# GIS-based Social Vulnerability Integration for Robust Flood Response, Disease Prevention and Community Resilience in Chennai Metropolitan Area post-Cyclone Michaung

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***Abstract***
*The present study outlines a comprehensive strategy for flood response, disease prevention and long-term community resilience in the aftermath of a recent Cyclone Michaung, with the proximity of landfall near Chennai and the increased likelihood of flooding in the CMA. Drawing insights from an existing social vulnerability map, the study addresses the unique challenges posed by flooding and aims to mitigate the heightened risk of waterborne and vector-borne diseases. Objectives encompass assessing social vulnerability, formulating a targeted flood response strategy, implementing healthcare interventions for disease prevention, strengthening information dissemination and advocating for long-term resilience planning. The methodology involves reviewing the existing vulnerability map, identifying vulnerable communities, integrating flood impact data and developing a comprehensive response plan.*

*The study utilizes GIS and Remote Sensing technologies for monitoring and assessing the results. Key findings from the social vulnerability assessment inform prioritized intervention areas for both flood response and disease prevention. The discussion interprets results in the context of strategy effectiveness, emphasizing the significance of a nuanced and inclusive approach. This manuscript serves as a guide for stakeholders in implementing a holistic strategy that addresses immediate concerns, prevents disease outbreaks and fosters long-term community resilience.*

**Keywords:** Social Vulnerability, Flood Response, Disease Prevention, Community Resilience, Remote Sensing and Geographic Information System (GIS).

## Introduction

Chennai, a city known for its resilience, recently faced the formidable impact of Cyclone Michaung on December 4, 2023, resulting in severe floods and an increased risk of waterborne and vector-borne diseases. In the wake of this crisis, the necessity for a comprehensive response becomes evident, encompassing disease prevention with effective flood response measures and strategies to enhance community resilience. The stagnant floodwaters serve as breeding grounds for disease vectors such as mosquitoes and other pathogens. This situation poses an immediate threat to public health, as water-borne diseases like typhoid, cholera, leptospirosis and hepatitis A and E and vector-borne diseases such as dengue and dengue hemorrhagic fever (DHF), malaria, yellow fever and West Nile fever may become rampant if not addressed urgently[44,48,63].

Addressing social vulnerability is of utmost importance, which refers to the susceptibility of certain groups or communities to adverse impacts of a disaster, especially in the social context, which magnifies the challenges faced. Social vulnerability analysis includes a combination of factors from different domains or dimensions such as (1) socioeconomic factors related to economic conditions, income levels, employment opportunities and overall financial well-being of individuals or communities. (2) demographic factors which involve characteristics of the population such as age, gender, education levels and other demographic features that may influence vulnerability and (3) built-environmental factors, which pertain to the physical infrastructure and environmental characteristics of an area, including housing conditions, accessibility to services, land-use and the overall built environment.

The combination of these factors helps researchers and analysts to understand the social dynamics and conditions that contribute to vulnerability. Social vulnerability analysis helps to identify and quantify these factors to determine the extent to which a community or population is at risk during a disaster. This information is valuable for disaster preparedness, response planning and resource allocation to ensure that the most vulnerable groups receive appropriate attention and assistance. As communities grapple with the aftermath, addressing social vulnerability emerges as a pivotal component of the comprehensive response[4].

Simultaneously, an effective flood response strategy is paramount in minimizing the immediate impact of the floods[66]. Swift evacuation plans, robust emergency shelters and efficient coordination among rescue teams are essential components. Ensuring the availability of clean water, sanitation facilities and medical aid contributes significantly in mitigating the immediate health risks posed by the floodwaters[30]. Fostering community resilience becomes instrumental in navigating the aftermath of the cyclone. Empowering local communities with knowledge about

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disaster preparedness, establishing community support networks and providing psychological support can enhance their ability to cope with the challenges.

Moreover, initiatives for rebuilding infrastructure and creating sustainable urban planning contribute to long-term community resilience, reducing vulnerabilities to future disasters[12,21]. This introduction lays the groundwork for the multifaceted investigation, emphasizing the need to integrate social vulnerability considerations into flood response and disease prevention strategies[20]. It recognizes the interconnected nature of these elements and underscores the importance of addressing social vulnerability for a more effective and inclusive response. Amidst the intricate aftermath of Cyclone Michaung, the present study aims to formulate a comprehensive approach to flood response and disease prevention in Chennai.

The main objective is to carefully incorporate information from an existing social vulnerability map into targeted interventions. By doing so, we aspire to improve the efficacy of immediate relief efforts, prevent disease outbreaks and foster enduring community resilience. The present study tries to answer the following questions:

- How can we best use the social vulnerability map to improve flood response in vulnerable communities?
- How insights from social vulnerability guide the customizations of healthcare interventions to prevent and mitigate waterborne and vector-borne diseases?
- What role does information dissemination, rooted in social vulnerability considerations, play in fostering community engagement and resilience?
- How can advocacy efforts, guided by social vulnerability data, influence long-term resilience planning and infrastructure development in post-disaster scenarios?

## Study Area

The profile of Chennai Metropolitan Area (CMA), covering aspects such as its physical environment, weather patterns, climatic conditions, land utilization, socioeconomic condition and population characteristics, are based on a thorough examination of the second master plan of CMA[14], City Disaster Management Plan (CDMP)[23], District Census Handbook[11] and District Statistical Handbook[25]. The Chennai Metropolitan Area (CMA) is currently home to 12 million people, as estimated in the latest revision of the UN World Urbanization Prospects[61]. Chennai, formerly known as Madras, serves as the capital city of Tamil Nadu. It is located on the North-Eastern part of Tamil Nadu on the Coromandel coast of the Bay of Bengal and lies between 12.9º and 13.29º north latitudes and 80.01º and 80.35º east longitudes, with a coastline stretching about 49 km.

The CMA spans over 1188 km$^2$ and encompasses the Greater Chennai Corporation (GCC), Avadi Corporation, Tambaram Corporation, 5 Municipalities, 3 Town Panchayats and 10 Panchayat Unions (comprising 179 villages) within Chennai and parts of Tiruvallur, Kancheepuram districts as shown in figure 1[15,59]. Chennai and its suburbs are no strangers to natural, climatic, or health-related hazards[39], mainly due to its geographic setting and proximity to the warmer sea, the Bay of Bengal and the thermal equator. Tsunamis, cyclones, storms, floods, droughts and erosions are the disasters that have threatened Chennai in the past[26]. It was one of the worst-affected areas during the 2004 Indian Ocean tsunami, 2015 and 2023 flooding, 2016 Vardah, 2020 Nivar and 2023 Michaung cyclones as well as the 2020 COVID-19 incidents.

In December 2015 and 2023, Chennai and its suburbs flooded due to torrential rainfall, marking an event occurring once in over 100 years. In 2015, 200 people lost their lives and in 2023, 14 people lost their lives, millions were left without clean water and business and other operations came to a halt. Such events are becoming more frequent and intensified in the years to come. The worsening flood risk, stemming from increased rainfall and potential sea level rise, impacts the city's most vulnerable communities, along with the spread of Leptospirosis and other vector or waterborne diseases among communities after flooding. While floods continue to pose a risk, water scarcity has also become a daily concern for the city's growing communities, attributed to the over-exploitation of groundwater leading to a reduction in the water table level[10].

In response to these challenges, the State Government of Tamil Nadu in India is actively reimagining its capital, Chennai and its suburbs, to create a green, livable, smart, competitive and resilient metropolis. The Asian Infrastructure Investment Bank (AIIB) is playing a crucial role in this transformation, aligning with its mission to finance green and resilient Infrastructure for Tomorrow (i4t)[1]. Simultaneously, the city invested in the new stormwater management system to minimize leakage. These initiatives mark the initial steps in Chennai's journey towards becoming a water-secure and resilient metropolis[10].

## Material and Methods

The social vulnerability index incorporates socioeconomic and built-environment data. To assess socioeconomics in CMA, we utilized population enumeration, house listing and housing data from Census India 2011 (https://censusindia.gov.in/) to map demographic and socioeconomic characteristics for 440 units at district, village, or ward levels. Census India 2011 lacks built-environment data like healthcare locations, land use and shoreline information. Healthcare facility positions were manually extracted via HERE Map's Geocoding and Search API (https://geocode.search.hereapi.com). Land use and shoreline information for Chennai Metropolitan Area were extracted through visual interpretation in ArcGIS 10.5 Environment from Landsat 8 OLI satellite imagery obtained from USGS Earth Explorer site (https://earthexplorer.usgs.gov/).

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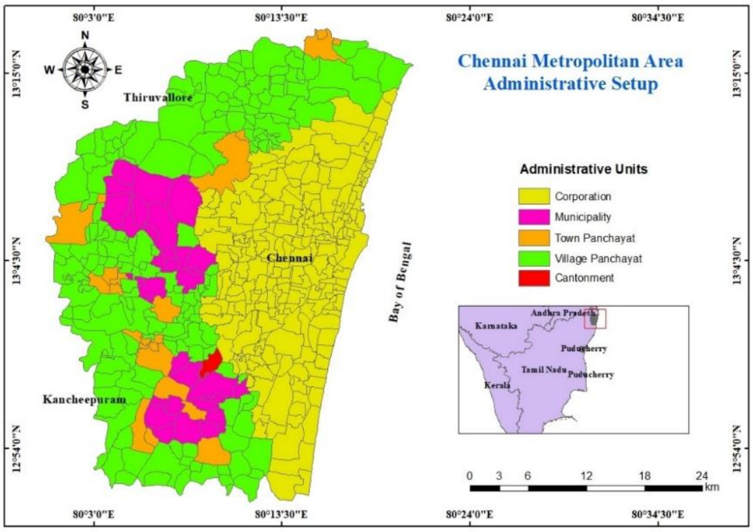


**Fig. 1: Study Area: Chennai Metropolitan Area (CMA).**
Source: CMDA 2022[15]

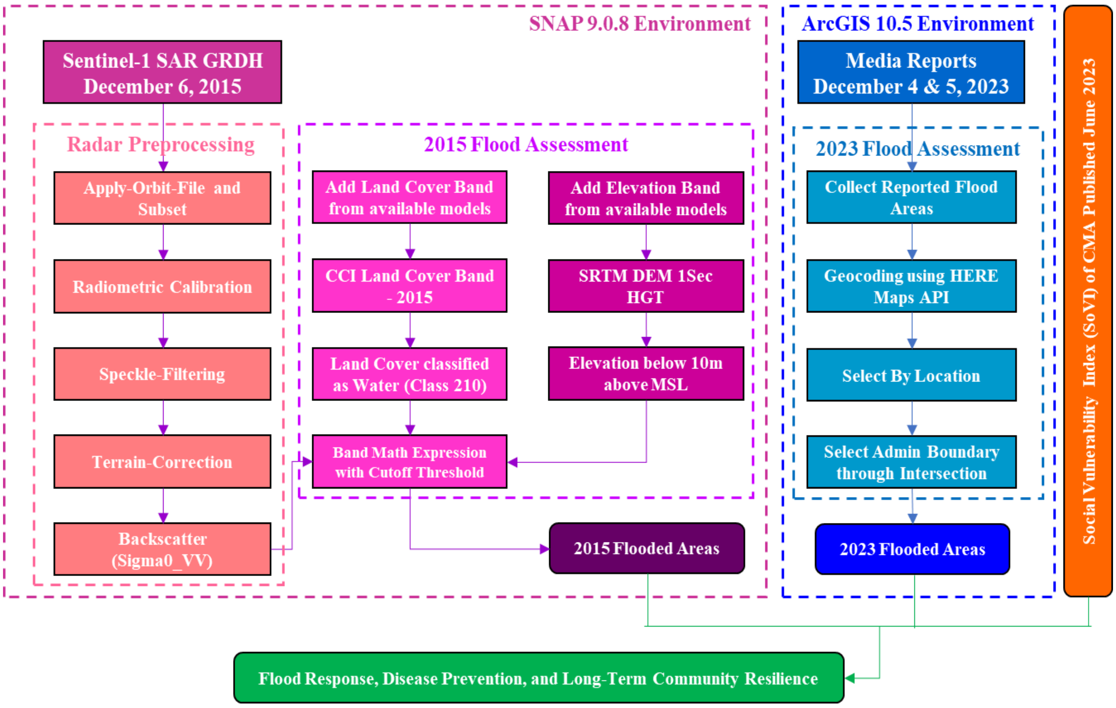


**Fig. 2: Integrating Social Vulnerability into Comprehensive Flood Analysis and Management**

Statistical analysis including Descriptive Statistics and Principal Component Analysis (PCA), was performed in IBM SPSS Statistics 29 and results were converted to spatial form using ArcGIS Desktop 10.5. To map flood-affected areas in CMA, we processed Ground Range Detected (GRD)-type Sentinel-1 SAR (Synthetic Aperture Radar) products obtained from Copernicus Open Access Hub (https://scihub.copernicus.eu/). The data, collected on December 6, 2015, that intersected with CMA and had VV polarization, was analyzed in SNAP Desktop 9.0.8. Additionally, flooded areas on December, 4, 2023, resulting from Cyclone Michaung, were identified through media reports (thenewsminute.com; timesofindia.indiatimes.com; https://www.timesnownews.com; thehindubusinessline.com and weather.com).

For mapping reported flooded areas, ArcGIS Desktop 10.5 was utilized to depict administrative boundaries instead of the actual flood extent. This approach was adopted due to the current unavailability of remote sensing data from the respective organizations which is essential for precise mapping and analysis of 2023 Chennai floods. Therefore, we employed a holistic methodology for flood response, disease prevention and community resilience as illustrated in figure 2.

## Results

In the aftermath of flooding events in regions like the Chennai Metropolitan Area (CMA), a multitude of challenges emerge, significantly impacting the community and its resilience. Waterlogging disrupts transportation and daily life, while infrastructure damage hampers emergency response efforts[53]. The proliferation of waterborne and vector-borne diseases poses severe health risks and displacement has become a stark reality for many residents[29,38]. Economic losses, communication breakdowns and environmental impacts further compound the complexities faced by the community[52].

Moreover, these challenges are often magnified by pre-existing social vulnerabilities including socio-economic disparities and inadequate infrastructure, disproportionately affecting marginalized communities[5,58]. Recognizing and comprehensively addressing these multifaceted challenges is imperative for the development of effective flood response, disease prevention and community resilience strategies. Therefore, this study aimed to integrate social vulnerability considerations into flood response, disease prevention and community resilience strategies in the Chennai Metropolitan Area (CMA). Our research sought to enhance the precision of interventions and address the immediate flooding challenges in this region, guided by a strategic amalgamation of social vulnerability insights and empirical data. This approach is essential for a more targeted and efficient approach to enhance the overall resilience of communities in the face of flooding scenarios[28].

**Social Vulnerability Analysis:** Initially, we examined the established social vulnerability map for CMA (Fig. 4A) which was meticulously crafted through the integration of socioeconomic, demographic and built-environmental factors and served as a foundational resource for the research. The map offered a detailed understanding of communities in CMA that are particularly susceptible to adverse impacts. Wards such as Adyar (C13), Alandur (C12), Anna Nagar (C8), Kodambakkam (C10), Royapuram (C5), Teynampet (C9), Thiru Vi Ka Nagar (C6) and Tondiarpet (C4) in Chennai City exhibited the most significant social vulnerability. Additionally, regions like Sriperumbudur (K73 and K109), Pallavaram (K158), Tambaram (K166), Nedugundram (K9), Chengalpattu (K9) in Kancheepuram and Ambattur (T58, T144 and T146), Poonamallee (T22 and T42) and Ponneri (T50, T97, T103, T106, T128, T131 and T132) in Tiruvallur districts demonstrated high social vulnerability.

The vulnerabilities observed in these regions are characterized by a higher percentage of the population with low social status, challenging demographics and suboptimal housing conditions. Contributing factors include a high percentage of the elderly population, female-headed households, dilapidated housing conditions, low educational attainment and elevated unemployment rates. Moreover, these regions exhibit the highest population and housing density, featuring the highest percentage of built-up areas compared to other locations in the CMA. They also face challenges such as extended distances to medical or healthcare centers and proximity to the coastline[4]. Furthermore, CMA has experienced the highest urban population growth in India during the last census period (Fig. 3A), particularly concentrated in southern Chennai, driven by the Information Technology (IT) and automobile industries. However, this rapid development has obstructed waterways, lakes and smaller water bodies, increasing vulnerability to events like heavy rainfall, flooding and water-related disasters. The influx of population into urban and peri-urban areas has altered land use patterns, contributing to an increased vulnerability to flooding (Fig. 3B).

Additionally, the concentration of industries has further amplified the community's susceptibility to floods, impacting social, political and economic dimensions[4]. This phase, involving a comprehensive examination of the existing social vulnerability map, not only laid the groundwork for our subsequent research but also provided valuable insights into the multifaceted nature of vulnerability in CMA. The detailed understanding gained from this process became instrumental in informing targeted interventions aimed at enhancing the resilience of these vulnerable communities in the face of flooding events.

**Flood Impact Assessment:** Secondly, we thoroughly assessed the flood impact on CMA, utilizing Ground Range Detected (GRDH) Sentinel-1 SAR products and information from media reports. The assessment focused on two significant episodes—December 6, 2015 and December 4, 2023 (immediately after Cyclone Michaung). Our analysis incorporated VV polarization data, a crucial parameter in SAR imaging that enables a detailed examination of the backscattering properties, providing insights into the nature of flooded areas in the Chennai Metropolitan Area (CMA) during 2015[40]. For the 2023 floods caused by Cyclone Michaung, the affected areas are identified based on information gathered from various media reports (Fig. 4B and 4C). The synthesis of SAR data and media reports allowed us to map and visualize the extent of flooding in CMA on the specified dates, contributing to a nuanced understanding of the severity of the flooding impact.

The flood-reported areas following Cyclone Michaung on December 4, 2023 and the flood-affected regions identified from the December 6, 2015 floods using Sentinel 1 SAR data coincide with high social vulnerability zones, emphasizing the critical overlap between flood-affected regions and socially vulnerable areas. This alignment significantly amplifies the risk and potential disruption to the community's livelihoods. Recognizing these intersections is pivotal and the regions that overlap with high social vulnerability require special attention in formulating targeted interventions for effective flood management, implementing public health initiatives and enhancing community resilience for future flood events.

**Healthcare Infrastructure Analysis:** Geocoding healthcare facilities are a critical component of flood management strategies.

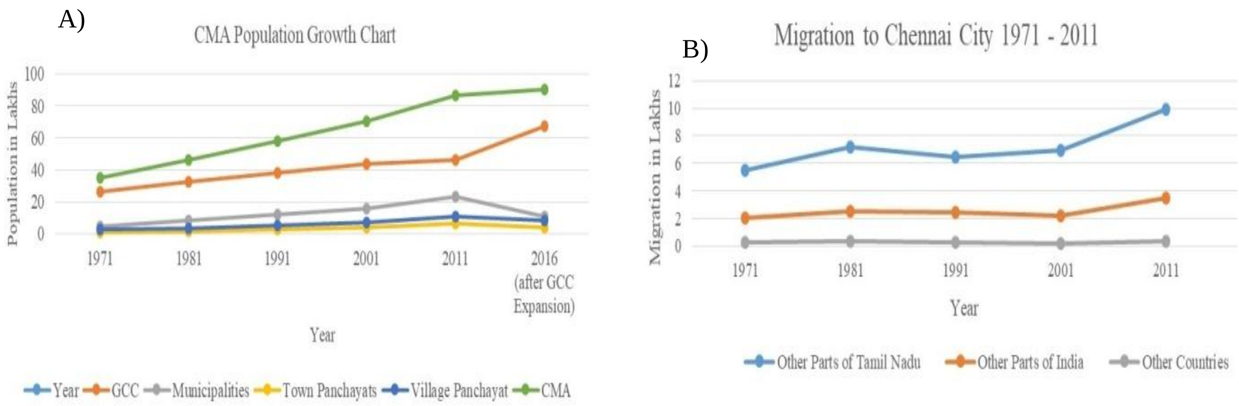


**Fig. 3: (A) CMA Population Growth 1971 – 2016 and (B) Migration to Chennai City 1971 – 2011**

This location precision ensures that emergency teams can quickly and accurately navigate to affected areas, optimizing the allocation of medical resources such as supplies, personnel and equipment, thereby minimizing the impact of water- and vector-borne diseases[41]. Overlaying geocoded healthcare facility locations with a social vulnerability map is instrumental for a precise and comprehensive analysis in flood-prone areas (Fig. 5A). By overlaying these datasets, we gain a nuanced understanding of the spatial distribution of healthcare resources in relation to socially vulnerable populations. Identifying areas with heightened social vulnerability and limited access to healthcare empowers authorities to implement targeted interventions, effectively address disease outbreaks and facilitate the strategic deployment of medical resources and emergency response teams in the aftermath of floods[34].

**Land use and Vulnerability Correlation:** Correlating Land Use and Land Cover (LULC) classes with flood vulnerability is crucial for understanding the dynamics of vulnerability in different areas. Each LULC class in figure 5B contributes uniquely to the flood vulnerability or resilience of the region, providing valuable insights for effective flood management and resilience planning[55]. Water bodies and inland wetlands are typically vulnerable to flooding, particularly during heavy rainfall and storm events. However, they can act as natural buffers, absorbing excess water and mitigating the impact of floods. Barren rocky including rocky areas and roads, typically has low permeability while potentially reducing flood risk in these areas as water is less likely to be retained.

Roads may contribute to vulnerability in terms of limited infrastructure development and may experience challenges during floods, as their design might not always account for intense water flow, leading to instances of flooding. The built-up nature of urban areas may lead to increased impervious surfaces, resulting in higher surface runoff during rainfall and contributing to urban flooding. The concentration of infrastructure in built-up areas can lead to widespread damage and economic loss during floods. Unculturable wastelands within urban areas may represent limited green spaces. The absence of greenery can exacerbate flooding impacts since vegetation plays a role in water absorption, reducing surface runoff. Forested areas including deciduous and plantation lands serve as natural barriers to flooding.

The vegetation can absorb and slow down the impact of rainfall, reducing surface runoff and preventing soil erosion. Green spaces offer recreational opportunities, support biodiversity and enhance overall community well-being. These are the factors that can positively influence resilience to environmental stressors including floods.

Crop lands are susceptible to flooding, especially during heavy rainfall or river overflow, leading to potential crop damage and economic losses. Sustainable agricultural practices and crop diversification can enhance resilience. Sandy areas, if devoid of vegetation, may have reduced capacity to absorb and retain water, potentially contributing to increased runoff during heavy rainfall. Fallow lands, if left unplanted and barren, may be prone to soil erosion and increased surface runoff during rainfall[55].

## Discussion

**Precision in Intervention:** Integrating social vulnerability data into flood response strategies enables a more targeted and precise approach. By understanding the specific vulnerabilities of communities, emergency responders can allocate resources effectively, reaching those who need assistance most urgently. The following recommended intervention strategies are tailored to the identified regions and aim to address the multifaceted challenges faced by socially vulnerable populations to flood events:

- Early Warning Systems and Evacuation Plans – Implement and enhance early warning systems to provide timely alerts to residents in socially vulnerable areas. Develop and communicate clear evacuation plans tailored to the unique needs of socially vulnerable populations including elderly individuals and those with limited mobility[56].
- Community Engagement and Information Dissemination – Conduct outreach programs to educate residents in socially vulnerable zones about flood risks, preparedness measures and evacuation procedures[32,49].

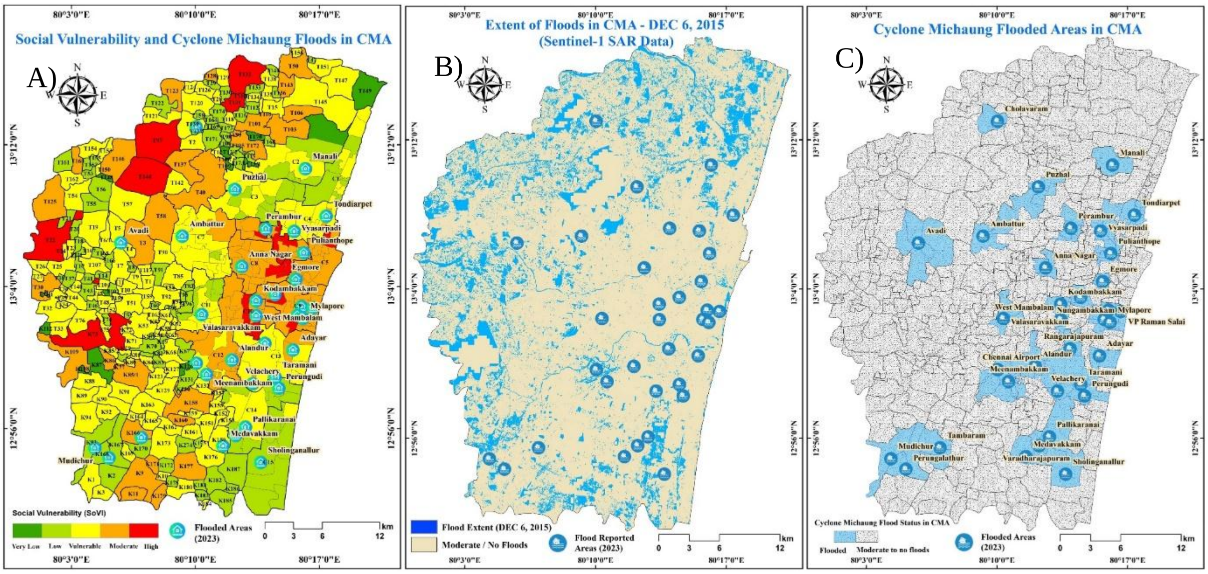


**Fig. 4: (A) Social Vulnerability and 2023 Flood Reported Areas in CMA, (B) Flood extent on DEC 6, 2015 in CMA and (C) Cyclone Michaung flood affected areas DEC 4, 2023 (Source: media reports).**

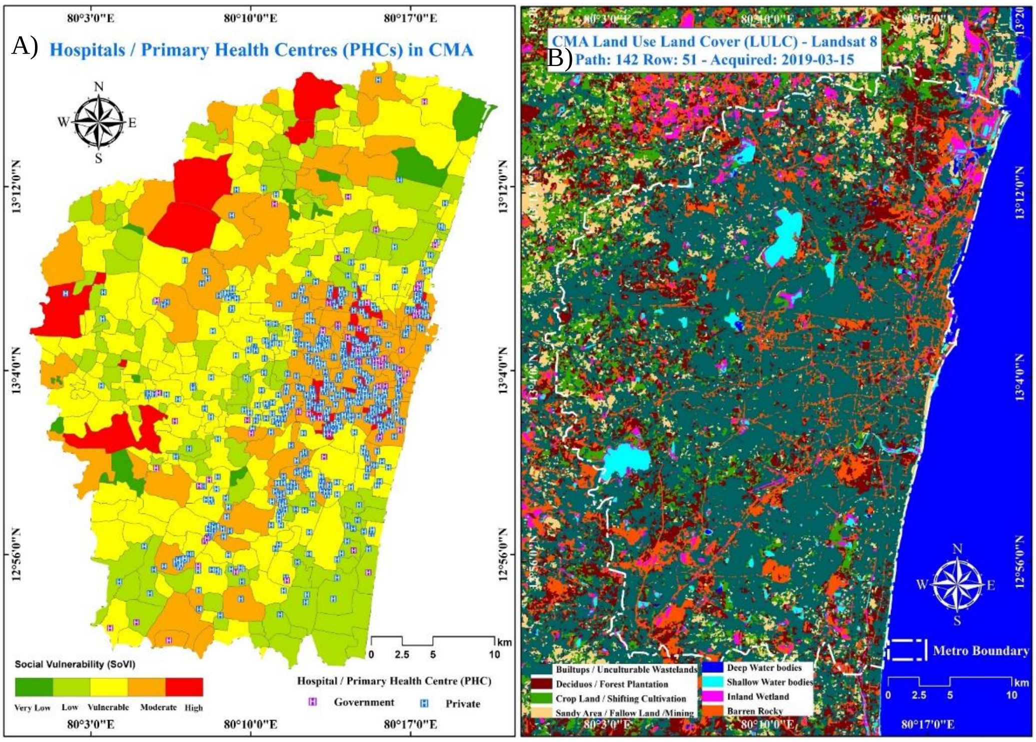


**Fig. 5: (A) Locations of Healthcare Facilities and (B) LULC extracted using Landsat 8 OLI.**

Establish local community centers or hubs to serve as information dissemination points and provide educational resources[49].

- Medical Outreach and Support Services – Set up temporary medical clinics or mobile medical units in socially vulnerable areas to provide healthcare services during and after flood event. Ensure the availability of medical supplies including those needed for pre-existing health conditions prevalent in vulnerable populations[64].
- Social Support Networks – Strengthen community support networks by collaborating with local organizations, NGOs and volunteers to assist, especially elderly residents and female-headed households. Establish communication channels for residents to seek help or report emergencies during floods[46].
- Infrastructure Improvements – Invest in resilient infrastructure development in socially vulnerable areas such as improved drainage systems and elevated housing, to minimize the impact of flooding. Upgrade and maintain roads and transportation infrastructure to facilitate safe and efficient evacuation[18].
- Accessible Shelters and Aid Distribution – Identify and designate accessible shelters equipped to meet the needs of socially vulnerable populations including medical care provisions, sanitary facilities and assistance. Coordinate with local authorities and humanitarian

organizations for timely and equitable aid distribution, considering the unique requirements of vulnerable residents[33].

- Psychosocial Support – Provide psychosocial support services to help residents cope with the mental health challenges associated with flooding, especially considering the potential trauma experienced by vulnerable populations[31,9].
- Post-Flood Recovery Assistance – Implement targeted recovery programs that focus on rebuilding homes, restoring livelihoods and providing financial assistance to socially vulnerable households affected by floods[21,47,60].

**Disease Prevention Strategies:** Flooding in socially vulnerable areas increases the risk of waterborne and vector-borne diseases. Tailoring disease prevention strategies to address the unique health vulnerabilities in these regions is crucial for anticipating and preventing disease outbreaks in the aftermath of floods. The following are the preventive strategies crucial in mitigating the impact of these diseases in flood-prone areas. Public health initiatives should prioritize these measures to safeguard the well-being of communities.

- Vaccination:
  - Typhoid Vaccination – Administering vaccines like Typhim Vi or oral Ty21a provides immunity against *Salmonella typhi*, the bacterium causing typhoid[3].
  - Hepatitis A and E Vaccination – Recommending vaccines for hepatitis A and E such as Havrix and Vaqta, especially in regions with a high prevalence of these viruses[45].
  - Dengue vaccination – Vaccines like Dengvaxia provide partial immunity against the dengue virus. However, vaccination strategies may vary depending on the region and prevalence[62].
  - Malaria Vaccination – Recommending antimalarial medications for travelers to endemic regions[54].
- Water Purification:
  - Boiling – Boiling water for at least one minute is a common practice to kill waterborne pathogens including those causing typhoid, leptospirosis and hepatitis A and E[13].
  - Chlorination – Adding chlorine to water sources is a widespread method for disinfection and is crucial for preventing the transmission of waterborne diseases[57].
- Vector Control:
  - Insecticide treated Nets (ITNs) – Using ITNs to prevent mosquito bites can reduce malaria transmission, distributing ITNs in malaria-endemic areas, particularly to vulnerable populations like pregnant women and children[37].
  - Indoor Residual Spraying (IRS) and Vector Surveillance – The IRS involves spraying insecticides on the interior walls of homes to kill or repel mosquitoes, reducing the risk of malaria transmission[65]. Monitoring and controlling mosquito populations through surveillance programs help to prevent the spread of dengue and malaria[16].
- Sanitation Improvements:
  - Improved Sewage Systems – Upgrading sewage systems helps to prevent the contamination of water sources with human waste, reducing the risk of waterborne diseases[22].
  - Elimination of Breeding Sites – Preventing stagnant water accumulation helps to control mosquito breeding, reducing the risk of dengue and malaria[35].
  - Waste Management – Proper disposal of waste, especially medical waste, is essential to prevent the spread of infections. Adequate waste management protects water quality and reduces potential breeding grounds for disease vectors[50].

**Community Resilience Enhancement:** Addressing fundamental causes of vulnerability such as economic disparities and restricted access to resources, becomes integral for effective long-term resilience planning. Designing such programs empowers vulnerable populations and can vary based on local needs, culture and resources.

- Community Workshops and Training – Workshops on disaster preparedness including flood response and evacuation procedures. Training sessions on health and hygiene practices to prevent water-borne diseases[17].
- Public Awareness Campaigns – Publicizing information through various media channels to raise awareness and ways to mitigate flood risks and conducting campaigns on the importance of vaccinations, clean water and sanitation for disease prevention[49].
- Community Meetings and Forums – Arranging meetings to discuss local issues, vulnerabilities and potential solutions and organizing forums for open dialogue between community members and local authorities[46].
- Local Volunteer Networks – Establishing and training local volunteer groups for emergency response and community support during and after floods[2].
- Crisis Communication Systems – Developing community alert systems and helplines for disseminating timely information during emergencies[51].
- Infrastructure Improvement Projects – Engaging the local community in projects like improving drainage systems and building shelters to strengthen the local infrastructure's resilience[8].

Implementing these programs in CMA involves understanding the local context and collaborating with community leaders, NGOs and local authorities. Additionally, utilizing communication technology and education can be effective in urban settings.

**Policy Implications:** Emphasizing the significance of land use and healthcare infrastructure in built-environment considerations can guide specific policy recommendations. If particular land-use patterns contribute to vulnerability, adjustments in urban planning policies may be necessary. Likewise, addressing gaps in healthcare infrastructure can inform targeted interventions. The following are the policy implications considered for long-term community resilience:

- Land Use Planning
  - Zoning Regulations – Implement zoning regulations to incorporate social vulnerability considerations of areas to flooding and other climate-related risks. Restrict certain types of infrastructure developments in high-risk zones and ensure that flood-prone areas adhere to resilience standards that account for the needs of vulnerable populations[6].
  - Green Infrastructure - Promote the integration of green spaces, wetlands and other nature-based solutions into urban planning. These elements can act as buffers against storm surges and flooding, contributing to urban resilience[7].
- Healthcare Infrastructure
  - Climate-Resilient Facilities – Develop and upgrade healthcare facilities focusing on climate resilience and designing critical healthcare infrastructure to withstand extreme weather events and flooding[27,36].
- Cross-Sectoral Collaboration
  - Interagency Coordination - Establish policies that promote collaboration between land use planners, healthcare professionals, environmental scientists, disaster management authorities, policymakers and local governments. Integrated approaches can lead to holistic solutions that address the intersection of land use, public health and social vulnerabilities[19].
  - Data Sharing and Analysis - Encourage policies to facilitate data sharing between health and social services which can be used for comprehensive vulnerability assessments, allowing for more targeted and effective interventions[43].
- Data-Driven Decision Making
  - GIS and Remote Sensing - Invest in technologies like Geographic Information Systems (GIS) and remote sensing for better mapping and monitoring of vulnerabilities and risks. Use data-driven insights to inform land use and healthcare policies[24].

## Conclusion

In this study, we undertook a comprehensive analysis of the intersectionality between social vulnerability, disease prevention and community resilience in the context of flooding, with a specific focus on Chennai Metropolitan Area (CMA). Through integrating advanced technologies, including satellite imagery and real-time data, coupled with insights derived from community engagement, we sought to unravel the nuanced dynamics that shape vulnerability and resilience in the face of floods[42]. Our examination of the social vulnerability map revealed vulnerable hotspots such as Adayar, Alandur, Anna Nagar, Kodambakkam, Royapuram, Teynampet, Thiru Vi Ka Nagar and Tondiarpet in Chennai City, other areas including Sriperumbudur, Pallavaram, Tambaram, Nedugundram, Chengalpattu in Kancheepuram district and Ambattur, Poonamallee and Ponneri in Tiruvallur districts emphasizing the critical need for precision in interventions.

Flood-affected areas, both in the aftermath of Cyclone Michaung in 2023 and the floods of 2015, coincided with regions characterized by heightened social vulnerability. This alignment magnifies the risk and potential disruption to the community's livelihoods, underscoring the urgent need for targeted strategies. The precision in intervention strategies proposed encompasses a multifaceted approach, addressing issues ranging from early warning systems and evacuation plans to infrastructure improvements and psychosocial support. Tailored strategies for disease prevention highlight the importance of considering unique health vulnerabilities in socially vulnerable areas, emphasizing the necessity of proactive measures to anticipate and prevent disease outbreaks post-flooding. The study also shed light on the role of community resilience enhancement, emphasizing the significance of community strengths and weaknesses in resilience planning.

Our findings underscored the severity of flood impacts on CMA, with socially vulnerable areas facing compounded challenges. The policy implications derived from our study emphasize the need for social vulnerability-informed health policies, resilient land use planning, cross-sectoral collaboration and inclusive post-flood recovery programs. These policy recommendations serve as a roadmap for decision-makers, guiding the development of holistic and context-specific strategies. Therefore, our study contributes valuable insights into the intricate relationship between social vulnerability, disease prevention and community resilience in flood-prone areas.

By recognizing and addressing the unique challenges faced by socially vulnerable populations, we pave the way for a more resilient and equitable response to floods, ultimately fostering sustainable and adaptive communities in the face of future challenges[67].

As we move forward, incorporating these findings into policy and practice becomes paramount, representing a crucial step in fortifying the overall flood resilience of CMA.

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