Examining Environmental and Structural Impact of Extreme Events on Land Cover

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Abstract

Extreme earth events are a large global issue, with over 100 extreme events striking the United States annually (Boustan et al., 2020). In this research, our objective was to assess the impact of extreme events on land cover. Our research question was: how have various extreme events environmentally and structurally impacted land cover in areas across the United States? We used NASA Worldview, Python image analysis and Excel to assess the healing of a patch of land burnt in California's Camp Fire (2018), and manual analysis of GLOBE Observer Land Cover data to check for structural damages in Northern New Jersey from Tropical Storm Elsa (2021). Over the course of 26 weeks after the Camp Fire, the patch of land partially regained its greenness. No structural damages in the surveyed areas of New Jersey were found. We concluded it takes over 6 months for a burnt area's greenness to be restored after a severe wildfire and that New Jersey's land cover was not impacted by Tropical Storm Elsa. These results demonstrate the environmental damage that wildfires can cause and the potential of greenness and citizen science as methods for analyzing land cover.

Key words: extreme events, wildfire, land cover, environmental science, tropical storm

Research Question

As the environment is changing every day, both due to global heating and other causes, and the frequency of extreme events is increasing, it is of utmost importance to monitor how extreme events of various types and severity levels are contributing to these changes. Thus, our research question is: how have various extreme events environmentally and structurally impacted land cover in areas across the United States? Our hypothesis is that the land affected by the Camp Fire will be damaged significantly, but will recover partially by the end of the investigated period, and that Tropical Storm Elsa caused no changes in land cover in the investigated areas of New Jersey.

Introduction

The Intergovernmental Panel on Climate Change defines extreme events as "the occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends of the range of observed values of the variable" (Seneviratne et al., 2012). These events may be defined as occurring in the highest or lowest of any percent of the range of values (Peterson et al., 2012). The "extreme" nature of an event is relative to events within a specified time period and at a certain location and climate. This definition of extreme events thus includes extreme wildfires and tropical storms.

Extreme events result in significant environmental, structural, and human costs. On average, extreme events kill 60,000 people and cost 45.7 billion dollars annually (Ritchie and Roser, 2014, Smith, 2021). The resulting reductions in firm productivity and wages also contribute to the decay of poor communities by encouraging wealthier families to leave affected areas (Boustan et al., 2017). Extreme events also endanger public health. Long-term effects like air pollution caused by the Amazon wildfires damage DNA and cause cell death (de Oliveira Alves et al., 2017).

Climate change has increased the frequency and intensity of extreme events. The number of climate-related extreme events has tripled, and storms have become increasingly destructive over the last thirty years (Oxfam International, 2020). Higher global temperatures have also increased the number of wildfires and their severity (Stocks et al., 1998). A method for measuring the impact of an extreme event is thus in need to ensure effective prevention and reconstruction policies.

Studies on the scope and intensity of extreme events have utilized remote sensing. Landsat data has helped to map burn severity (French et al., 1996). Open-access data have facilitated the development of algorithms to monitor changes in land cover (Wulder et al., 2018). For example, Zare et al. (2013) employed an artificial neural network to give the normalized difference vegetation index (NDVI), a measure of vegetation health related to greenness. Models predicting the impact of future storms have also been developed. Hoque et al. (2017) found that post-classification change detection was effective in determining the impact of tropical cyclones and the necessary recovery measures. Negrón-Juárez et al. (2008) used climate data to document land cover changes due to Hurricane Rita.

This investigation aims to determine the immediate and long-term environmental impacts of wildfires and storms through greenness and the GLOBE Observer citizen science app. We sought to test the usefulness of these methods. The metric of greenness was developed to assess land cover changes due to wildfires. The 2018 Camp Fire was selected for burning 62,052 hectares (Syifa et al., 2020). Tropical Storm Elsa's impact on New Jersey in 2021 was studied using data gathered by Sherbatov via the GLOBE Observer app. The use of citizen science data makes this study's methods applicable to other extreme events. Impact assessments are especially relevant to coastal areas as more people move to these high-risk regions (Pielke et al, 2008).

Research Methods

Planning Investigations

The Camp Fire occurred near Paradise, California in the Sierra Nevada foothills, which has a Mediterranean climate characterized by cool, wet winters and hot, dry summer. Elevation varied from 200 to 5100 feet. We planned to use code to find the greenness values of images from NASA Worldview. Greenness would serve as a measurement of the health of vegetation. We planned to analyze a baseline pre-fire image, one immediate post-fire image, and 26 weekly post-fire images. Weekly pictures would allow us to choose pictures least obscured by cloud cover.

Tropical Storm Elsa hit New Jersey on July 9 and 10. On average, Bergen County gets 10 more inches of rain per year than the rest of the United States. Bergen County has a continental climate, with cold winters and warm, humid summers. The investigated area, which contains points in the towns of Paramus and Fair Lawn, has a relatively level elevation with no mountains or large hills. We planned to take two pictures, one before the storm and one after, at three locations through the GLOBE Observer app. The time of day did not matter. The only requirement was sufficient lighting to clearly see all structures and trees.

Carrying Out Investigations

We carried out our plans. CV2 in Python was used to analyze the RGB content and produce the greenness value of satellite images of the Camp Fire from NASA Worldview. We analyzed a baseline pre-fire image, one immediate post-fire image, and 26 weekly post-fire images. We took before and after pictures at three locations in Bergen County, New Jersey through the GLOBE Observer app.

Caption: study site of Paradise, California and Bergen County, New Jersey on Google My Maps

GLOBE Badges

Be a Data Scientist

This report involved deep analysis of the greenness values produced from the images of the Camp Fire and the land cover observations made by Sherbatov through the GLOBE Observer app. We graphed the greenness values over time in Figure 1 and produced moving average and polynomial trend lines. We assessed outliers among greenness values. We also compared our data and results to other studies on wildfires and storms. We ultimately answered our research question and found that the Camp Fire did significant damage while Tropical Storm Elsa did not heavily affect New Jersey. We tested greenness and citizen science data as viable methods for analyzing the impact of extreme events. The use of data from NASA Worldview, a remote sensing database, further developed our skills as data scientists.

Make an Impact

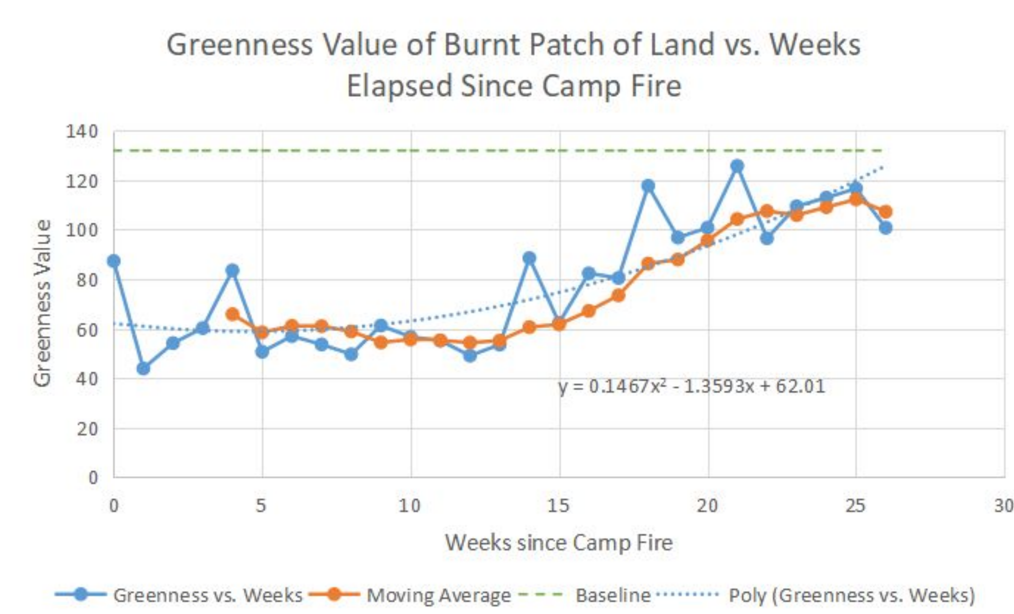
This investigation analyzed the effects of local extreme events. By examining the impact of Tropical Storm Elsa on New Jersey and the Camp Fire on California, two locations in which members of the team live in, we proposed greenness and citizen science observations as methods for better understanding the extent of damage and the expected recovery time. We recommended these methods for determining the reconstruction and conservation policies needed to minimize structural and human costs due to extreme events around the globe.

Results

For the Camp Fire, we plotted greenness vs weeks starting at week 0. The blue continuous trend line on the graph represents the greenness over time while the green dotted line on top is the baseline greenness. We found that damage was substantial as shown by the 34% drop in greenness from the baseline greenness to the week 0 greenness. Greenness increased, but all greenness values after the fire were lower than the baseline greenness value. This result suggests that the land did recover from the fire, but recovery was incomplete. Finally, there were no outliers among greenness values after the fire.

We found that of the 12 different photos facing a cardinal direction at one of the three locations, two thirds showed no changes while one third was inconclusive. You can see the before and after photos at one location.

Figure #1



Greenness value of burnt patch of land over the course of 26 weeks after the Camp Fire

Figure #2

Coordinates of Observation	North Picture	East Picture	South Picture	West Picture
40.941093°, -74.109019°	 	 	 	 

Before (top) and after (bottom) pictures at one location

Discussion

Our hypothesis was correct. We found that wildfire recovery takes longer than 26 weeks, and Tropical Storm Elsa had little impact. Regarding errors, our choice of weekly images may have introduced bias, and the single baseline measurement may not be accurate. For GLOBE Observer, some of the before photos did not show the same land cover features as the after photos. Other studies made burn severity maps using the normalized difference water index or NDWI. This metric measures moisture and is more accurate, but our method is still applicable to other natural disasters because it uses open access satellite imagery. While others have used satellite data to analyze changes in land cover due to natural disasters, fewer have relied on citizen science to understand the effects of storms.

Conclusions

We ultimately found that greenness and ground-level pictures can provide information on the severity of damage caused by extreme events and the time for recovery. We could replicate our investigation on wildfires and extend it past 26 weeks to see if or when complete recovery is reached. We could also take more pictures before and after storms in order to more thoroughly document their impact. Future studies can use our methods to assess the impact of other extreme events. The use of machine learning may also allow us to better analyze changes in land cover. Finally, impact assessment shows the importance of research on land cover and allows for more comprehensive measures to prepare for extreme events.

Bibliography

This investigation used many sources. They are all listed at this link:
https://rentry.co/ptvoq

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