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Rainforests In Hot Water:

Warming Oceans and Their Effect on Wildfires in the Temperate Rainforests of the Pacific Northwest.

Abstract

In an era of increasingly large and destructive wildfire seasons, it is important to understand how fire seasons have changed over time, which environmental factors have influenced these changes, and how these changes have affected specific biomes. This project examines how climate change has affected wildfires which occur in the dense and verdant temperate rainforest regions of the U.S. Pacific Northwest. It examines the size of burned areas of rainforest over time and assesses the correlation of burned area size to environmental factors such as average air temperature, ocean temperature, and number of days of precipitation per year. In this way I will seek to examine the central question of how climate change has affected the size and severity of wildfires which occur in these sensitive ecosystems. Large wildfires in the Pacific Northwest are often tied to extended periods of warmer and drier than average conditions. Periods of drought are likely to become more common in a warming world, which will likely result in larger and more severe wildfires, compared to the twentieth century. (1) Additionally, warmer sea surface temperature anomalies such as La Nina have proven to be predictive of severe wildfires in the western U.S. in general, and warmer sea surface temperatures in the North Pacific have a correlation to larger wildfires in the pacific northwest specifically (5). This project seeks to determine the effect of these large-scale climactic phenomenon on the temperate rainforest biome, and the incidence of wildfire within this environment. The results of this project will demonstrate the overall scale of wildfire within temperate rainforests over time and its correlation to air and sea surface temperatures. An understanding of how environmental factors influence wildfires in any given environment is critical for both researchers seeking to document natural processes, and land managers seeking to better forecast significant wildfire events in their regions.

Research Background

Increasingly hot, dry summers and warmer ocean temperatures are leading to an increasingly long, increasingly hazardous wildfire seasons in the American Pacific Northwest (1). This has led to an increasing level of direct threat by fire to rural and suburban communities directly adjacent to forested lands as well as indirect threats to urban centers caused by dense

wildfire smoke and airborne particulates. The Pacific Northwest is naturally a cool, wet climate, with dense forests of old growth trees and high annual rainfall. Because of this, wildfires in Western Oregon and Washington have typically been smaller than those observed in the warmer, drier climate of southern and central California (10). Although wildfires are a natural part of forest ecosystems throughout the Pacific Northwest, large uncontrolled wildfires, crown fires, and other destructive fire events have typically occurred under generally atypical circumstances such as drought and high wind (10). The resulting fires, although still large and high intensity, have been more limited in total area burned and shorter in duration than those that now occur regularly in California. Despite the relative difference in the scale and frequency of wildfires in this region, scientists, resource managers, and emergency responders alike have grown increasingly concerned that a warming climate, drier summers, warmer ocean temperatures, and the spread of insect parasites that leave areas of forest as little more than dry tinder are beginning to erode the advantages of the naturally less fire prone forests of the Pacific Northwest (1,5,8). Large wildfires in Washington State, Oregon, Idaho, and Montana have gained increasing attention in recent years, drawing in ever more of the precious and thinly spread firefighting infrastructure of the American West. (1,6) According to current climate projections based on historical data compiled through the late twentieth century to today, increasingly common drought conditions in the Western U.S. will have a drying affect on fuels within forested areas. This in turn will lead to increasingly long and hazardous wildfire seasons, with new fires igniting more easily among the highly flammable dry fuels available in high density forested areas (1,9). Additionally, the decline of arctic sea ice and rising ocean temperatures in the north pacific are diminishing the periods of cool, wet weather which makes the rainforests of the Pacific Northwest more resilient to large wildfires than other areas of the West Coast. (4)

Roadmap

This project will track the changes in rainforest areas of the Pacific Northwest over time and will assess the size, scope and frequency of large uncontrolled burns, crown fires, and other destructive fire events. This information will be compared to average temperature and rainfall in these areas during the same period to determine the effect of local weather conditions on wildfire proliferation, and the degree to which climate conditions such as the number of rainy days per year and average temperature affect the pattern of wildfires in these areas. The project will also assess the causes of fire events, whether caused by human activity or by natural causes such as lightning strikes to determine the degree to which severe fire events are directly caused by human activity or generated by naturally occurring phenomenon. I will lean on publicly available data from federal and state land management organizations including the Bureau of Land Management, the U.S. Forest Service, U.S. Geological Survey, and the Northwest Fire Consortium for information on wildfire events over time in the Pacific Northwest. I will also utilize information from the NOAA's National Centers for Environmental information to assess the oceanic and atmospheric temperatures in the U.S. Pacific Northwest region during the years which those fire events occurred.

Hypothesis and Problem Statement.

The primary hypothesis of this research is that increasing ocean temperatures, increasing average ambient temperatures, and decreasing numbers of rainy days per year in the Pacific Northwest have a direct quantitative correlation with the total acreage of wild land that is burned each year during wildfires. The secondary hypothesis of this project is that the aforementioned factors are also correlated with an increase in the total number of high intensity and uncontrolled fire events such as crown fires that occur each year in high density old growth forests. The ignition source of wildfires, natural vs those caused by human activity, will be examined as an independent variable in this context to determine the association between the causes of wildfire and their effects with regard to the total acreage burned and the number of high intensity fire events that occur during the course of each wildfire season.

Study Region.

The Study region for this project will consist of the areas of Pacific temperate rainforest within Washington State, Oregon, and northern California. The Pacific Northwest's temperate rainforests are a unique and incredibly dense forest environment which stretches along the Pacific Coast of North America from northern California to southern Alaska. The rainforests within this region are incredibly verdant, with old growth hardwood trees, firs, lichens, mosses, and ferns dominating nearly every surface capable of supporting plant life. The temperate forests of this region even surpass their tropical counterparts in their overall density, which constitutes the largest contiguous biomass in the world (24). Temperate rainforests in the Pacific Northwest are characterized by their high annual rainfall (from 140 to 167 inches annually) and their moderate temperatures, which rarely exceed 80 degrees Fahrenheit even in summer. The forest floor contains not only a huge number of low ferns, mosses, and other undergrowth species, but large decaying "nurse logs", the fallen trunks of old growth trees, which can also serve as nurseries for further plant growth on the crowded forest floor (13). The moist climate of these rainforests creates an incredible density of plant life and fallen trees, which under normal weather conditions create a thriving ecosystem. Under drought conditions however, there is a danger that this density of uncharacteristically dry plant material can serve as fuel for intense wildfires. In this project, I will examine the temperate rainforest areas within the contiguous United States, this focus will allow me to compare data which has been compiled and shared by agencies cooperating under the auspices of the U.S. Federal Government, and the State Governments of the Pacific Northwest.
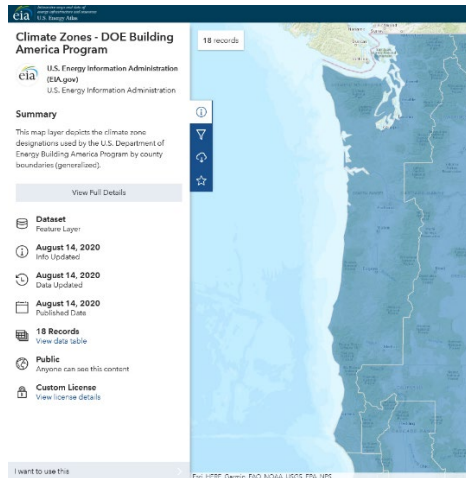
U.S. DOE Pacific marine Climate Zone (15)
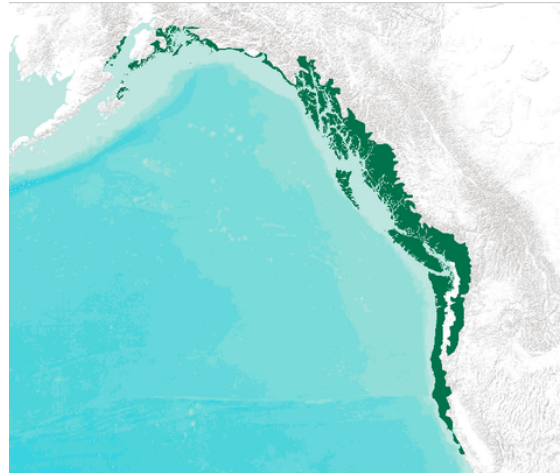
Total extent of the Pacific temperate rainforest biome (16)

Courtesy of U.S. National Park Service, Olympic National Park (13)

Data and Methods

For this project I will analyze data collected by U.S. Federal Government agencies involved in public land management, wildland firefighting, environmental conservation, and climate and weather monitoring. My land-based data will consist of 30m land cover raster data from the U.S. Geological Survey's National Land Cover Database (20) and 30m resolution Landsat raster data from the USGS National Burned Area Dataset (19). This will allow me to compare land cover with burned area data from year to year using raster units of the same size, allowing for a more accurate assessment of the impact of wildfire across different types of forest and land cover types. My sea surface data will be drawn from the USGS North Pacific Nearshore Sea Surface Temperature dataset (21). This raster dataset has a resolution of 4km, with monthly mean and median temperatures included. This data will be useful in comparing sea surface temperatures prior to and during fire season in the Pacific northwest in order to assess any correlation between near-shore ocean temperatures and wildfire size in pacific coastal rainforest areas. To complete my land-based data, I will utilize a 1-meter Digital Elevation Model map derived from the USGS National Map. This will allow me to more accurately assess how topography effects of the maritime climate of the Pacific Northwest on fire weather on the coast

is affected by mountain ranges and other topographical features (26). To that effect, I will also add the NOAA Climate Data Record of Cloud and Clear-Sky Radiation Properties (27) and Wind Speed Direction information derived from the NOAA Data Catalog in order to better assess the maritime climate for each year. I will also utilize comparative climatic data from the National Oceanic and Atmospheric Administration's National Centers for Environmental Information in order to determine both the mean number of days with temperatures in excess of 90 degrees Fahrenheit and mean number of days with 0.01 inches of precipitation or more. (17) This will provide a fuller picture of the overall climate shaping the wildfire environment for each fire season.

Once I have compiled the data on total acreage of rainforest lost, ocean temperatures, air temperatures and weather, I will clip the land data to include only the relevant study area and utilize the land cover dataset to focus on rainforest areas specifically. I will take an average of air and ocean temperatures in the study area for each year, as well as an average of days above 90 degrees Fahrenheit, days with precipitation above 0.01 inches, and days with clear skies and low marine layer cover. With these averages I will create boxplots to assess for normal distributions, and to gauge the approximate ranges for each variable. I will also test each variable using a Thiel Sen estimator to determine linear regression. I will then perform Mann Kendall Tests of each variable to assess how each variable has changed over time, i.e. Whether the oceans have consistently warmed, and whether wildfires have consistently expanded in size, etc. I will also run a Pearson Correlation Coefficient test to determine any correlation between these factors within the specified study period.

I will store all data and related products for this project in a geodatabase, which will be backed up in a repository on GitHub. Files in the online repository will continuously be updated as changes are made, with version controls instituted and previous version maintained in the event of data loss or file corruption.

Project Schedule

The Following is the summer work schedule for the Capstone project, broken down by week and month. Phases red through yellow will consist of all necessary review and preparation prior to initiating work on the main body of the project. Phases green through violet will include all data processing in ARCGIS, as well as review of the map products created during these phases. Phases brown through black will consist of compilation of results into a formal report, as well as any final edits to the report as needed prior to submission.

Schedule Part 1: Preparation and Production.

Capstone Project Schedule Summer 2022	May			June				
	15 - 21	22-28	29-31	1 - 4	5 - 11	12- 18	19 - 25	26 - 30
Research Review	▮	▮						
Format Backup Data Repositories			▮					
Data Compilation and Preparation				▮	▮	▮		
Project Outline					▮	▮	▮	
Preliminary Data Processing						▮	▮	▮
Map Product Creation								▮
Map product review								
Compile results and Create Summary								
Final Paper								
Final Paper Review and Submission								

Schedule Part 2: Synthesis, Review, and Submission.

July					August		
1 - 2	3 - 9	10 - 16	17 - 23	24 - 31	1-6	7 - 13	14-19
▮	▮						
	▮	▮					
		▮	▮				
			▮	▮	▮		
				▮	▮		

Project Deliverables.

The end result of this project will be a series of raster datasets depicting the average temperature ranges on land and at sea from 1982 to present, and a series of vector datasets depicting the size of burned areas for each of those years. These datasets will depict how average air and ocean temperatures have fluctuated the years, and how the total area of temperate rainforest affected by wildfire has changed over time as well. Metadata for the files will be enclosed as a .txt file in the data folder within GitHub for the land temperature, ocean temperature, and burned area datasets. A summary of the analysis of the data and the correlation of average air and ocean temperatures, with the size of burned areas in temperate rainforest will be included in a written report which will accompany the data files in the main GitHub folder. This report will also compare the data outputs of the GIS process with NOAA data on the number of rainy days and overall precipitation for each of those years in order to determine how this correlates with the temperature and burned area data.

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