Identifying hotspots of vulnerability during hurricane storm-surge inundation (Python Implementation)

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Introduction

Storm surges during hurricanes can cause significant flooding in coastal and inland regions resulting in damage to property and loss of life. Identifying regions that are most vulnerable to such damage is essential for improving disaster response and building community resilience. Timely evacuation during such disasters are crucial for saving lives and understanding the impact on infrastructure can help better planning and preparedness. Hurricane storm surge inundation is provided by the SLOSH (Sea, Lake and Overland Surge from Hurricanes) model by NOAA. Integrating the output of SLOSH model with socio-economic data can provide valuable insights into the affected regions. They can help identify populations at highest risk, help in guiding evacuation efforts and prioritizing resource allocation. Providing timely and crucial information can also help citizens access necessary resources for their safety and well-being.

Approach:

A comprehensive two-part analysis is conducted to understand the impact of storm-surge inundation:

1. **For Planners / Government Agencies**: The first part focuses on providing spatial information for planners and government agencies. The data mapped includes key demographic, economic and housing characteristics. Choropleth maps are used to visually depict the distribution of populations affected by storm surges across various census tracts of Washington, DC along with other attributes. These visualizations are designed to help decision-makers prioritize resources and tailor their response strategies for different categories of storms, thus enabling a more effective, data-driven approach to disaster preparedness and mitigation.

2. **For Citizens**: The second part adopts a citizen-centric approach to empower individuals with actionable information in the event of a storm. By allowing users to input a specific point location, the analysis identifies the category of storm that would affect that area, the pharmacies within a one-mile radius, highlighting those that would be inundated by storm surge waters. This information can be vital for individuals needing access to essential services like pharmacies during emergencies.

Methodology

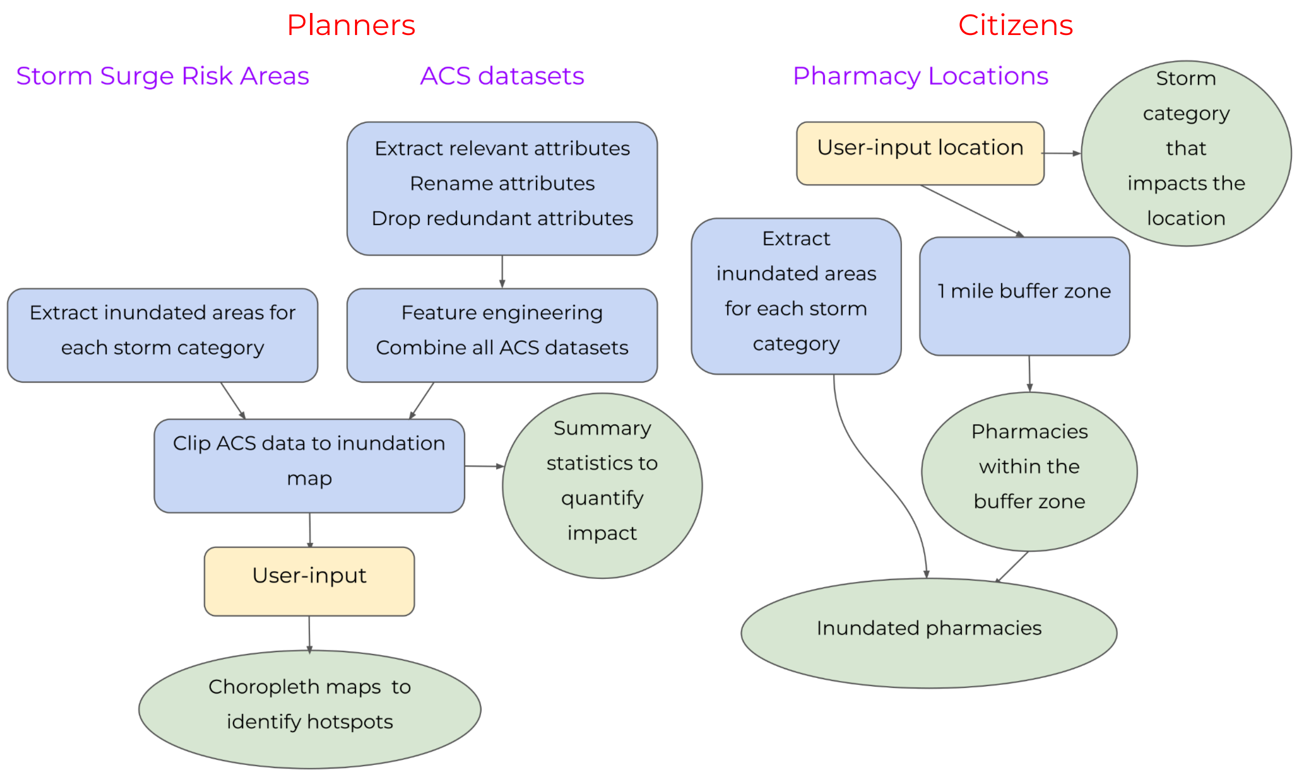

Figure 1: The workflow of analysis used in this study

Data: Source - Open Data DC portal ((https://opendata.dc.gov/)).

1. **Storm surge risk areas(category-wise) in DC:**
   - Shapefiles that give areas in DC that are at risk of inundation for different categories of storms.
2. **ACS 5-year data for DC census tracts:**
   - Shapefiles of census data that include information on population, housing, income etc. within each census tract in DC.
   - 3 categories of data were used:
     i. Demographic: Total population, Median age in years, Population over 65 years, Population under 10 years.
     ii. Economic: Median income in dollars, Percentage below poverty level.
     iii. Housing: Total housing units, Housing units built before 1950.
3. **Pharmacy locations in DC:**
   - Shapefile with locations of licensed pharmacies in DC.

Results

Part 1: For Planners

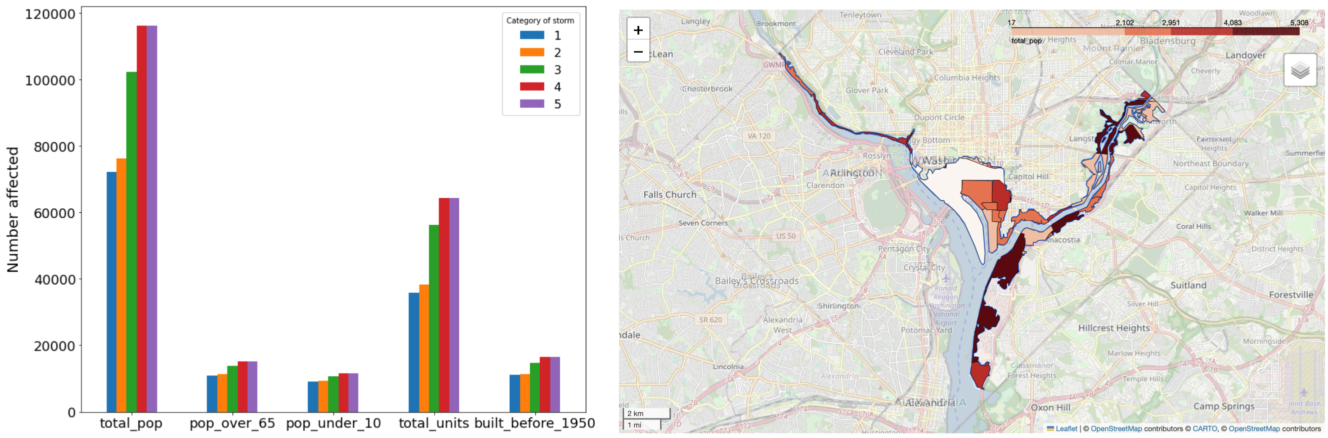

Figure 1: (a) Impact of each category of storm-surge inundation on people and housing units. (b) Spatial distribution of total population in DC census tracts impacted by a category 5 storm.

Figure 1a indicates that the severity of the storm increases the extent of its impact. Notably, the total population and number of housing units affected by category 4 and category 5 storms are identical. This could be attributed to the clipping process, which assigns actual attribute values to the clipped areas rather than proportional values. As category 5 does not encompass any additional census tracts beyond those affected by category 4, the total values remain unchanged.

The choropleth maps (refer to Jupyter notebook) show the distribution of vulnerable populations and help identify the key hotspots:

Areas with high population could be vulnerable spots during evacuation. Further, vulnerability could be higher in areas where elderly people (over 65 years) and children (under 10 years) reside in larger numbers. These areas may need additional resources and time for evacuation.

Infrastructure susceptible to damage can pose challenges during disasters. They could potentially complicate evacuation efforts if the damage to these infrastructure results in blocking of evacuation pathways. For example, older housing units (built before 1950) within the storm-inundated areas could be evacuation bottlenecks. Providing the spatial distribution of these can help in guiding available resources towards areas that may need the most support.

Regions with lower median income or higher poverty levels could indicate areas where recoverability from damage induced by disasters could be lower. These areas might warrant better preparedness in order to enable better community resilience to hurricane storm-surge inundations.

Part 2: For Citizens

`Your location is affected by storm category 5 or above!`

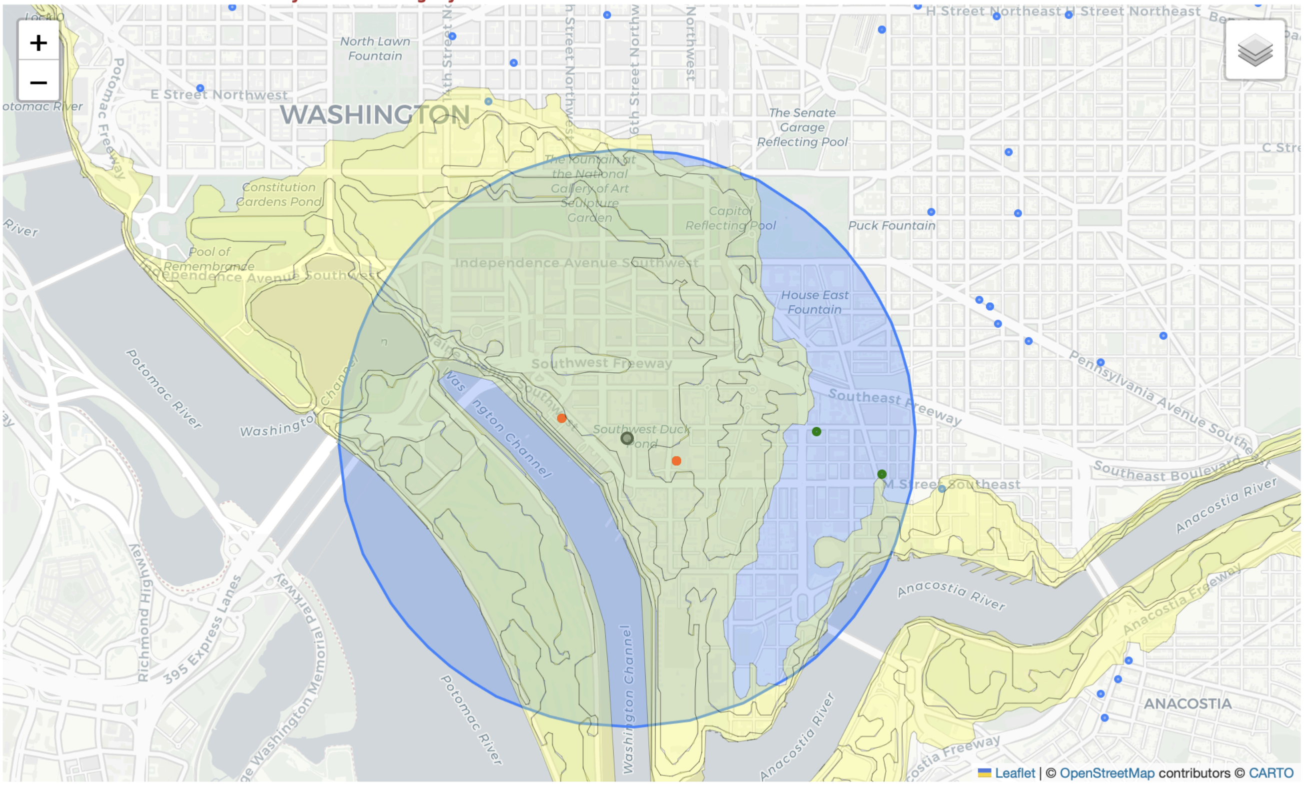

Figure 3: Storm category 5 impacts this location. Of 4 pharmacies in the 1-mile radius, 2 are impacted by surge inundation.

For the point location given (black) by the user, the category of storm that would impact the location is provided (see message on top). The pharmacies within a 1 mile radius are marked in green. Of these, the pharmacies which would be inundated by the same category of storm are marked in red. The results are validated by overplotting the surge inundated area for the category (yellow).

Scalability

To improve the scalability of such analyses, especially when applied to larger geographic areas or when integrating higher volumes of data (e.g., socio-economic data from census blocks), Apache Spark can be utilized. Spark's distributed computing framework excels at processing large datasets quickly by parallelizing tasks across a cluster of machines. In this context, Spark could help speed up the data ingestion, processing, and geospatial analysis required for the hurricane surge impact assessments, making it feasible to extend the analysis to wider regions or run multiple scenarios in parallel. It could ensure that both government and citizen-oriented analyses remain efficient even as the data size grows.

Future Scope

- Interactivity of the analysis can be improved to enhance user experience. A portal which can provide visualizations and further information can be created.
- Datasets providing storm-surge heights can be incorporated to further guide the resource allocation, planning and evacuation.
- The analysis can be extended to a finer spatial scale using data for census blocks.
- More datasets such as locations of primary care centers, hospitals, police stations, fire stations etc. can be included to provide all essential information to the user in case of a storm event.

References

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