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Understanding Drivers of Wildfires in California

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ABSTRACT

This research study investigates the intricate relationship between El Niño events, precipitation patterns, and wildfires in California over the past two decades. California, known for its susceptibility to wildfires, has experienced significant variations in precipitation influenced by the El Niño-Southern Oscillation (ENSO) phenomenon. The objective of this research is to examine the impact of El Niño events on California's precipitation patterns and subsequently assess their association with wildfire occurrences. Predicting wildfire and precipitation wildfires are important to California's significant agriculture production and better preparing for possible droughts or wildfires. To achieve this objective, a comprehensive analysis of climate data spanning the last 20 years was conducted. Historical records of El Niño episodes, obtained from reputable sources, were measured by correlation with precipitation data acquired from meteorological databases. Additionally, wildfire occurrence and severity data were collected from relevant agencies and organizations to be measured for correlation. As it turns out, while there was some positive correlation with El Nino and precipitation, there was little direct correlation between El Nino and wildfires. This means that there are many more complex factors to be assessed when figuring out causes of wildfires in addition to El Nino. The findings of this research will contribute to a better understanding of the main causes of wildfires in California. The results can inform policymakers, land managers, and disaster response agencies in developing more effective strategies to mitigate the risks associated with wildfires. Additionally, the study will provide valuable insights into the influence of climate variability on fire-prone ecosystems, aiding in the prediction and management of future wildfire events.

Introduction

California, renowned for its scenic landscapes and diverse ecosystems, has long been plagued by the devastating impact of wildfires. Its unique combination of dry vegetation, frequent droughts, and strong winds make it highly susceptible to these natural disasters. Over the past few decades, the state has experienced a dramatic increase in the frequency, intensity, and scale of wildfires, causing widespread destruction of forests, wildlife habitats, and human settlements (NASA, 2021). Adding on, California, through its many dry seasons and "wet" seasons, has seen odd precipitation patterns, ranging from entirely dry seasons to an extremely rainy mass flood-causing wet season (Leonard and Moriarty, 2023). Among the various factors influencing California's wildfire patterns and unpredictable precipitation, the El Niño-Southern Oscillation (ENSO) phenomenon has gained considerable attention. Normally, trade winds in the Pacific Ocean push warm waters towards the western Pacific Ocean, towards Asia and Australia. On the other side of the ocean, near the Americas, as the warm water is pushed away from that area, it's replaced by cold water from deep in the ocean. This balance of ocean temperature causes more in the ocean near Australia and Asia, causing more rainfall in that area. Conversely, near the Americas, a lack of evaporation near them usually leads to less precipitation. When those trade winds that cause this balance weaken, that's when a weather pattern known as El Nino occurs. This causes the warmth in the ocean to move eastward as there's less wind to push it towards the west. With newfound warmth in the eastern pacific, there is now more evaporation in that area and therefore, usually more precipitation than average

(USGS, 2023). Studying the relationship between El Niño, precipitation, and wildfires in California is of paramount significance. Precipitation plays a crucial role in mitigating the risk of wildfires by replenishing soil moisture and reducing the flammability of vegetation (NASA, 2021). The influence of ENSO on precipitation patterns in California has been well-documented, with El Niño events typically associated with above-average rainfall in the state. Through understanding the interplay between El Nino and precipitation, researchers can potentially gain ways to track California's precipitation. In recent years, the field of predictive modeling has emerged as a powerful tool for understanding and managing natural disasters, including wildfires. By utilizing historical data, climate records, and advanced modeling techniques, researchers and policymakers can develop predictive models that estimate the likelihood, intensity, and spread of wildfires under varying climatic conditions. These models can provide critical information for proactive planning, resource allocation, and early warning systems, enabling more effective adaptation and response strategies to mitigate the impact of wildfires. The primary objective of this study is to delve into the complex relationship between El Niño, precipitation, and wildfires in California using predictive modeling techniques. By analyzing historical climate data, wildfire records, and ENSO indices, we aim to develop a robust predictive model that can accurately forecast the influence of El Niño on precipitation patterns and subsequently assess its impact on wildfire occurrence and behavior. This research endeavor will contribute to a deeper understanding of the intricate connections between climate phenomena, precipitation, and wildfires, ultimately leading to more effective wildfire management strategies and improved resilience in California.

Methodology

Data Collection

This research looked at four different variables (ENSO Index, Total Annual Rainfall, Number of Hectares Burned, and Number of Wildfires) across three databases. All data was averaged for the corresponding year between the time range of 2000 to 2023.

The ENSO Index is derived from satellite sea level observations published by NASA Measures/PO.DAAC and can be found publicly at https://ggweather.com/enso/oni.htm.

The annual precipitation data used in this study was obtained from NOAA (https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/county/mapping/4/pcp/201902/1/value")

The data for the number of hectares burned and the number of wildfires was collected from the Historical Wildfire Occurrence records maintained by the Department of Forestry and Fire Protection CAL FIRE statistics. This can be accessed publicly online at https://www.fire.ca.gov/our-impact/statistics.

Overall, a summary of this data in its raw form can be seen in the annex.

Data Analysis

First, the trends in all the variables were assessed over time to gain an initial understanding of their temporal patterns and potential connections. This involved a comprehensive examination of how each variable evolved throughout the study period, allowing us to identify any notable shifts or patterns that might warrant further investigation.

Next a Pearson's correlation matrix was conducted. This is a statistical tool used to measure the linear relationship between variables in a dataset. It provides a way to quantify how strongly two variables are related and in what direction (positive or negative) that relationship exists. The correlation coefficient, often denoted as "r," ranges from -1 to +1, where -1 indicates a perfect negative correlation, +1 indicates a perfect positive correlation, and 0 indicates no linear correlation. The purpose of constructing a Pearson's correlation matrix is to gain insights into the relationships between variables in a dataset so that linear relationships can be identified, and the most relevant variables can be identified and selected for further analysis.

Lastly, a multiple linear regression model was used. A multiple linear regression model fits multiple variables and determines how “linear”, or in other words, correlated, they are. Multiple linear regression is a statistical technique used to establish a relationship between a dependent variable and two or more independent variables. In this method, the goal is to find the best-fitting linear equation that explains how the dependent variable changes concerning the independent variables. By analyzing the data, the model estimates the coefficients for each independent variable, representing their individual contributions to the dependent variable's variation. The resulting equation can then be used to make predictions or understand the impact of changes in the independent variables on the dependent variable (Wagavkar, 2023). Correlation matrices allow for more variables to be added in and measured at the same time, which can provide a better understanding of the dependent variable and the factors influencing it (wildfires). In this case, we have multiple independent variables (total annual precipitation, ENSO Index Average) that show correlations that are at least somewhat visible with the number of wildfires. By including these variables in a correlation matrix, we can examine their combined effects on the prediction of wildfires.

Results

Trends

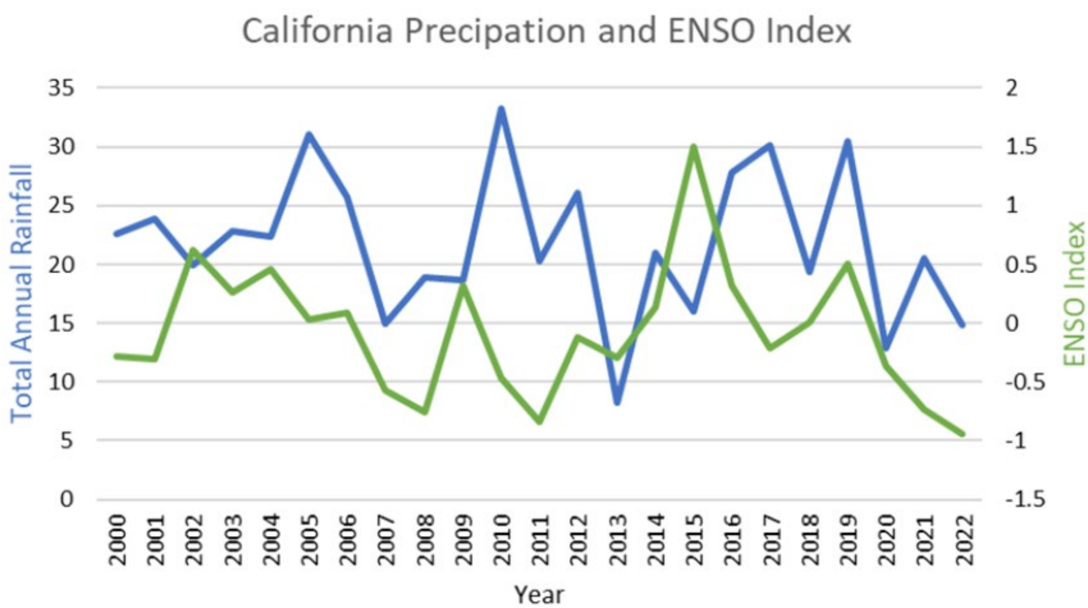

Figure 1.

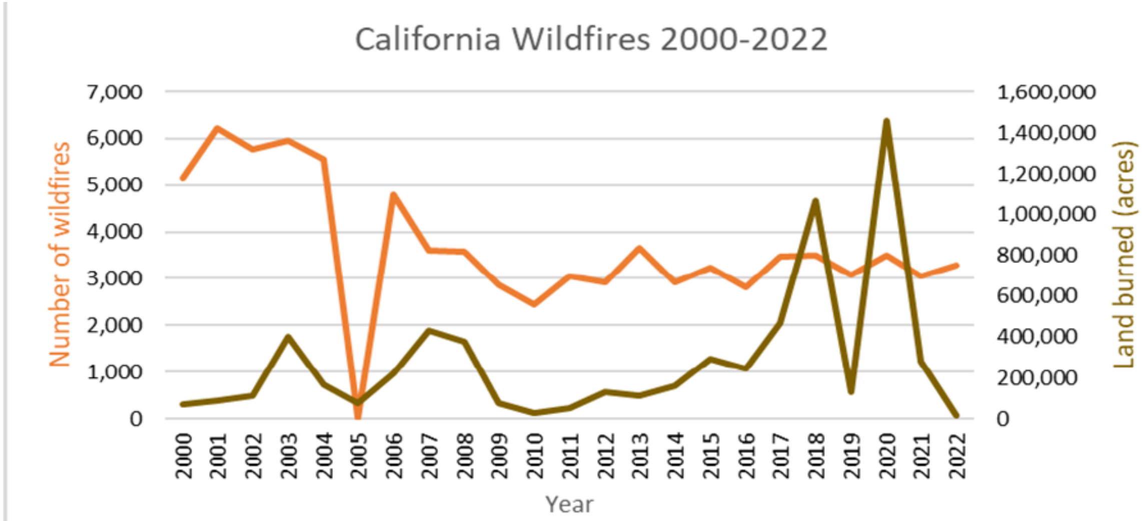

Figure 2.

Correlation Matrix

Measured Correlation between all Variables

	Total annual rainfall	Number of Wildfi-res	Land Burned (Acres)	ENSO Index Ave-rage
Rainfall	1	-0.21	-0.31	0.13
Wildfires	-0.21	1	0.03	0.13
Land Burned	-0.31	0.03	1	-0.04
ENSO Index	0.13	0.13	-0.04	1

The Pearson's correlation matrix was analyzed to determine the relationships between the variables: "Total Annual Rainfall," "Number of Wildfires," "Land Burned (Acres)," and "ENSO Index Average." The correlation coefficients reveal important insights into the associations between these variables.

Firstly, there was a weak negative correlation observed between "Total Annual Rainfall" and the "Number of Wildfires" (-0.21). This suggests that as the total annual rainfall increases, there tends to be a slight decrease in the number of wildfires. While the correlation is weak, rainfall still has some effect on decreasing wildfires, leaving in many other possible factors that decrease the number of wildfires.

Additionally, a slightly stronger negative correlation was found between "Total Annual Rainfall" and "Land Burned (Acres)" (-0.31). This indicates that as the total annual rainfall increases, the total land burnt by wildfires annually tends to drop. This correlation makes logical sense as when rain slightly decreases the number of wildfires, the amount of land burned correlatively goes down.

Furthermore, a weak positive correlation was observed between "Total Annual Rainfall" and the "ENSO Index Average" (0.13). This implies that as the total annual rainfall increases, there tends to be a slight positive association with the ENSO (El Niño-Southern Oscillation) Index Average. The ENSO Index measures the state of the El Niño or La Niña climate patterns, which can influence weather conditions globally. This correlation suggests that higher precipitation levels might be influenced by specific phases of the ENSO cycle, which displays the wetter side of the Pacific Ocean caused by El Nino's weather disturbance.

Regarding the relationship between the "Number of Wildfires" and "Land Burned (Acres)," a very weak positive correlation was found (0.03). Although this correlation is not significant, it suggests a slight tendency for a higher number of wildfires to be associated with a slightly greater extent of land burned. However, the correlation coefficient indicates that this relationship is not particularly strong.

Furthermore, a weak positive correlation was observed between the "Number of Wildfires" and the "ENSO Index

Average" (0.13). This implies that there is a weak positive association between the number of wildfires and the ENSO Index Average. It suggests that some parts of the ENSO cycle may be a factor increasing wildfires in California.

Lastly, a weak negative correlation was found between "Land Burned (Acres)" and the "ENSO Index Average" (-0.04). This indicates that there is a weak negative relationship between the extent of land burned by wildfires and the ENSO Index Average. Although this correlation is not particularly strong, it suggests that certain phases of the ENSO cycle might have a slight influence on the severity and extent of wildfires.

Multiple Linear Regression

The objective of the multiple linear regression analysis was to establish a predictive relationship between the extent of land burned (measured in acres) and a set of five independent variables. The analysis yielded insightful statistical metrics for evaluating the model's performance. The multiple correlation coefficient (Multiple R) indicated a moderate positive association between the predictors and the land burned variable. The coefficient of determination (R Square) revealed that approximately 22.14% of the variability in land burned could be accounted for by the chosen predictors. However, the adjusted R Square, showing a negative value, suggests the potential presence of overfitting or underscores the necessity for additional pertinent variables. The computed standard error underscored the variability between predicted and observed values.

The p-value associated with the F-statistic surpassed the conventional significance level of 0.05, implying that the model's statistical significance in explaining the variance in land burned might be limited. The examination of the individual predictor coefficients unveiled that none of the variables exhibited statistically significant relationships with land burned at the 0.05 significance threshold. This observation was further supported by the p-values corresponding to the t-statistics, which all exceeded 0.05. Consequently, the individual predictors did not yield substantial predictive insights into the extent of land burned.

Discussion

The Pearson's correlation matrix was analyzed to determine the relationships between the variables: "Total Annual Rainfall," "Number of Wildfires," "Land Burned (Acres)," and "ENSO Index Average." The correlation coefficients reveal important insights into the associations between these variables.

There was a weak negative correlation observed between the rainfall" and the number of wildfires, a slightly stronger negative correlation between rainfall and land burned, a weak positive correlation between rainfall and El Nino, a very weak positive correlation between wildfires, and land burned, a weak positive correlation between the number of wildfires and El Nino, and a weak negative correlation was found between land burned and El Nino.

Overall, these correlations provide valuable insights into the relationships between the variables studied. It is important to note that weaker correlations may have been resulted from large differences in numbers due to different ways in which the different variables were measured (i.e. acres of land, inches of rainfall, number of wildfires, etc.). It is also important to note that correlation does not imply causation, and other factors not considered in this analysis could also contribute to the observed patterns. However, these results may very well be the start of a better way to understand different drivers of wildfires in California. Further research and analysis are needed to fully understand the complex interactions between annual precipitation, wildfire occurrence, land burned, and the ENSO climate patterns.

Conclusion

The purpose of this experiment was to measure the correlation between the occurrence of El Nino with the amount of precipitation, number of wildfires, and land burned in each individual year of the 21st century in California so far. Through the correlation matrix and the multiple linear regression, there seems to be little positive correlation between the occurrence of El Nino and the amount of precipitation, wildfires, and land burned in California. This goes against the initial prediction that there would be a significant positive correlation with precipitation. This also goes against the prediction that there would be a negative correlation between El Nino and wildfires. A possible explanation for this could be due to El Nino causing more precipitation in the winter but not as much in the summer. Through the wetter winter season in CA, more vegetation can be grown in the ground that subsequently turns into fuel for fires during the dry summer season. One way this experiment may be improved is by using firsthand data in addition to the secondary data as then there could be a bit more certainty on the findings of this experiment. Future research on this topic could allow for better and more accurate predictions on California's rainy seasons and dry seasons (Stevenson and Xingying, 2020).

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References

Huang, Xingying, and Samantha Stevenson. 'Contributions of Climate Change and ENSO Variability to Future Precipitation Extremes over California'. *Geophysical Research Letters*, vol. 50, no. 12, American Geophysical Union (AGU), June 2023, https://doi.org10.1029/2023gl103322.

Wagavkar, Sanskar. 'Introduction to the Correlation Matrix'. *Built In*, 17 Mar. 2023, https://builtin.com/datascience/correlation-matrix.

Center for Climate Science. *The Future of Extreme Precipitation in California*. Jan. 2017, https://www.ioes.ucla.edu/project/future-extreme-precipitation-california/.

'Less Predictable Precipitation'. *UCI News*, 16 Jan. 2018, https://news.uci.edu/2018/01/16/less-predictableprecipitation/.
The Science behind California's Extremely Wet Winter, in Maps. *The Washington Post*, WP Company, 10 Apr. 2023, www.washingtonpost.com/weather/2023/04/07/california-extreme-winter-storms-snow-climate/.

US Department of Commerce, and National Oceanic. *What Are El Nino and La Nina?* Mar. 2009, https://oceanservice.noaa.gov/facts/ninonina.html.

What Is 'El Niño' and What Are Its Effects? https://www.usgs.gov/faqs/what-el-nino-and-what-are-its-effects. Accessed 3 Sep. 2023.

What's behind California's Surge of Large Fires? NASA Earth Observatory, Oct. 2021, https://earthobservatory.nasa.gov/images/148908/whats-behind-californias-surge-of-large-fires.