scale of 123 countries spanning the world, a regression analysis will aim to determine how population density, as opposed to population change, affects the quantities of fires detected by the VIIRS sensor suite.

Active Fires by Country: Visualization

To investigate any relationships between active fires and population change the Fire data for each country from Groups A and B were plotted using Cartopy to determine if the changes would be visible when plotted by latitude and longitude on the maps of each country. Prior to this analysis, the data was cleaned up according to the “Confidence” attribute provided in the VIIRS dataset, with events having confidence under 10% removed from the data. A selection from Group A and Group B are found in **Figure 3** and further visualize the changes across years. The remainder of the maps for each group across the entire range of years can be found in **Appendices A** and **B**, respectively.

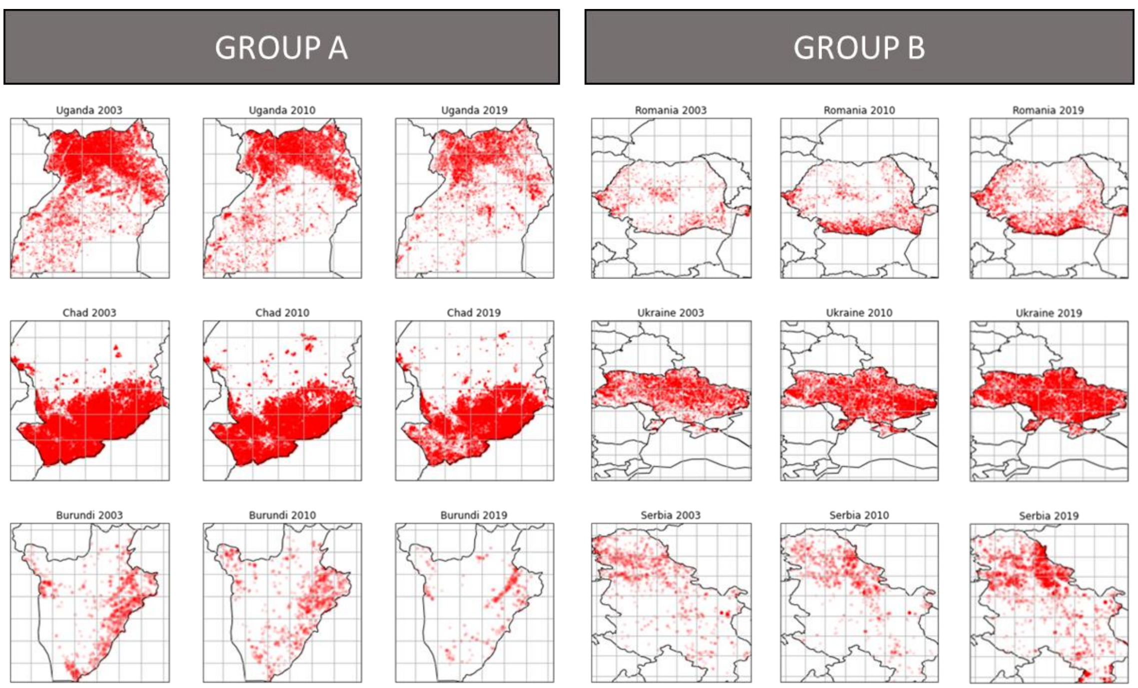


Figure 3: Fire data plotted over maps of each country reveal further a negative trend in Group A and a positive Trend in Group B. The years 2005 and 2015 are omitted for display purposes.

It is mostly evident in these plots that Groups A and B have a different trend associated with the time period of 2003-2019. A further regression analysis was performed to continue investigating this trend.

Active Fires by Country: Regression

In order to understand the correlation more fully between the population change of a country and its number of instances of active fires, a linear regression analysis was performed on each country in Groups A and B. The results of this analysis are presented in **Figure 4.** In the data selected from Groups A and B it is most frequent that correlation is negative for both sets. In the case of Group A, 8/10 reflect a negative correlation with population and fire instances. In Group B, 6/7 reflect a negative correlation between population and fire instances.

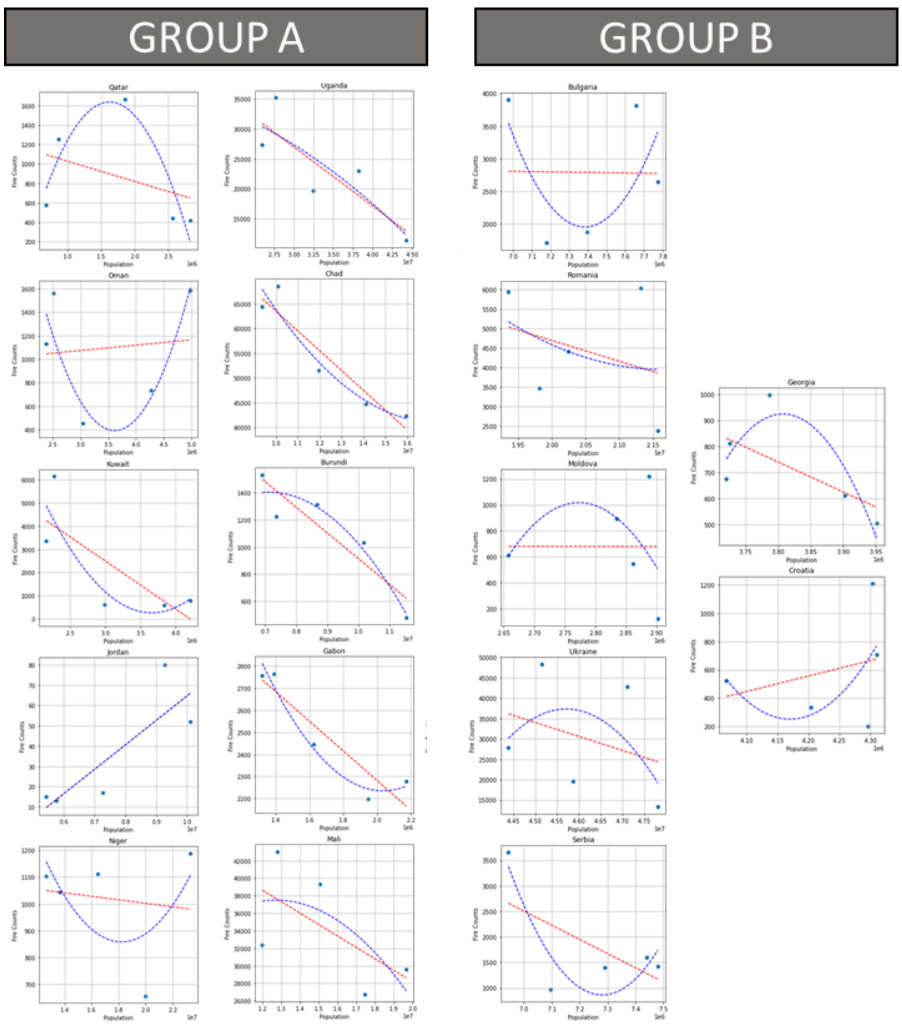


Figure 4: The linear and quadratic regressions associated with each country across the range of years.

Further analysis of all countries in the dataset was performed to further support the result. An analysis of 123 of the 195 countries in the world was performed in the same manner as Groups A and B, and the regression coefficients were obtained. The results of this analysis are presented in **Figure 5.** Only 123 countries were considered in the analysis as the datasets for 2003, 2005, 2010, 2015, and 2019 only share 123 of the 195 internationally recognized countries. The results of this study indicate that both the strongest and most frequent relationships between the population density and fire instances are negative relationships. Among the most certain of correlations (r = 1, r = -1) it was found that negative relationships are more than twice as frequent as positive relationships.

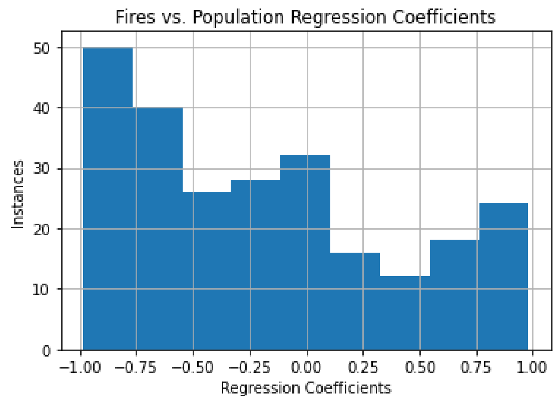


Figure 5: Regression coefficients of the 123 of the 195 recognized countries across the years 2003-2019.

Active Fires by Population Density

A final analysis considering all 123 countries sought to analyze how population density (People per Square Mile) affects fire instances. The results of this analysis are presented in **Figure 6**.

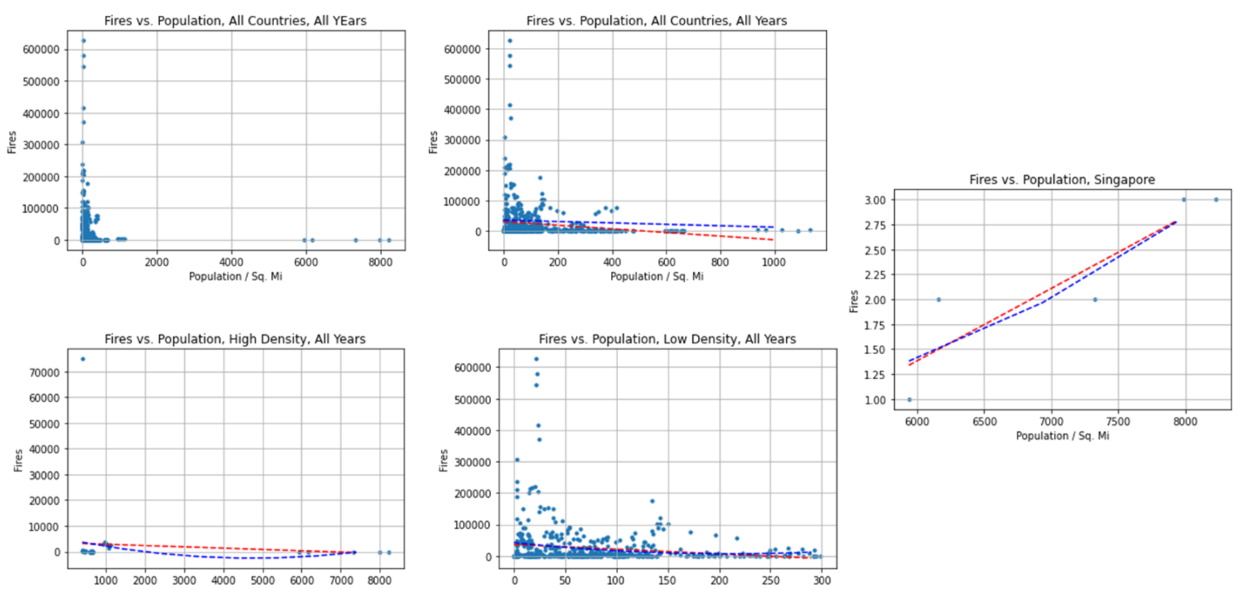


Figure 6: Fire instances as related to population density for all countries, and in various subsets of the population density.

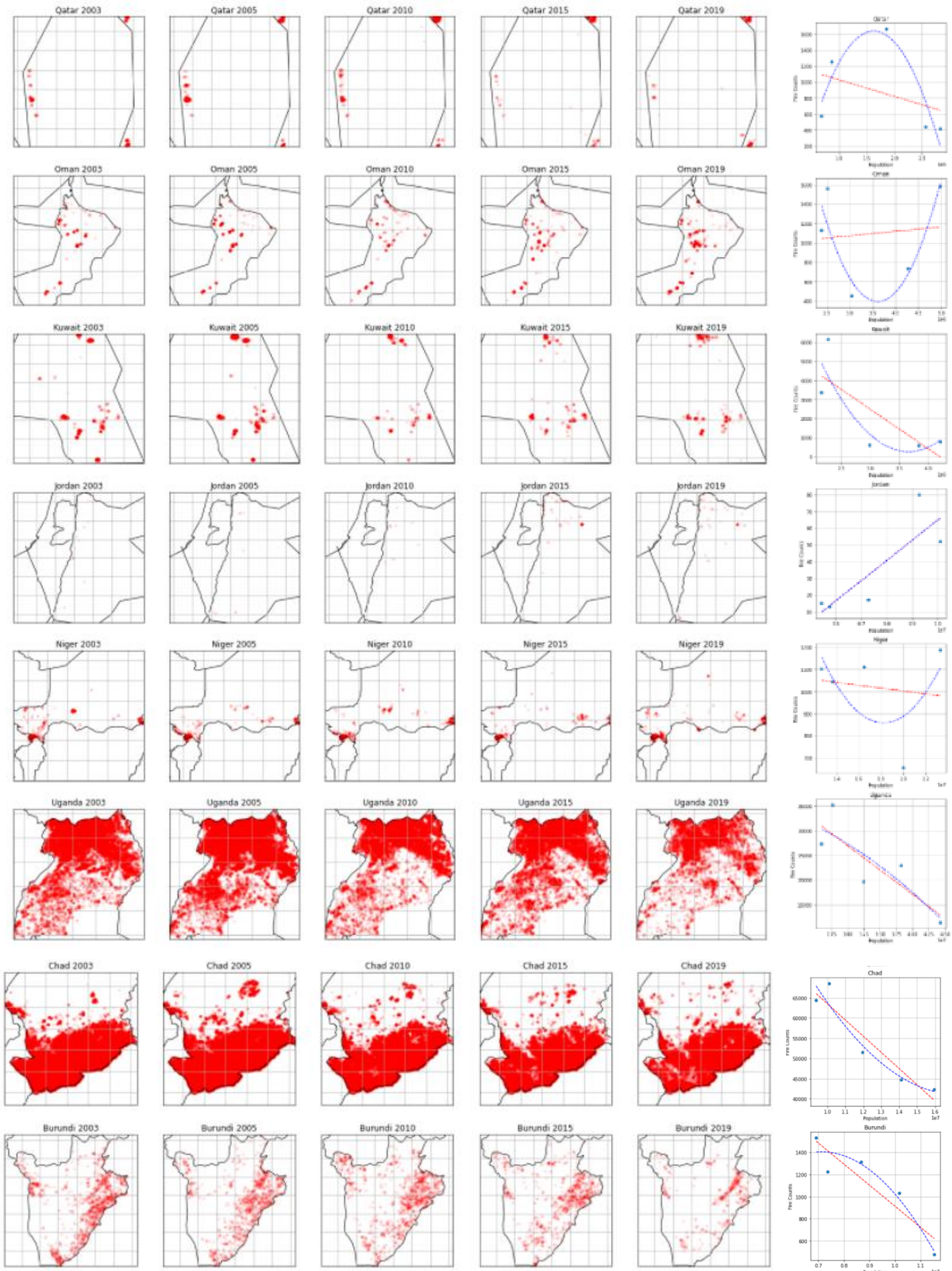
This analysis too found that a general reduction in the quantity of fires is found as population density increases. Further analysis sought to look at the relationships in areas with ranges of population density and found in each case the same negative trend. The area of exception to this trend is in the far right of each plot. The country with the highest population density in the dataset is Singapore. Many of the fires detected in Singapore by the VIIRS sensor package were low confidence (0-10%), and the total counts of fires recorded in Singapore in a single year was at a maximum of three. This is considered an anomaly in the dataset.

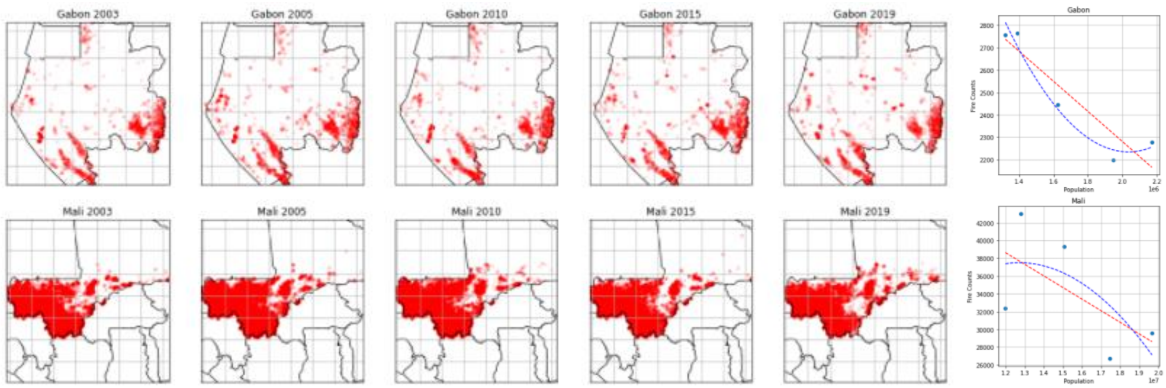
Discussion and Conclusions

Though each regression in the data is not particularly strong, the unanimity of the results indicates a negative relationship with fire instances and population change. Meaning, as population increases, fires decrease or the contrary: as fires increase, population decreases. Either of these explanations is a plausible explanation for the results. Intuitively either of the explanations are also plausible. Human response to fires causing a decrease in fire activity, human industrialization and residential zoning reducing the available combustible material in a region, or conversely; an increase in fires causing deaths and migration patterns of the populations of the area. Furthermore, it is found that in countries with a higher population density, that a decrease in active fires is to be expected. This also is an intuitive result considering the effect of human population on the presence of natural combustible materials such as trees and grasslands. These results go against the intuition and hypothesis that human activities are the cause of fires worldwide. Though the damage, cost, tragedy, and loss of life associated with fires in populous areas may cause a base-rate neglect fallacy when considering the real instances of these fires.

As to the question of causation, whether it be fires causing migration of populations, or migration of populations preventing fires, is difficult to analyze and remains for further investigation. Because population of various countries is widely reported on a yearly basis, and not a smaller interval, it is difficult to do such analysis. Other methods of analysis than presented here, or targeted case studies in the areas of rapid population growth and decay will be required to determine causation for the relationship between population and active fires.

APPENDIX A – GROUP "A" PLOTS




Gabon 2003
Gabon 2005
Gabon 2010
Gabon 2015
Gabon 2019
Gabon
Fire Counts
Population
Mali 2003
Mali 2005
Mali 2010
Mali 2015
Mali 2019
Mali
Fire Counts
Population

APPENDIX B– GROUP “B” PLOTS

Group ‘B’ Regression data (right) should be read in reverse as population of Group B decreases yearly.