Modeling the Impact of the 2024 Flood Event in Vadodara

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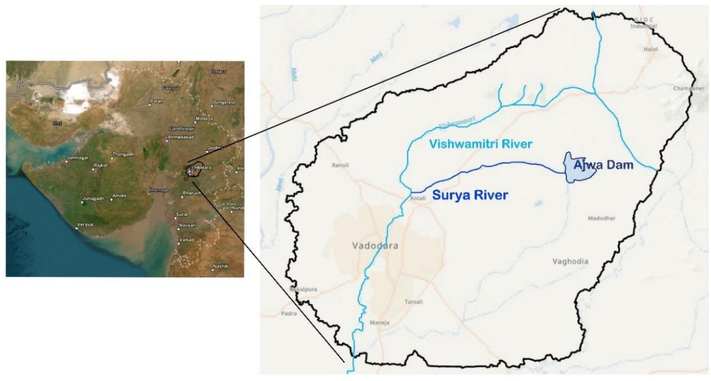
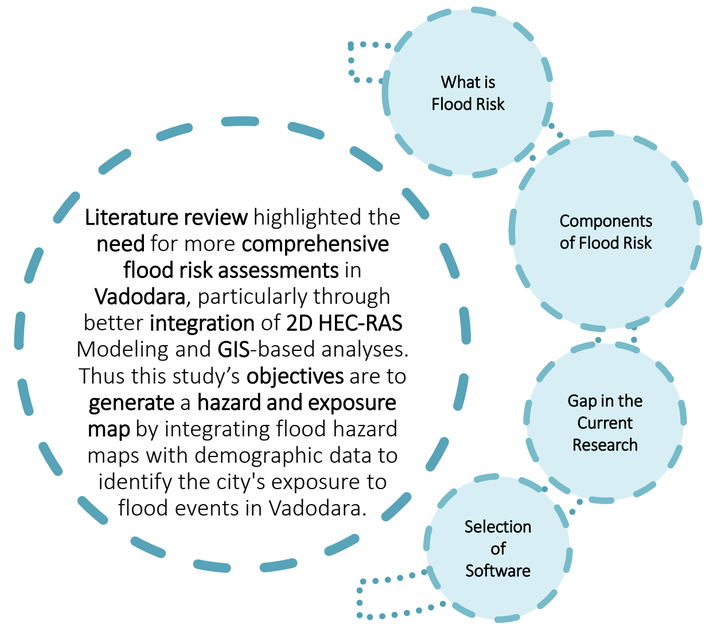
What is Flood?

- **Floods** occur when **water levels** in rivers **rise**, **inundating** typically **dry areas**, and account for 44% of global annual natural disasters between 2000 and 2019 (CRED, 2020). Over this period, they caused **USD 651 billion** in **losses**, over 100,000 fatalities, and **affected 1.65 billion people** globally (CRED, 2020). Flood-prone regions, particularly in Asia, face heightened risks due to low elevation, high rainfall intensity, and insufficient infrastructure (Alves, 2024). **Climate change** has **increased flood frequency** and intensity worldwide (Ali et al., 2019; Wang et al., 2022), with urban areas being particularly vulnerable due to dense populations and inadequate drainage systems (Bibi & Kara, 2023).
- India, where 15% of the land is flood-prone, has experienced frequent flooding, with 847 million people affected and 72,039 fatalities between 1900 and 2015 (CWC, 2020; CRED, 2020). Gujarat recorded 42 flood events over the past 50 years, including significant ones in Vadodara, which spans 158 square kilometers at 22°18´ N, 73°12´ E (Kumar, 2023).

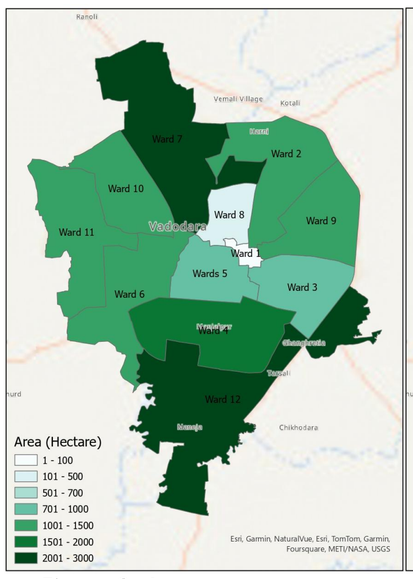
Need for the study?



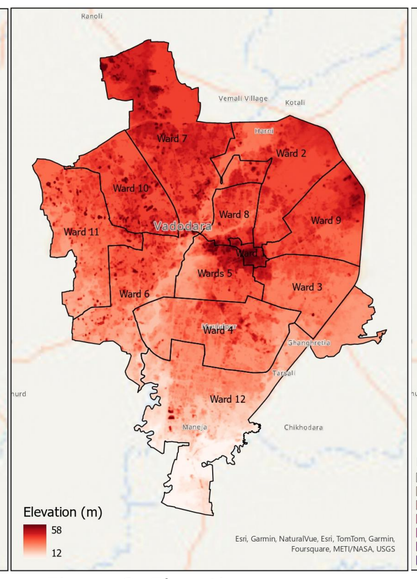
- *Figure 1: Catchment of Vishwamitri river.*
- The **Vishwamitri River**, which typically has depths of 1.2–2.7 meters, **swells** to **10 meters** during floods. The **August 2024 flood** in Vadodara, with **water levels** reaching **10.8 meters**, surpassed the danger level by 2.7 meters, **breaking** a **19-year record** and exceeding the 2005 flood extent (TNN, 2024).



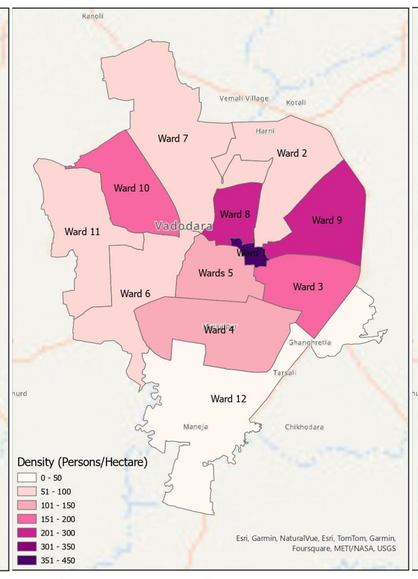
Data Used



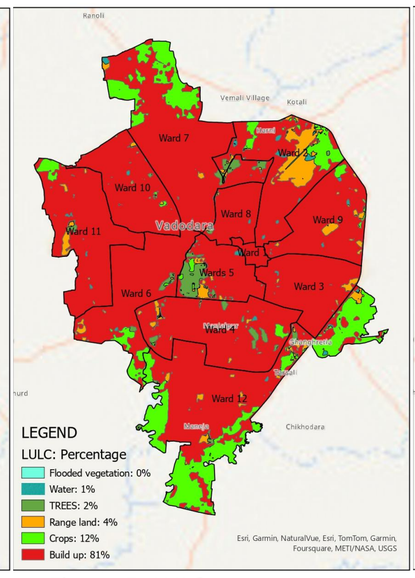
- *Figure 2: Area*



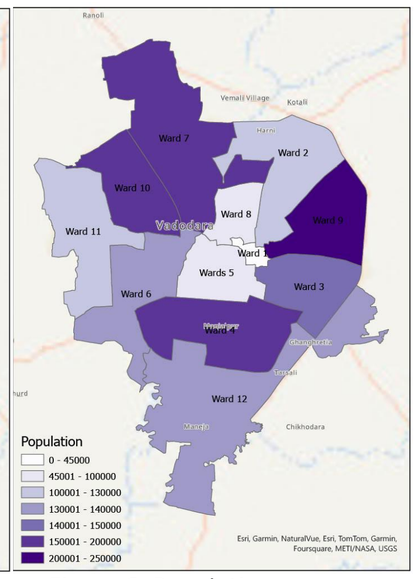
- *Figure 3: Elevation*



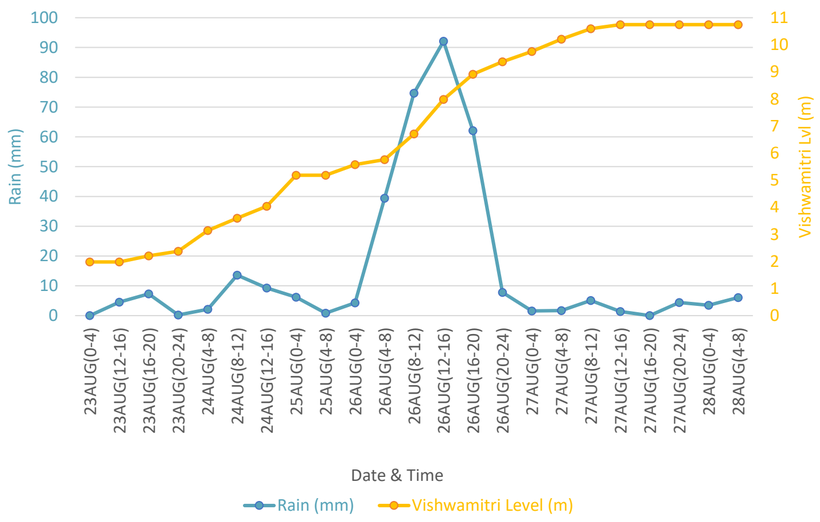
- *Figure 4: Density*



- *Figure 5: LULC*

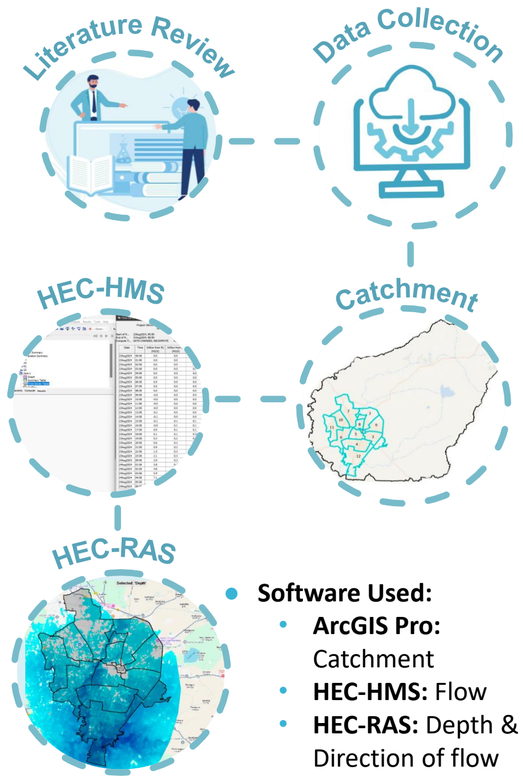


- *Figure 6: Population*



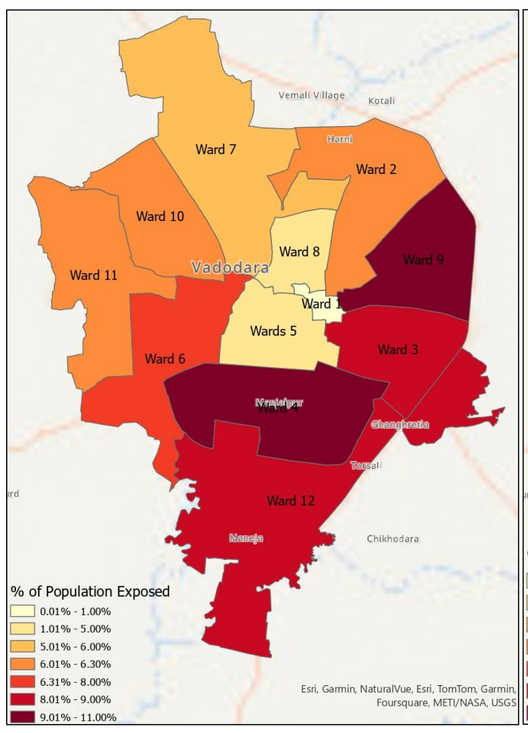
- *Figure 7: Rainfall Vs Vishwamitri river level*

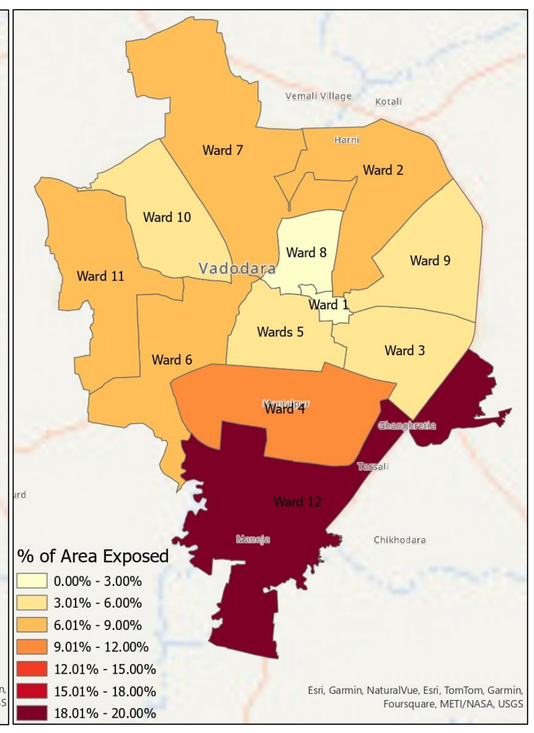
Methodology

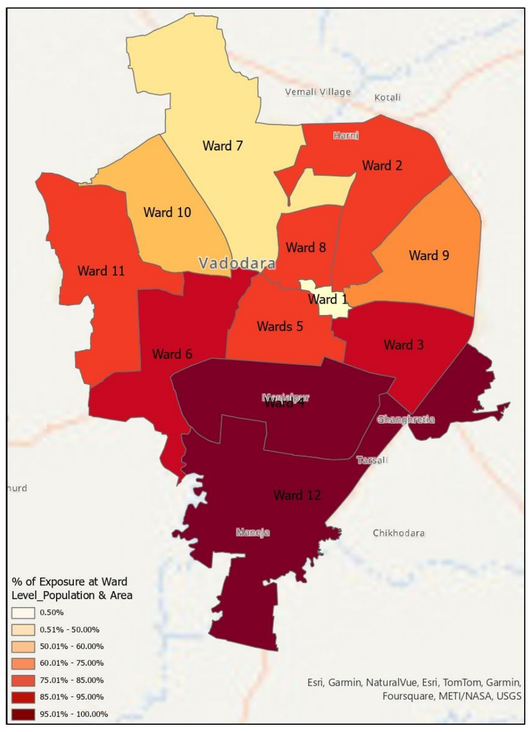


- **Raster Data:** • **DEM** (Digital Elevation Model): 30m resolution from **Bhuvan** • **LULC** (Land Use Land Cover) Data: 10m resolution from **Sentinel** (TIFF file) • **Soil Group** Data: 250m resolution
- **Vector Data:** • Vadodara ward boundary: Shape file.
- **Tabular Data:** • Demographic data: Excel file. • Rainfall data: Excel file (mm/hr). • Water level data: Excel file (mm).
- **Software Used:**
  - **ArcGIS Pro:** Catchment
  - **HEC-HMS:** Flow
  - **HEC-RAS:** Depth & Direction of flow

Result: Exposure at Ward & Vadodara Level (Population & Area)

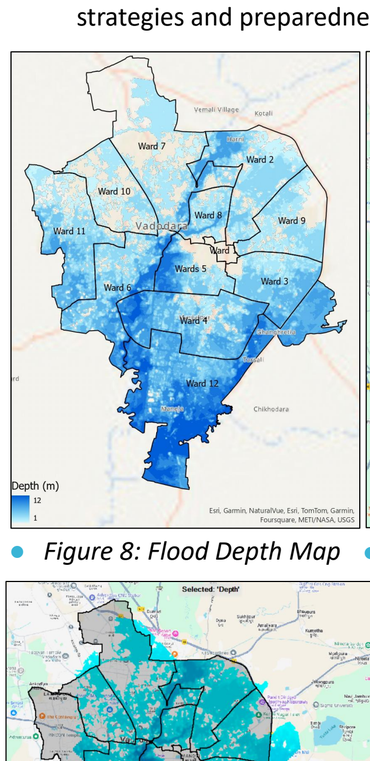




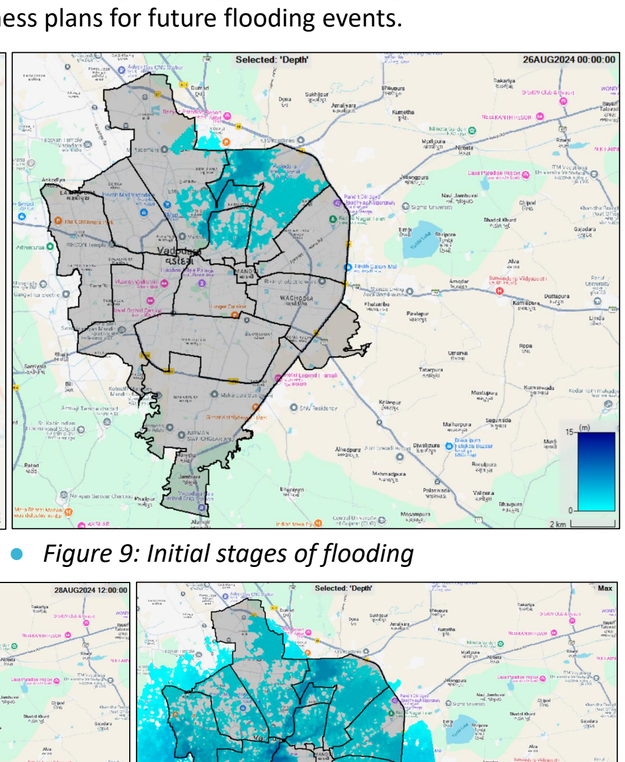


Result: Flood Water Pathway and Depth

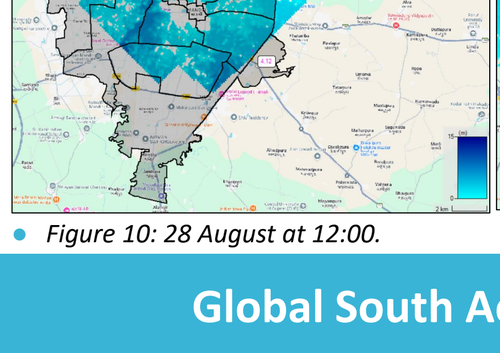
- The **HEC-RAS** model offers a detailed **visual representation** of potential **flooding scenarios** across Vadodara during a flood event. It uses a 2D model to map the spread of floodwaters throughout the city, including variations in **flood depths**. This helps in understanding the **movement** of **floodwater** and **identifying high-risk zones**. Flooding Progression: The model's progression is represented through several stages: Impact and Applications: The model provides valuable insights into flood hazard levels across Vadodara, enabling authorities to better assess the impact on different regions and populations. These insights can guide flood mitigation strategies and preparedness plans for future flooding events.



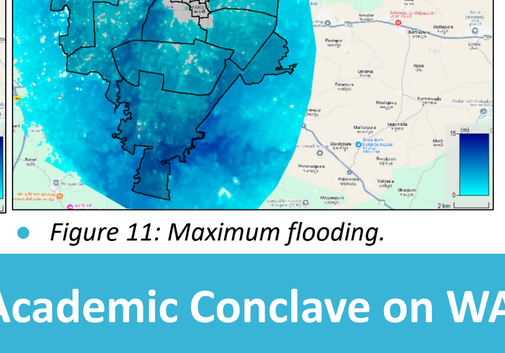
- *Figure 8: Flood Depth Map*



- *Figure 9: Initial stages of flooding*



- *Figure 10: 28 August at 12:00.*



- *Figure 11: Maximum flooding.*

Exposure at Vadodara Level

- At the citywide level, flood exposure across Vadodara's wards requires further **categorization** for a more accurate interpretation of the **results**.

Percentage of Population Exposed

- Overall, **76%** of **Vadodara's** total **population** is **exposed** to flood risk.
- **Ward 9:**
  - Ward 9, being the **most populated** ward (Figure 6), has the **highest population exposure**, with **10.266%** of its **residents exposed** to the flood event.
  - Ward 9 has the **second-highest** population **density** at **221 persons per hectare** (Figure 4), surpassed only by Ward 1.
  - Despite **Ward 1's higher density**, its bigger area (Figure 2) and **higher elevation** (Figure 3) result in **lower flood exposure** (Figure 7).
- **Ward 12:**
  - Despite **Ward 12's larger area** (Figure 2), it has a **lower percentage** of its **population exposed** to the flood event compared to Ward 9 (Figure 7), primarily due to its **smaller population size** (Figure 6).

Percentage of Area Exposed

- Overall, **80%** of **Vadodara's** total **area** is **exposed** to flood risk.
- **Ward 12:**
  - **Ward 12** has the **highest percentage** of its **area exposed** to the flood event, with **18.78%** of its area at risk.
  - This high exposure is primarily due to its **lower elevation** (Figure 3), leading to **greater flood extent** and **depth** (Figure 7).
  - Additionally, Ward 12 is the **largest ward** in terms of area, as shown in Figure 2, contributing to its higher percentage of exposed land.

Exposure at Ward Level

- **Ward 12** has the **highest exposure** to the flood event, with **99.7%** exposure in both area and population. Figure 7 shows that Ward 12 experiences the greatest flood extent and depth during the event.
- Contributing Factors: The higher exposure of Ward 12 can be attributed to its **lower elevation**, as indicated in Figure 3.

Summary

- For **effective flood management strategies**, it is recommended to **prioritize** the percentage of the **population exposed**, as this is **time-dependent** and reflects the **current risk profile**.
- For **future urban planning**, focusing on the percentage of **area exposed** across wards will provide valuable insights into the most vulnerable areas, which is **independent of time**. This approach can guide **development away from high-risk zones** and contribute to long-term resilience.

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