Climate Change and Flooding in Miami

Analysis of floods and risk mitigation

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ABSTRACT

The goal of this study is to conduct a thorough analysis of several factors that are contributing to Miami's rising risks for flooding. Specific variables that will be examined include heat severity, surface heat, and the city's expanding population. Using ArcGIS Pro's advanced spatial analysis features, I explore the complex interactions between manmade and natural factors that increase the area's susceptibility to flooding. In addition, this study analyzes the current flood mitigation facilities which include communication towers, emergency medical facilities, and evacuation routes. I observe possible holes in the existing disaster mitigation strategies using a geospatial perspective. The research, which makes use of the powerful ArcGIS Pro, not only clarifies the fundamental reasons behind Miami's floods but also provides suggestions to improve the city's preparedness for disaster response and recovery. To effectively handle the many issues brought on by urbanization and climate change, this project emphasizes the value of combining GIS technology with urban planning and disaster management techniques.

KEYWORDS

GIS, ArcGIS Pro, Disaster Management, Miami

1. INTRODUCTION

Miami-Dade County is an excellent example of the complicated relationship that exists between the environment and urban development, as it is situated in an area of natural beauty and climate challenges. Miami-Dade County, which has a special geographic configuration that makes it more susceptible to floods, is the focus of this project. Surrounded by large bodies of water, including Biscayne Bay, the Atlantic Ocean, and a system of rivers, lakes, and canals, the region is always vulnerable to excessive rainfall and storm surges that damage both its people and property [9].

According to recent studies, flooding is occurring more frequently in Miami Beach, mostly due to the sea level rising faster than it used to. Florida's water level has been rising around one inch every three years over the past 10 years. It took around 31 years for the water level to increase by 6 inches in Miami. Because of this, draining water in a nearly flat city that is very close to sea level is quite difficult. Without a slope, gravity doesn't do much to assist the water draining away very quickly. Miami has significant challenges as it attempts to manage increasingly regular floods.

The focus shifts towards the importance of surface heat and heat intensity in influencing local climate conditions, which in turn influences precipitation patterns and increases the risk of flooding. Surface heat causes the Urban Heat Island (UHI) effect, which raises temperatures in metropolitan regions relative to rural ones.

Not only does this phenomenon increase the intensity of the heat, but it also amplifies stormwater runoff because warmer air can retain more moisture, which in turn causes heavier precipitation events. This effect is made worse by Miami's urban expansion, which is evident by dense buildings and less greenery, making the city more vulnerable to floods during severe weather.

2. OBJECTIVES

1. Study of Heat-Flood Relationships: This involves a thorough examination of the relationship between fluctuations in surface temperatures and heat intensity and flood occurrences, which may provide insight into the effects of climate change on these phenomena. To clarify the direct and indirect consequences of higher temperatures on flood frequency and severity, the project will use certain data.
2. Heat Severity and Flood Incidents: To look at how heat severity is distributed geographically in Miami and how it relates to the locations and frequency of flood incidents. We will be able to pinpoint locations where elevated temperatures might aggravate the likelihood of floods due to our study. The study maps these associations to shed light on the ways that localized temperature rises and urban heat islands affect floods and help identify susceptible locations.
3. Impact of Population on Flood Risks: To find out if having more people living in an area makes it more likely to flood. To do this, we need to look at how growing numbers of people and where they live can lead to more or worse floods. This involves checking how crowded places are and comparing that information with how often and how badly

floods happen. By doing this, we can help those who plan cities and those who prepare for disasters to make better decisions, potentially leading to safer communities.

4. Identification and Evaluation of Flood Mitigation Measures: To find and judge at least one good solution to reduce flood damage when floods happen. We'll look closely at current methods like emergency alerts and evacuation plans to see how well they work and if they're practical. The aim is to suggest doable and lasting ways to make Miami better prepared for floods.

This project will gather and analyze data from a variety of sources to achieve the above-mentioned objectives. ArcGIS Pro's powerful tools will be used for mapping and analysis to turn this varied information into clear, easy-to-understand maps and visuals. These results will help to better understand how heat, flooding, and human activities are connected. They will also be helpful to those involved in disaster response, municipal development, and climate change initiatives, giving them the knowledge necessary to make wise choices.

3. LITERATURE SURVEY AND DATASETS

Florida is at risk of sea level rise because it has a long coastline, low elevation, and lacks good drainage [8]. By looking at data from two sources—the FEMA 1996 Flooding Index used for insurance rates in Miami-Dade County and US Census Tract data [9]— we can see how different factors like demographics relate to flood risk in different flood zones.

I've utilized Miami-Dade County's open data hub to better understand and retrieve data related to flooding frequency [1] to visualize the most susceptible regions around the coastal borders and populated urban areas. The demographics data [2],[3], and other heat severity-related data have been retrieved from notable ArcGIS Services directories. [5] has been a great resource for organizing and contemplating how different heat factors provoke sudden climate change eventually leading to flooding. The [4] ArcGIS hub throws light onto some emergency health and communication centers to assist the public in better preparedness in the event of a flood or natural disaster. The [6] resource assists in understanding primary evacuation routes from Statewide Regional Evacuation Studies.

4. METHODOLOGY

Data Collection: Initially, the project involved collecting all the datasets referenced in the Datasets section. The aim was to gather a broad spectrum of data that could provide insights into the various factors influencing flood risk and response capabilities in Miami.

Base Map Addition: It was essential to load a geographic framework using a detailed base map of Miami. The physical and urban geography of Miami was carefully represented in this base map, which is an essential point of reference for all future studies. It offered a spatial context that made it possible to correctly overlay the gathered data and made it easier to evaluate the factors influencing flood risk geographically.

Identification of High-Risk Flood Zones: Through the integration of data on flood occurrences with the base map, we have produced a detailed representation that highlights the area most vulnerable to floods. This phase was essential for identifying areas that needed to be addressed right away and for developing mitigation plans. Figure 1 provides a clear picture of the frequency of flooding in various Miami areas, laying its foundation for specific decisions.

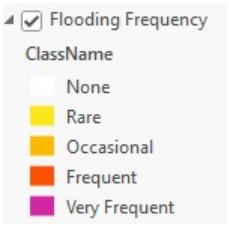

Figure 1: Legend - Flooding Frequency

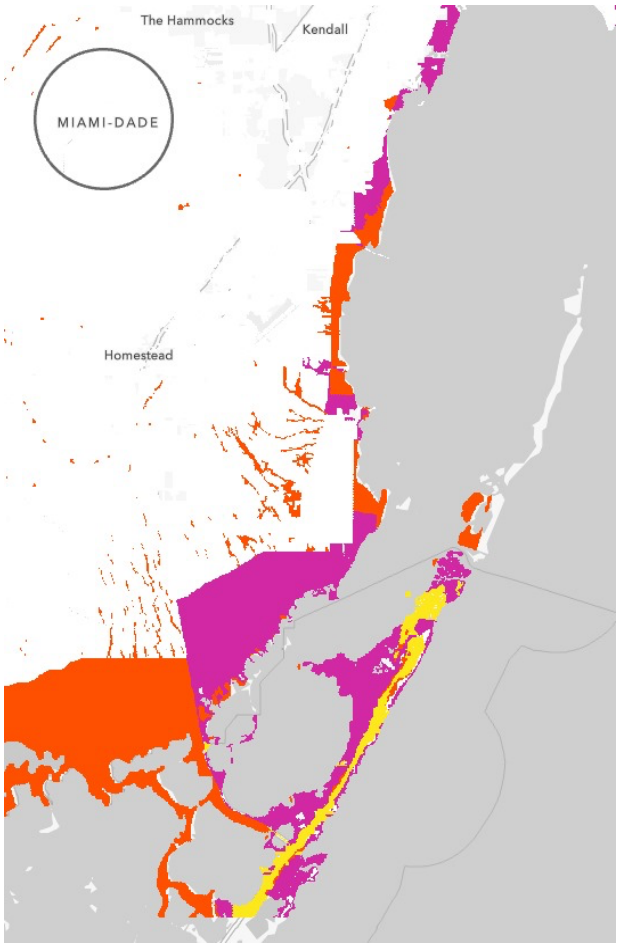

Figure 2: Flooding Frequency

Detailed Analysis of Heat Severity: Focusing on the year 2021, we analyzed heat severity across Miami using a color-

coded methodology that employed three distinct color bands to indicate varying degrees of heat intensity. This visual representation not only made temperature fluctuations easier to comprehend but also highlighted regions where heat reduction may also lessen the danger of flooding by pointing out possible relationships between heat intensity and flood risk. thermal discomfort.

Population Dynamics Analysis: To understand changes in population distribution, we utilized graduated symbols in our mapping. This technique enabled us to compare the population density of Miami-Dade County with that of other counties in South Florida visually. Through this analysis, I identified Miami-Dade County as a significantly more crowded or overpopulated area, underscoring the potential for a higher need for effective evacuation planning.

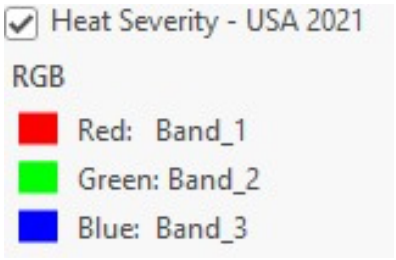

Figure 3: Legend – Heat Severity

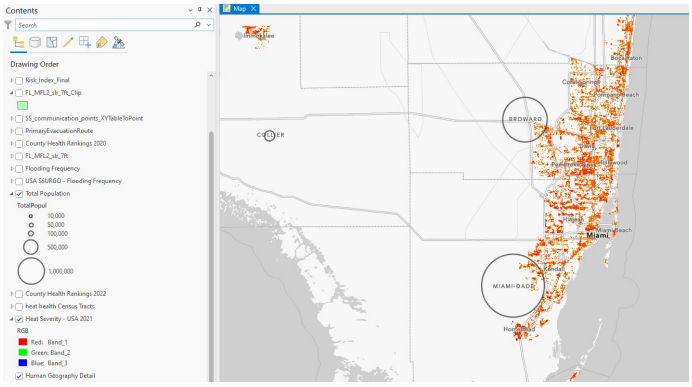

Figure 4: Heat Severity and Population Density

Surface Heat (Heat Health) Visualization: Next, we examined surface heat, another critical factor influencing urban heat islands and potentially exacerbating flood risks. I used an unclosed color scale to represent surface temperatures, with darker colors indicating higher heat intensity and lighter colors representing cooler areas. This approach helped to highlight the distribution of surface heat across Miami, identifying areas where mitigating heat could be particularly beneficial.

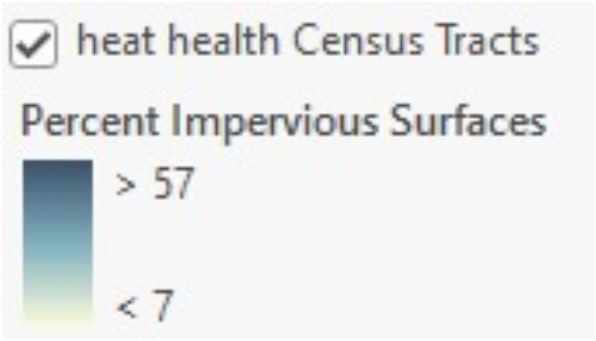

Figure 5: Legend – Heat Health (Surface Heat)

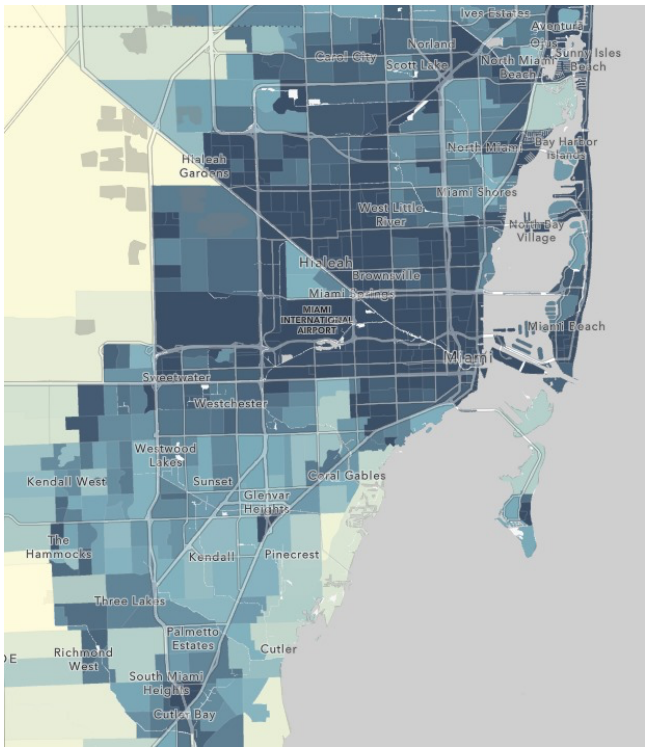

Figure 6: Heat Health (Surface Heat)

Emergency Response and Evacuation Planning: Recognizing the importance of preparedness, we mapped out emergency response assets and evacuation routes, particularly from coastal areas. Emergency health centers, crucial for providing medical resources and services during a disaster, were indicated with "heart" symbols. This mapping effort aimed to enhance public awareness and readiness for flood events by outlining the locations of critical health facilities.

Communication Centers Mapping: Lastly, we focused on the emergency communication infrastructure by identifying

the locations of communication centers with "tower" symbols. These centers are vital for ensuring that the public can maintain and engage in communication with disaster management services during floods, facilitating timely updates and instructions.

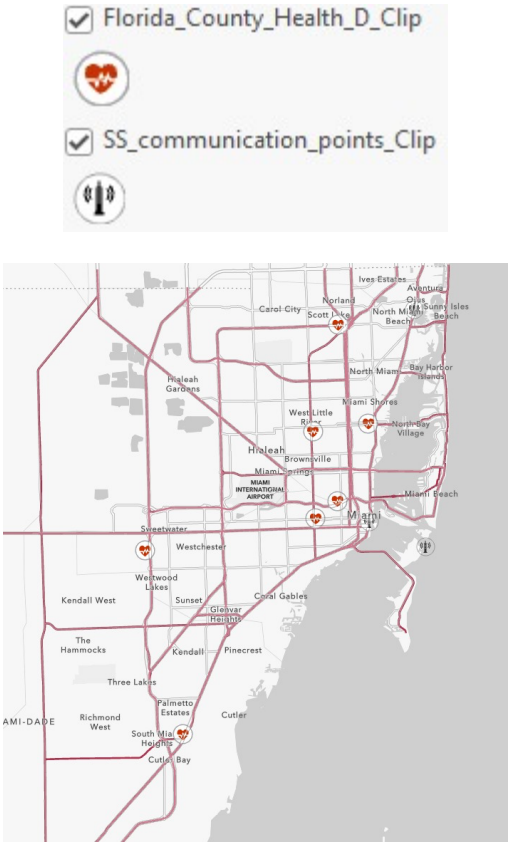

Figure 7: Evacuation Routes, Emergency Health Centers, Emergency Communication Centers

Downstream Analysis: I have traced downstream flow for around 5 points from the peak coastline region to better understand the pathways where strong water flow that may occur through heavy water-clogged regions.

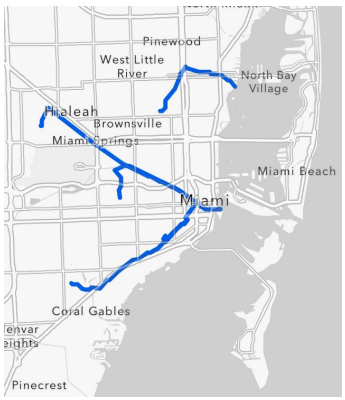

Figure 8: Downstream Analysis

5. RESULTS

Florida is one of the most exposed to sea-level rise due to its low elevation, dense population, and economic importance. Flooding frequency has increased significantly in numerous Miami-Dade coastal areas as sea levels rise at an accelerated rate. The average number of floods has been steadily rising due to extreme surface health close to the coastal border and Miami-Dade being on the edge making the region more prone to experiencing a higher risk of water overflows from the U.S Atlantic Coast. The beaches and popular tourist regions see a sea-level rise with the high heat severity from 2020 and onwards, this not only affects the heat health in general but also causes severe heat waves. Heat can have a substantial influence on floods in a variety of ways. While heat alone does not directly cause floods, it can contribute to circumstances that raise the frequency and severity of flooding occurrences. While some events can be mitigated, an immediate action plan is needed for which the emergency health centers clipped to the Miami-Dade County depicted on the map can deploy medical help and engage front-line doctors for efficient care, and the communication centers will trigger communications to FEMA or other disaster recovery services. The downstream flow will also help the public avoid those regions as they could have faster and deeper water flows causing large amounts of damage. The study also provides new evidence that connects the weakening of the Gulf Stream.

6. CONCLUSION

Climate change endangers not just the physical environment, but also the social and economic well-being of residents in places such as Miami [8]. Having an evacuation strategy in place before a flood can help minimize confusion, injuries, and property loss. More emergency health services will be established in flood-prone areas to provide fast response. Miami, Florida, is known for its hot and humid climate, with temperatures typically ranging from the mid-70s to the mid-80s Fahrenheit year-round. However, the severity of heat in Miami has increased due to climate change. Heatwaves in Miami have become longer, more frequent, and more intense, with temperatures reaching well over 90 degrees Fahrenheit for days on end. Miami Beach residents and businesses are urged to develop a disaster preparedness plan before an emergency strikes. Know where you will stay when you evacuate, how you will get there, and what supplies you will take.

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