Evacuation Planning For California Forest Fires

A disaster management planner using ESRI's ArcGIS Pro Application

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ABSTRACT

California faces annual wildfires that threaten lives and properties. During these emergencies, efficient evacuation routes are critical for saving the lives of humans and animals. This project aims to understand the counties highly affected by this and to optimize emergency routes for wildfire evacuation in California.

This paper aims to use historical data present on forest fires in california to target a few areas of high-risk and build evacuation plans using hardcoded points. The evacuation centers are assumed to be hospital & health care centers since no data was found explicitly on evacuation centers. There is scope to improve this project by talking to authorities and setting a system in place for evacuation centers and travel modes, but for now the paper draws a minimalistic picture of optimized and safe evacuation using ESRI's ArcGIS Pro software, specifically the network analysis section.

KEYWORDS

Geographical Information System, ArcGIS Pro, Network Analysis, Forest Fires

1 Problem Statement

California has been seeing an increase in forest fires over the past decade. Forest fires occur due to 3 major conditions: a Mediterranean climate prone to drought, strong winds and a landscape having rich vegetation. Nowadays, there are mechanisms put in place by many areas prone to such an issue. These involve using drones, satellite imagery [7] to understand the start of fires and to monitor its spread. Although there is data present on the areas that suffer through this problem, there is no method to use this data for finding easy ways to navigate through an affected area to reach a safe location.

Literature Review

Several papers provide insights into California wildfires and evacuation planning. Keeley and Syphard's (2021)[1] work offers a comprehensive overview of the 2020 fires, contextualizing them within historical trends.Wong, Broader, and Shaheen (2020) [2] focus specifically on reviewing California wildfire evacuations from 2017 to 2019. Their report sheds light on past evacuation strategies. However, it does not delve deeply into area-specific evacuation plans or the utilization of road systems for evacuation optimization.

Using GIS technology, Li, Cova, and Dennison (2019) introduced a new way to decide when to evacuate areas threatened by wildfires. They combined fire and traffic models in a "spatial and time-based" GIS system. This new approach suggests a better evacuation plan that considers specific locations and changing conditions. It has the potential to make evacuations more effective and safer.

Similarly, Parajuli et al. (2023) [4] contribute to evacuation planning in Nepal. Their research focuses on developing evacuation routes in flood-prone areas using GIS analysis. While their study pertains to a different hazard, it highlights the effectiveness of GIS-based approaches in creating efficient evacuation plans tailored to specific geographic conditions.

While these papers contribute valuable insights, there remains a gap in the literature regarding evacuation plans tailored to specific areas and leveraging road systems for optimized evacuation routes. This project aims to address this gap by utilizing GIS tools to develop area-specific evacuation plans that consider road networks and geographical features for efficient and effective evacuation strategies in California.

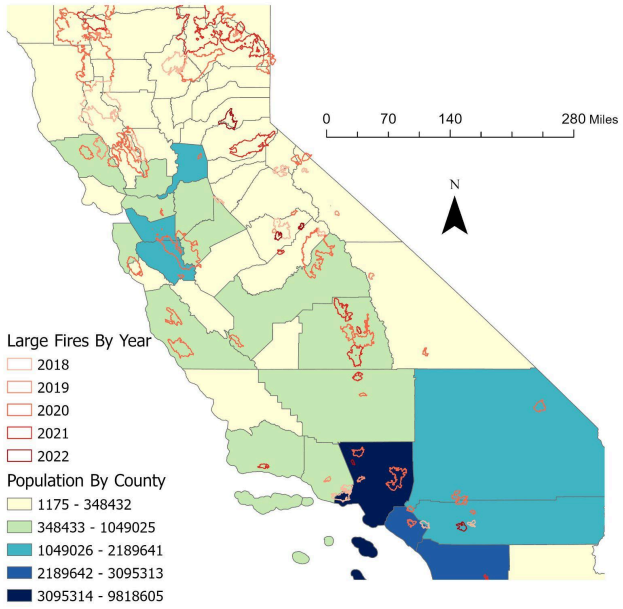

Figure 1: Map of Population of Counties in California and Large Fire Boundaries in Recent Year

2 Objective

The paper's main objective is to identify areas in California that are significantly affected by forest fires, using factors such as the frequency of disasters and population density and to find closest evacuation spots for the users. The study aims to conduct a network analysis to determine safe zones for evacuation. To achieve this goal, the research will:

1. Utilize data on population density in counties and historical forest fire occurrences to pinpoint high-impact zones in California.

2. Select a few of these high-impact zones for detailed evaluation, to understand the resources and the proximity.

3. Employ network analysis techniques to identify the nearest evacuation centers from areas close to the impacted zones.

4. Investigate how travel routes may change when affected areas are considered as obstacles in the evacuation planning process.

3 Methodology

Following are the steps taken in ArcGIS to understand the data, conduct experiments and draw conclusions.

A. Narrowing down high-risk areas:

After importing the datasets, I visualized the overlapping layers of population density across counties and the forest fire zones (see Figure 1). This provided insight into the areas where fire zones overlap multiple counties. Using the spatial analysis tool Spatial Join (with Overlap as the method), I calculated the number of forest fires each county experienced, indicating the frequency of fires in each county.
I identified two counties for further analysis:

- One which has the highest frequency of fires. This was determined by using the join data. This turned out to be *Siskiyou County*.
- The other one was the highly populated county: *Los Angeles*.

B. Apply Network Analysis on the counties

To simulate a user navigating to an evacuation center (in this case, the closest hospital), I used the *network analysis tool* (*Closest paths* configuration) to create a path from the incident (a hardcoded user's position) to the nearest facility (a hospital). I conducted tests with and without a barrier, specifically using the fire perimeters as the barrier, to observe any route modifications.

C. Analyzing outcome for LA county

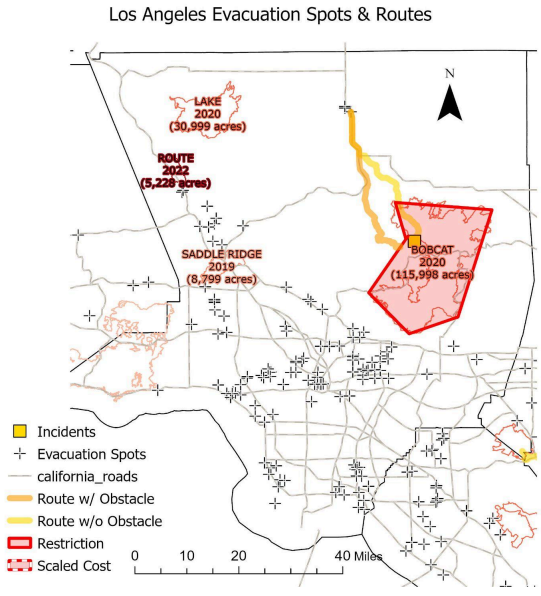

Figure 1: Closest Routes to Evacuation Centers in LA County using Hardcoded Incident

By creating a simulated data point representing a person near the border of the Bobcat fire boundary (see Figure 2), we can observe that the closest evacuation center is the AV Kidney Institute. As depicted, there are two distinct paths shown. These paths serve as a visual aid for individuals to consider alternative routes if the default path is deemed too hazardous due to its location within the fire boundary.

The two paths were generated using two network analysis tools, both utilizing the same input data points. However, the second path (shown in orange) was generated with an additional polygon obstacle feature. This feature simulates an area affected by the fire boundary, resulting in an altered path compared to the first one (orange path generator). This comparison allows users to assess different routes based on potential hazards posed by the fire boundary.

D. Analysis of Siskiyou County

This region is tricker due to the scarcity of evacuation centers and broader roads hence reducing accessibility.

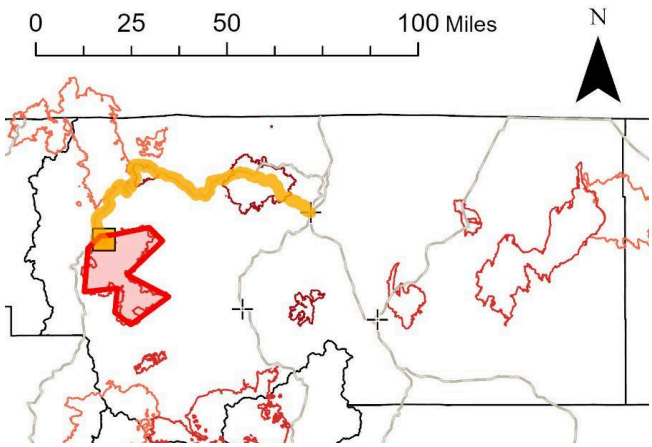

Figure 3: The image shows the resource scarcity in the Siskiyou region

From observation, I notice a higher concentration of forest fire impacted areas and fewer roads available for evacuation. Recognizing that not all forest fire areas are impacted simultaneously, we have developed a route accordingly. By incorporating the forecasting of wind directions, the application can be used to establish temporary evacuation hubs.

This concludes the steps taken for the analysis of this use case.

4 Datasets

The datasets were carefully selected with specific objectives in mind. Firstly, the evacuation center information was sourced from the hospital dataset within Humanitarian Data Exchange site [5]. This data is crucial for identifying safe locations for residents to seek shelter during emergencies, such as wildfires.There was explicit data for evacuation centers, hence this idea was taken from the [4].

Additionally, road data was collected from the same source as above, although it was not directly used by ArcGIS for network analysis. However, having this data on hand is essential for understanding the transportation infrastructure available for evacuations and for evaluating potential routes to these evacuation centers.

The feature for extracting data from ArcGIS online was also utilized to gather information on forest fire areas impacted in recent years [6]. This dataset specifically focuses on "large" forest fires exceeding 5000 acres. The aim here is to identify areas that have been significantly affected by wildfires in the past, aiding in the proactive planning and allocation of resources for future evacuations.

Lastly, the population distribution data across California counties, obtained from the census tract website, is vital for understanding the demographic density in various areas. This information is critical for effective evacuation planning, as it helps in prioritizing areas with higher population densities for timely and efficient evacuation procedures.

5 Result

Through spatial and network analysis in the ArcGIS Pro application, I gained insights into California's current resources, with a particular focus on two key areas. This provided a clear picture of the existing data points and highlighted the necessary steps for developing a comprehensive application that residents in forest fire-prone areas can use for safe navigation.

6 Conclusion & Future Work

This project serves as the foundation for developing a dynamic application where authorities can input crucial data such as the fire inception point, wind speed, and updated evacuation center locations. This application aims to be a robust tool for affected individuals to find routes leading to the nearest safe locations.

To enhance its functionality, the application can be integrated with drones and IoT devices in forested areas to provide real-time updates on fire spread. This data can then be utilized to predict further spread and identify areas to avoid. Residents, equipped with GPS technology, can use this real-time information to navigate around highly smoky areas and potentially dangerous zones.

Local authorities will also benefit from this tool, as it can aid in evaluating the resources available in the area, such as evacuation hubs and roads capable of handling increased population flow during evacuations. This comprehensive approach ensures better preparedness and safety measures for residents and officials alike.

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