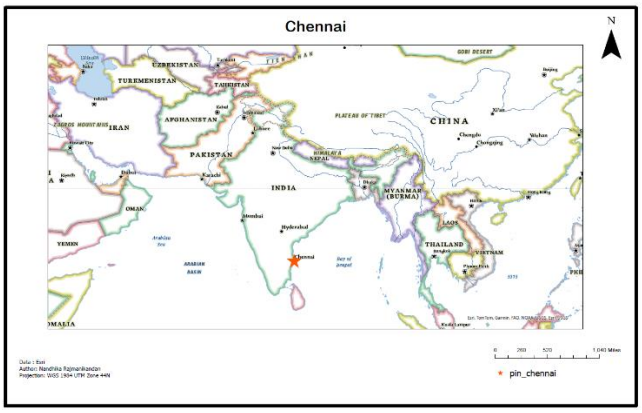
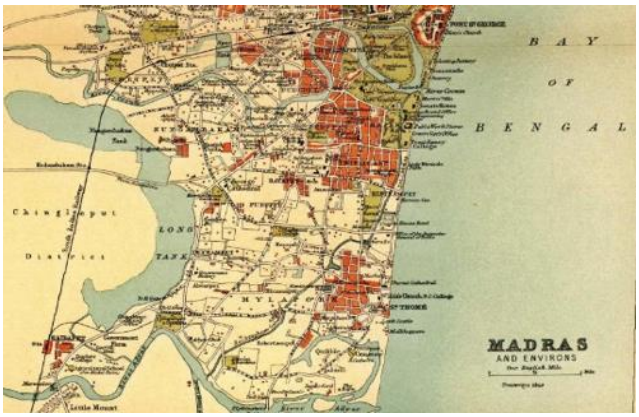
# Chennai - A Tale of Urbanization, Land Transformation and Flood risk

*When land forgets its water, water remembers its land ~* *Nandhika Rajmanikandan*

**Abstract:**

Chennai, the capital of Tamil Nadu, is situated along the Bay of Bengal on India's southeast coast. Chennai, a city well-known for its thriving culture, extensive history, and economic importance, is vital to India's urban and coastal dynamics. Chennai is a bustling Indian metropolis that has experienced tremendous change because of increased urbanization. With an emphasis on elevation dynamics, changes in land use and land cover, and the effects of reservoirs converted into rooftops, this study explores the changing link between urban expansion and vulnerability. The project investigates how Chennai's increased danger of floods is a result of land transformation and urbanization through a combination of historical insights and GIS analytics. Using various data models and analysis methods, the study seeks to pinpoint the main causes of flood susceptibility. "When land forgets its water, water remembers its land" is the subject that captures the findings, which highlight the difficult balance between development and sustainability.




**Purpose:**

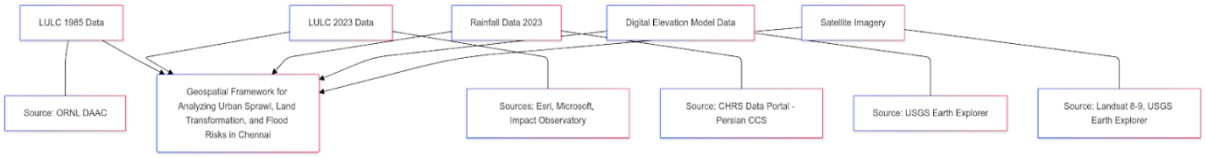
Historically, Chennai has been significant for its ancient ports and rich legacy, shaped by various rulers and dynasties. Among them, the Pallavas stand out for their foresight in infrastructure planning. They analyzed the region’s topography, including slopes and elevations, and took monsoon patterns into account. Their strategic placement of tanks and reservoirs played a crucial role in mitigating flood risks while ensuring water availability. The purpose of this project is deeply personal, as it stems from experiencing the December 2023 Chennai floods. Witnessing the devastating impact of urbanization on the city’s water resources and quality of life, the project aims to juxtapose historical insights with present realities. It seeks to analyze and highlight how urbanization has disrupted the balance between growth and sustainability, leading to increased flood risks.

**Criteria:**

The primary criteria for this project involve a qualitative representation of urban encroachment and its impact on flood vulnerability in Chennai. The analysis begins with

classifying the city's Digital Elevation Model (DEM) to understand the distribution of elevation and identify low-lying flood-prone areas. Historical maps are georeferenced and overlaid with current spatial data to visualize the locations of lost tanks and reservoirs that once played a crucial role in water management. Land Use Land Cover (LULC) data is then classified into categories such as urban, water bodies, and vegetation, followed by a change detection analysis to track land transformation over time. Finally, all the data, including elevation, LULC, and historical tank information, are synthesized to create a flood risk map spanning the municipal boundaries of Chennai, highlighting areas most vulnerable to flooding. This map serves as a critical tool for understanding how urban sprawl has increased flood risks. The project emphasizes the need to reflect on historical planning techniques and integrate them with modern methods for sustainable urban management. It also underscores the importance of protecting natural water resources to mitigate future disasters. By combining historical insights with advanced geospatial techniques, the study aims to provide actionable recommendations for flood risk management.

**Data:**




The data used for this project spans multiple sources and formats, incorporating both raster and vector models for a comprehensive geospatial analysis. Land Use Land Cover (LULC) data from 1985 was sourced from the Oak Ridge National Laboratory Distributed Active Archive Center (ORNL DAAC), while the 2023 LULC data was obtained from Esri, Microsoft, and Impact Observatory, providing a detailed view of land transformation over time. Rainfall data for 2023 was collected from the CHRS Data Portal using the Persian CCS dataset, offering high-resolution (0.04° x 0.04°) three-hourly precipitation measurements critical for analyzing rainfall patterns during flood events. Digital Elevation Model (DEM) data was acquired from the USGS Earth Explorer, aiding in the identification of low-lying areas and elevation variations across the city. Additionally, surface band reflectance data and imagery from Landsat 8-9, also sourced from the USGS Earth Explorer, supported analyses related to vegetation and water body identification. These diverse datasets were integrated to build a robust framework for exploring urban encroachment, historical land use changes, and flood risk mapping in Chennai. The vector data for this project includes shapefiles of the administrative and municipal boundaries of Chennai, which were essential for delineating the specific geographic areas of interest and ensuring that all spatial analyses were confined to the city’s limits. Additionally, an old georeferenced map sourced from Wikipedia was used to overlay historical land use and water resources, helping to visualize the lost tanks and reservoirs that were once integral to Chennai’s water management system. This map provided valuable historical context for understanding the city’s transformation over time, particularly in relation to urban encroachment and the subsequent loss of natural water features.

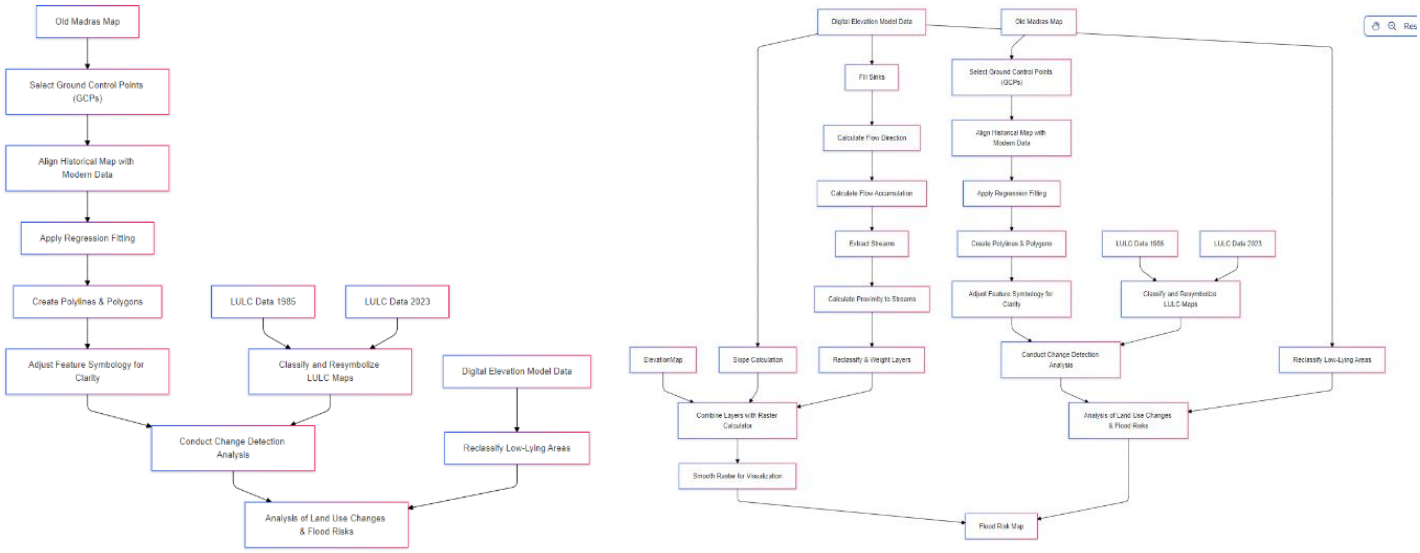
**Methodology:**

The methodology for this project involves several key steps, integrating multiple data sources to analyze urbanization and flood risks in Chennai. First, the Digital Elevation Model (DEM) data is used to classify the city based on elevation, generating an elevation map that highlights variations across the area. Next, the historical Madras map is georeferenced to align it with current spatial data. Ground Control Points (GCPs) are manually selected, and regression fits are applied to ensure proper alignment of the historical map with modern spatial data. New features, such as polylines and polygons, are created using the *Create Features* tool in ArcGIS Pro to trace out lost tanks and reservoirs that once played a crucial role in Chennai's water management system. These extracted features from the old map are incorporated into subsequent analyses, including the change detection map. The 1985 and 2023 Land Use Land Cover (LULC) data are then classified to produce updated LULC maps. A change detection analysis is performed, comparing the LULC maps to identify significant transformations over time, with a particular focus on urbanization and the loss of water bodies. The extracted historical features are integrated into this analysis to provide further context for land use changes. Finally, the precipitation data, DEM, and LULC data are combined to create a flood risk map, providing a comprehensive assessment of flood-prone areas in Chennai based on elevation, land use changes, and rainfall patterns. This methodology allows for a detailed understanding of how urbanization has impacted flood vulnerability in the city.


**Procedure/Workflow:**

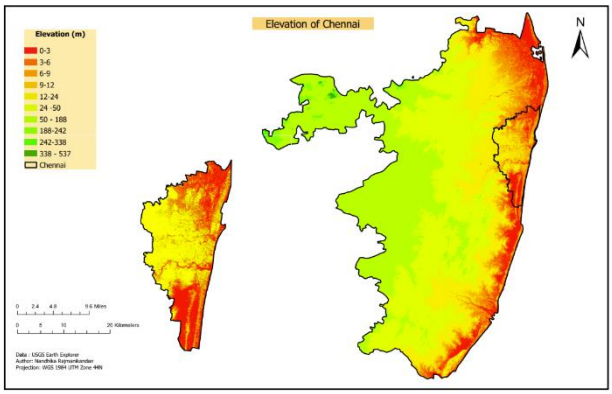
The procedure for this project begins with the classification of the Digital Elevation Model (DEM) data to identify the elevation distribution across Chennai. The *Reclassify* tool in ArcGIS Pro is used to bin the elevation data, focusing on low-lying areas prone to flooding, with classes based on the city's known topography. Next, the old Madras map is georeferenced using *Ground Control Points (GCPs)*, where the historical map is aligned with modern spatial data using regression fitting. New features, such as polylines and polygons, are created using the *Create Features* tool to trace the locations of lost tanks and reservoirs, and the symbology is adjusted for

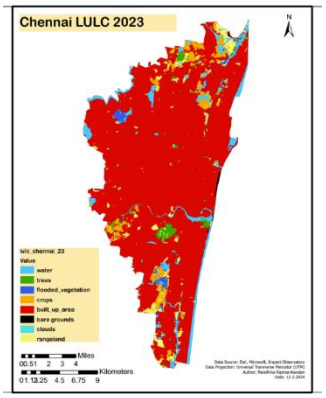
clarity. These features are then used in the change detection analysis to identify significant changes in land use. The 1985 and 2023 Land Use Land Cover (LULC) maps are classified and re-symbolized to ensure consistency between both maps. Change detection is carried out using ArcGIS Pro's built-in *Change Detection* function, which highlights important shifts in land use. In parallel, a flood risk map is developed by combining multiple layers: elevation, proximity to streams, LULC, precipitation, and slope, each weighted according to their significance in flood risk. Tools like *Fill*, *Flow Accumulation*, *Flow Direction*, and *Extract Streams* are used to process the DEM data, and the *Euclidean Distance* tool calculates proximity to streams. These layers are reclassified and combined using the *Raster Calculator*, with final adjustments made to smooth the raster for better visualization. This detailed workflow ensures a comprehensive flood risk map, integrating urbanization trends and environmental factors to assess flood vulnerability in Chennai.

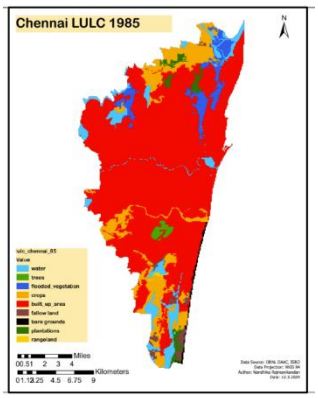


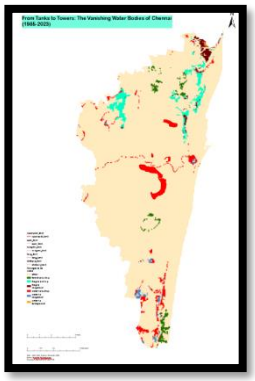

**Results:**

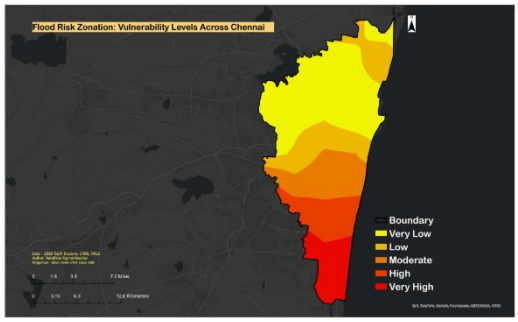
The elevation map highlights that most of Chennai lies within the 0-3 m elevation range, making it highly susceptible to flooding during monsoons or cyclones. This low elevation is a critical factor contributing to the city's recurrent waterlogging issues. A comparison of the Land Use Land Cover (LULC) maps from 1985 to 2023 reveals a significant rise in urbanization, with a notable increase in development around water bodies. Many of these water bodies, including tanks that once played a vital role in managing water resources, have been completely urbanized and erased over time. The LULC change detection analysis identifies these transformations, with the red areas in the map explicitly marking water bodies that have been encroached upon and converted for urban use. Furthermore, the flood risk map underscores the severity of the situation by correlating flood risks with the city's low elevation and the extensive land use changes. Together, these maps emphasize the urgent need for sustainable urban planning and flood risk mitigation strategies to address the growing vulnerabilities in Chennai.







**Discussions:**

These maps demonstrate that several water bodies have been urbanized, yet there has been no investigation into the reasons and processes behind their disappearance. This issue warrants further exploration and could also inform Urban Planning studies. In ancient times, the construction of tanks was strategically planned to conserve drinking water and mitigate flood risks. However, with the exponential growth in population density near water bodies and across Chennai city, these practices have largely been overlooked. This analysis remains a preliminary qualitative assessment, highlighting the need for a more robust quantitative approach, which should be actively encouraged.

**Citations:**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