Fueling the Flames*

An analysis of the impact of key environmental factors on the escalation and intensity of global wildfires.

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This paper presents an analysis of the impact of key environmental factors on the intensity of global wildfires. Wildfires now result in 3 million more hectares of tree cover loss per year compared to 2001. This paper delves into the relationships between wildfire area and various predictors including CO2 emissions per capita, average temperature, global population, and mean sea level. The results of this data displays the critical need for policy interventions that address not only emissions and population factors but also consider land management. Future research is warranted to incorporate additional variables such as land use changes, humidity levels, and wind patterns to enhance the model's predictive capacity.

1 Introduction

The global landscape is increasingly being effected by wildfires, a phenomenon exacerbated by climate change and anthropogenic influences. With a staggering 3 million additional hectares of tree cover lost annually since 2001 due to wildfires, understanding and mitigating this threat has become a critical environmental imperative (Data (2024). Wildfires not only result in substantial ecological damage but also pose significant threats to human life and global biodiversity. The urgency and devastation these evnts can bring about calls for a thorough examination of the factors contributing to the rising intensity and frequency of wildfires. This paper aims to dissect the complex interactions between environmental variables and wildfire statistics, seeking to highlight a new pathway through which climate change is fueling these natural disasters.

Wildfires are natural occurrences that play a key role in the maintenance of many ecosystems. However, the recent surge in their intensity and frequency points towards an alarming trend that is being attributed to human activity and climatic shifts. Factors such as CO2 emissions

*Code and data are available at: https://github.com/Lwall02/guitars.

per capita and average temperature have been postulated to correlate with wildfire occurrences, forest dryness, and extreme weather conditions. Moreover, the expansion of the global population and its encroachment into forested areas has not only increased the likelihood of fire ignition but also the complexity of fire management. Mean sea level rise, an indicator of climate change, is also hypothesized to have far-reaching impacts beyond coastal ecosystems, potentially influencing weather patterns and, by extension, wildfire prevalence. Our analysis looks deeper to these associations, employing a linear model to quantify their influence and predict future wildfire occurences.

As wildfires continue to intensify, there is a growing need for policies that not only reduce emissions but also address broader environmental and social dynamics. Effective land management, which includes fire prevention strategies and sustainable land conversion planning, are large factors in our climate changing and that take decades to reverse. The lack in policy to prevent further destruction will have lasting impacts on a global scale. This paper not only identifies the current gaps in policy but also paves the way for future research to explore overlooked variables that could further elucidate wildfire behavior. By broadening the scope of analysis to include factors such as land use changes, humidity levels, and land fuel levels in vegetation, we can enhance the predictive models that guide these policy decisions. In doing so, we may develop a general global approach to wildfire management and climate change mitigation, hopefully introducing immediate response strategies with long-term environmental rewards.

The open source programming language R was used in the making of this report (R Core Team (2022)).

2 Data

2.1 Annual Area Burnt By Wildfires

The data set downloaded from 'Our World in Data' contains the annual area burnt by wildfires per year from 2012 to 2024. The area burnt by wildfires in is reported in hectares. The data includes cumulative annual figures for Africa, Asia, Europe, North America, South America, and Oceania. The total figures for annual global data can be calculated by summing the mentioned regions. The data also contains complete 13 year data for 252 individual countries. 48 countries have recorded 0 hectares burnt for all 13 years of study Data (2024). This paper will cover the data from 2012 to 2022.

The area, in hectares, burnt by wildfires is estimated based the satellite imagery technologies MODIS (Moderate Resolution Imaging Spectroradiometer) and VIIRS (Visible Infrared Imaging Radiometer Suite). The VIIRS is a relatively new satellite first launched into orbit in late 2011. It collects data on the atmosphere, land, and oceans to measure a host of properties of Earth including present aerosols, ice movement, cloud properties, temperature data, and fires. (EarthData (2024)). MODIS is another satellite that collects and montiors patterns on

Earth's surface through satellite images. The information gathered is very useful for climatologists including global agricultural monitoring and forecasting, biogeo-chemical modeling, land use planning, land-cover change detection, and habitat preservation (Survey (2024)).

The Global Wildfire Information System (GWIS) interprets the collected information from the above satellites and releases data sets which includes metrics such as the area of land burnt, cumulative burnt areas, carbon dioxide emissions from fires, cumulative carbon emissions, the number of fires, and cumulative fire counts. An important aspect to note and will be brought later in discussions is that GWIS is "presently engaged in a global accuracy assessment and acknowledged that they might be underestimating the genuine impact of wildfires, primarily due to constraints imposed by the spatial resolution of the sensors they employ" (Data (2024)). This does not impede the effectivity of the data I employ as the underestimates still yield trends of interest. The data was made easily accessible through 'Our World in Data' with minor data cleaning.

2.2 Per Capita CO2 Emissions

The data set downloaded from 'Our World in Data' contains annual per capita CO2 emissions per country or region, excluding land-use change, measured in tonnes per person. Land use change can release carbon dioxide into the air mainly through the process of agricultural conversion and will be covered in a separate data set. Similar to the wildfire data, it includes cumulative annual figures for Africa, Asia, Europe, North America, South America, Oceania, and the World (not included in wildfire data). As well as data for 252 countries spanning 1750 to 2022. I have selected only to examine the data from 2012 to 2022 for the cumulative figures mentioned above.For the purposes of this paper, we use the global data which is includes emissions from aviation and shipping.

The Global Carbon Project (GCP) is an international science team that tracks the trends in global carbon emissions and sinks and is a key part of facilities the goals of the Paris Agreement. It's widely recognized as the most comprehensive report regarding carbon dioxide emissions. The GCP has been publishing estimates of global and national fossil CO2 emissions since 2001. (Andrew (2023)). The GCP has made their comprehensive data available and "Our World in Data' has cleaned and made it easily accessible.

2.3 Global Average Temperature

The data set downloaded from "Our World in Data" contains detailed information on the average recorded temperature for 195 countries from 1940 to 2024. This data is produced by the Copernicus Climate Change Service which is ran by the European Centre for Medium-Range Weather Forecasts. The service provides hourly, global temperature data recorded all over the globe. There is both monthly and annual data, we focus on annual data in this paper. The temperature is recorded in Celcius and measured 2 meters above the surface of the land, sea, and in-land waters. The global average annual temperatures per year are obtained by averaging the 195 countries' data. (Service (2019)).

2.4 Global Population

The data set downloaded from "Our World in Data' has made global population data released by the United Nations easily available (Data (2022)). More specifically the Population Division of the Department of Economic and Social Affairs of the United Nations releases a revision of population data every two years. The 2022 Revision of World Population Prospects was released on 11 July, 2022 which contains estimates from 1950 to the present for 237 countries. The next revision of this data by the UN is due in 2024. The 2022 World Population Prospects considers the results of 1,758 national population censuses conducted between 1950 and 2022, as well as information from vital registration systems and from 2,890 nationally representative sample surveys. The 2022 revision also presents population projections to the year 2100 that reflect a range of plausible outcomes at the global, regional and national levels (Economic and Division (2022)).

2.5 Sea Level

The data for the global mean sea level is produced by NASA using satellite radar altimetry. That is the process of measuring the distance of the surface from orbit using radar pulses. NASA make available the recorded change in sea level since January 5, 1993 to present.

3 Model

3.1 Model set-up

3.1.1 Model justification

4 Results

5 Discussion

Appendix

A Model details

A.1 Posterior predictive check

	(1)
(Intercept)	39.148
annual_co_emissions_per_capita	−0.400
average_temp	0.214
global_population	−1.041
gmsl	0.000
Num.Obs.	11
R2	0.408
R2 Adj.	−0.034
Log.Lik.	13.177
ELPD	9.0
ELPD s.e.	3.1
LOOIC	−18.1
LOOIC s.e.	6.2
WAIC	−19.3
RMSE	0.76

Figure 1: This displays model summaries for both linear models. It shows the coeffieceints as well as the R squared coefficients. From these tables, the R squared coeffecient is very low and is indicative of a very ill-fitting model.

	(1)
(Intercept)	7.430
annual_co_emissions_per_capita	−0.074
average_temp	0.032
global_population	−0.145
gmsl	0.000
Num.Obs.	11
Log.Lik.	−36.092
ELPD	−38.0
ELPD s.e.	0.7
LOOIC	76.1
LOOIC s.e.	1.3
WAIC	75.6
RMSE	63.95

Figure 2: This displays model summaries for both linear models. It shows the coeffieceints as well as the R squared coefficients. From these tables, the R squared coeffecient is very low and is indicative of a very ill-fitting model.

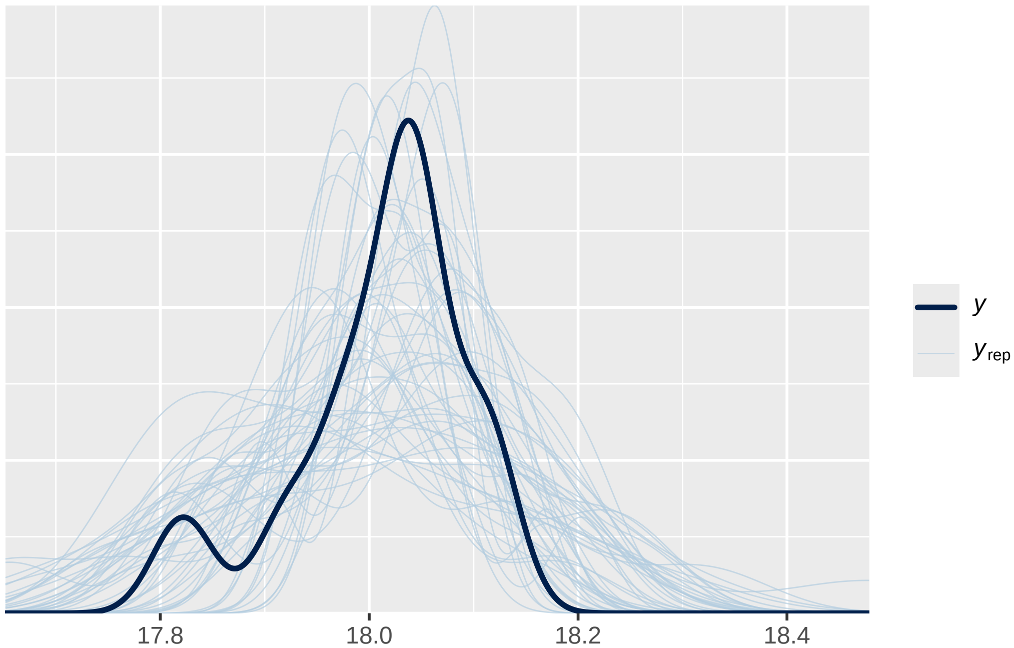

Figure 3: This displays the posterior predictive check that were ran on both linear models. As you can see the first linear model based on a gaussian distribution is the more fitting model. This aligns with the results of the model as the R squared is much higher compared to the second Gamma-derived model. The second model should be discarded.

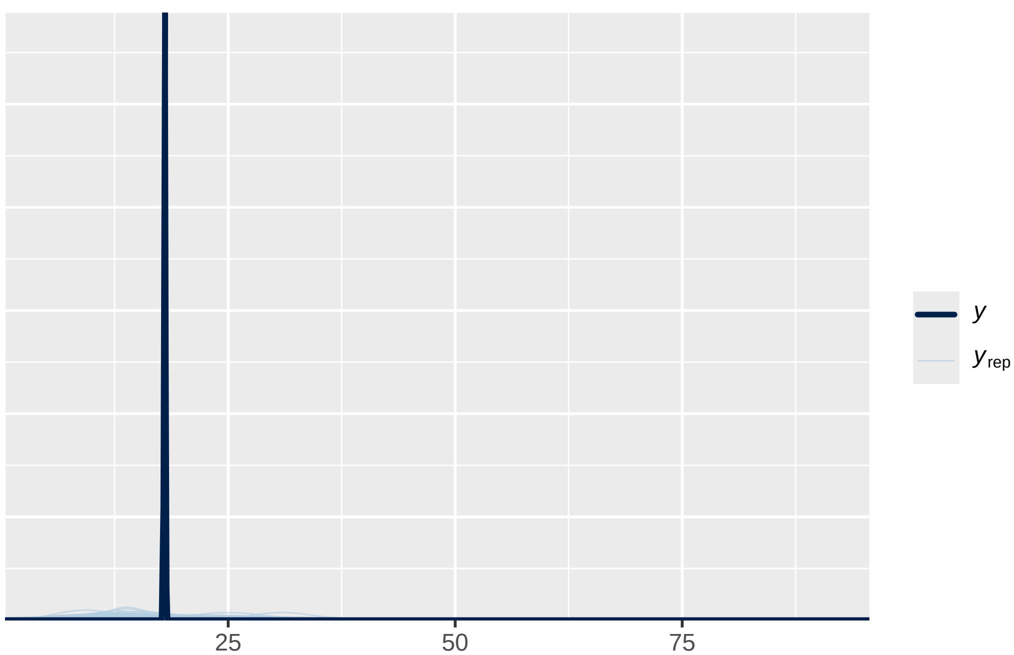

Figure 4: This displays the posterior predictive check that were ran on both linear models. As you can see the first linear model based on a gaussian distribution is the more fitting model. This aligns with the results of the model as the R squared is much higher compared to the second Gamma-derived model. The second model should be discarded.

References

Andrew, & Peters, R. M. 2023. *The Global Carbon Project's Fossil CO2 Emissions Dataset (2023v36)*. Zenodo. https://doi.org/10.5281/zenodo.10177738.

Data, Our World in. 2022. *Population*. https://ourworldindata.org/explorers/population-and-demography?facet=none&country=CHN~IND~USA~IDN~PAK&hideControls=false&Metric=Population&Sex=Both+sexes&Age+group=Total&Projection+Scenario=None.

———. 2024. *Annual Area Burnt by Wildfires*. https://ourworldindata.org/grapher/annual-area-burnt-by-wildfires.

EarthData, NASA. 2024. *Visible Infrared Imaging Radiometer Suite (VIIRS)*. https://ladsweb.modaps.eosdis.nasa.gov/missions-and-measurements/viirs/.

Economic, Department of, and Social Affairs Population Division. 2022. *2022 World Population Prospects*. United Nations. https://population.un.org/wpp/.

R Core Team. 2022. *R: A Language and Environment for Statistical Computing*. Vienna, Austria: R Foundation for Statistical Computing. https://www.R-project.org/.

Service, Copernicus Climate Change. 2019. *Annual Average*. https://doi.org/10.5281/zenodo.10177738.

Survey, U. S. Geological. 2024. *Moderate Resolution Imaging Spectroradiometer (MODIS) Overview*. https://pubs.usgs.gov/fs/2008/3061/pdf/fs2008-3061.pdf.