PLANNING STRATERGIES FOR MITIGATION OF URBAN FLOODS

A Thesis Submitted

in Partial Fulfilment of the Requirements

for the Degree of

MASTER OF PLANNING

by

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Under the Supervision of

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I, Mr. KUMAR DIVYAM, the author of the thesis titled ": PLANNING

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EXECUTIVE SUMMARY

In the current scenario, the rapid increase in population, coupled with changing lifestyles and preferences, is putting immense pressure on nature and natural resources. According to a United Nations report on World Urbanization, India is experiencing unprecedented urbanization, resulting in a higher urban population than ever before. This urbanization trend exposes cities to various disasters, with floods being one of the most frequent and prominent. Floods not only pose problems to vulnerable communities but also have a significant economic impact, setting back the nation's progress by several years.

Therefore, addressing urban floods and mitigating their impacts has become an urgent priority. Cities vulnerable to floods require comprehensive mitigation strategies that go beyond mere management. Proactive and progressive mitigation strategies are crucial due to the sudden and unpredictable nature of urban floods, as observed in various Indian cities in recent times.

While traditional flood control and management approaches contribute to urban floods by failing to address and accommodate unexpected hazards, it is essential to incorporate proactive and progressive measures that consider residual risks and are cost-effective in the long run. Achieving urban resilience, which enhances a city's capacity to withstand and recover from physical and socio-economic destruction caused by disasters, including floods, is one way to control and mitigate flood impacts. Cities undergo significant physical and social transformations, and the rapid pace of demographic, economic, and social changes in developing nations overwhelms local authorities' ability to provide essential urban services, especially during disasters. This highlights the crucial role of communities, citizens, and administrators as the first responders in such events.

This research aims to study and analyze the role of communities in mitigating urban floods to enhance city resilience and contribute to the achievement of Sustainable Development Goals (SDGs). Urban flooding is a major problem globally, particularly in coastal cities, leading to numerous catastrophic events each year. While urban floods cannot be prevented, they can be managed and mitigated through proper flood management planning. It is important to recognize that floods often result from anthropogenic activities such as encroachment in low-lying areas, illegal dumping, and the loss of wetlands due to concretization.

Floods occur when water overflows and submerges otherwise dry land, causing devastating impacts on life and property. Floods constitute a significant percentage of known disasters,

resulting in substantial social, cultural, economic, and ecological losses, especially in developing nations with inadequate adaptation and mitigation strategies. This research will focus on urban flooding and its associated aspects, emphasizing how proactive and progressive approaches can minimize flood impacts. In recent times, India has witnessed various urban floods, including the floods in Chennai, Kerala, Hyderabad, and cities in the Ganga and Brahmaputra basins. Urban flooding has become an annual and recurring phenomenon due to urbanization, which increases flood peaks and volumes. Unlike rural flooding, urban flooding affects densely populated areas, causing immense suffering and loss of life.

In addition to immediate human suffering, floods lead to secondary impacts such as infections, loss of livelihoods, and, in severe cases, death. Urban areas also host critical infrastructure that must be safeguarded, as damage to such infrastructure has far-reaching consequences. Disruptions in transportation, electricity, and the occurrence of epidemics are common outcomes of urban floods, resulting in loss of life, property, and economic activity.

Therefore, prioritizing flood mitigation and control is essential to mitigate the growing trend of urban flooding. As urbanization progresses rapidly, more challenges arise. Well-planned cities are crucial in the current context. In India, flooding in urban areas is a common problem that leads to significant destruction of life, property, and livelihoods. Inadequate drainage systems and encroachment of water bodies in cities and towns contribute to the increasing severity and unpredictability of urban floods.

Despite the involvement of various organizations in flood protection, there is a lack of cooperation in flood prevention, often excluding vulnerable communities. Public participation is vital in the planning and management process as they are the first responders during disasters. Engaging communities and utilizing their local knowledge is crucial for building resilience. Communities play a significant role in disaster response, including floods, and enhancing their capacity to cope with disasters is essential.

This research aims to develop aspects of flood risk management through community resilience, including preparedness, response, and recovery. By proposing a citizen-centric flood management framework that fosters inclusivity and progressiveness, this research seeks to promote public participation in flood control and management, contributing to the achievement of SDGs.

1. INTRODUCTION

The chapter commences by presenting an overview of the research topic, incorporating essential elements to grasp the background, challenges, gaps, and other pertinent factors. The introduction serves as a fundamental pillar for the entire research, drawing extensively from existing literature, scholarly investigations, and authoritative reports.

1.1. Background

Urban flooding poses a significant challenge in various regions worldwide, particularly in coastal cities, making it one of the most prevalent and recurring natural disasters annually. While it is impossible to prevent urban floods as they are natural occurrences, their impacts can be managed and minimized through timely and proactive measures.

Effective flood management and practical mitigation planning can help prevent the losses associated with such disasters. Urban flooding occurs when urban areas experience land or property inundation due to uneven rainfall distribution, extensive urbanization, and inadequate drainage systems.

In recent times, we have witnessed or at least heard of numerous urban floods in India, including the Chennai floods, Kerala floods, Hyderabad floods, and those affecting cities in the Ganga and Brahmaputra basins. Urban flooding has become an annual and recurring phenomenon.

Urban flooding differs significantly from rural flooding due to the modifications and establishment of catchments resulting from urbanization. Urban areas have a higher population density, which means more people are living in vulnerable areas compared to rural regions, resulting in greater suffering from flooding and potential loss of life. Additionally, the secondary impacts of floods, such as infections, can cause further human suffering and even fatalities. Furthermore, urban areas house critical infrastructure that must be protected at all times.

The consequences of urban flooding extend beyond the local level and have implications for the state, country, and even the global community. Major cities in India have experienced loss of life and property, disruptions in transportation and electricity, and the outbreak of epidemics as a result of urban flooding. Therefore, it is crucial to prioritize the mitigation and control of urban flooding.

The increasing trend of urban flooding is a global phenomenon, posing significant challenges for urban planners worldwide. The impacts of urban flooding can range from

minor incidents to severe events, causing cities to be submerged for hours, days, or even months. Consequently, the effects can be far-reaching, including temporary displacements, disruptions in public services, compromised water quality, and the potential for epidemics (NMMC, 2018). In times of unfortunate incidents such as flooding, communities are often the first responders. Individual residents and families residing in vulnerable areas play a crucial role in this regard.

Therefore, it is essential to raise awareness among disadvantaged populations and enhance their capacity to cope with such disasters. Adaptive urban institutions and societies should be capable of embracing, confronting, recovering from, and learning from such incidents. The objective of this study is to strengthen the capacity of urban structures and communities across all stages of flood risk management, including preparedness, response, and recovery. Through community resilience, various aspects of flood risk management, such as Reflect, Relief, Resist, Response, and Recovery, will be developed.

1.2. Problem Statement

In recent years, numerous research studies have focused on addressing the growing challenges posed by urban flooding, including its increasing frequency, magnitude, intensity, and uncertainty. However, there has been limited emphasis on proactive and progressive approaches, integrated and inclusive flood management strategies, and citizen-centric mitigation measures that incorporate local knowledge.

1.3. Need for study

Recent floods in various states of India have caused significant devastation to both lives and land. While natural factors contribute to flooding, there are also man-made causes that exacerbate the problem. India, with a large portion of its land area susceptible to annual flooding, remains highly vulnerable. The substantial losses and damages resulting from floods highlight the country's limited capabilities in terms of adaptation, mitigation, disaster management, and preparedness. Given that communities are the first responders in times of disaster, it is crucial to educate, train, and empower them to effectively respond to such events.

This approach not only helps minimize economic and physical losses but also enables authorities to mount a more rapid response. The focus is not only on improving but also on improving quickly, as immediate on-site crisis management is primarily carried out by local communities. Therefore, conducting research on inclusive and holistic flood management and mitigation frameworks, along with practical strategies, becomes imperative.

This research aligns with Sustainable Development Goal 11, which aims to create sustainable, inclusive, safe, and resilient cities and communities. The selection of this research topic is motivated by two main reasons:

a. Rapid urbanization: With urbanization occurring at a rapid pace in India, where over 34% of the current population resides in urban areas, as reported by the UN World Urbanization Report, it is crucial to address the challenges posed by urban floods.
b. Prominence of urban flooding: Urban flooding has received significant attention in recent times, particularly regarding how several major cities in India have been affected.

1.4. Research Gaps

Despite numerous efforts and research conducted on urban flood management both in India and abroad, the problem has persisted over the decades with limited improvement. Moreover, there has been minimal research focusing on the impacts of floods on the lives and livelihoods of affected communities. This serves as a warning to acknowledge the seriousness of the situation and address the existing gaps to achieve effective urban flood control and minimize the adverse physical and socio-economic consequences on cities. There are plethora of research papers available that highlight the significant yet often overlooked gaps, including epistemological (knowledge and awareness) gaps, institutional gaps, and strategic gaps in flood management (Albris, 2020).

These gaps need to be addressed in order to enhance understanding, strengthen institutions, and develop strategic approaches to mitigate the effects of urban floods. By conducting further research and filling these gaps, we can work towards achieving more comprehensive and sustainable solutions for urban flood management.

According to the 2017 audit report by India's Comptroller and Auditor General (CAG) on "Schemes for Flood Control and Flood Forecasting," several significant problems have been identified in flood management in India (CAG, 2017). These include:

a. Inadequate flood forecasting system: The flood forecasting network of the Central Water Commission (CWC) does not effectively cover or monitor the entire nation, and there are issues with the functionality of existing flood forecasting stations.
b. Insufficient flood risk mapping: The special task force established by the CWC in 2006 for flood risk mapping did not complete its assigned task. Furthermore, India's vulnerability atlas lacks comprehensive flood zoning, and assessments of flood damage are inefficient.
c. Delays in project completion: There are significant delays in completing projects related to flood management, primarily due to a lack of assistance from the central government.
d. Lack of integrated approach: Flood management operations in India are often approached and implemented in isolation, rather than being part of an integrated and coordinated strategy.
e. Inadequate disaster management plans for dams: A large number of dams in India do not have proper disaster management plans and mitigation strategies.
f. Only approximately 7% of the country's large dams have emergency action plans and/or disaster management plans.

Additionally, other shortcomings can be observed in existing flood management plans in India. One significant issue is the reliance on an outdated and passive approach, where the focus is primarily on structural measures.

This approach neglects crucial elements such as community engagement, pre-implementation planning and zoning, non-structural interventions, and effective coordination between different entities. It is a reactive strategy that becomes active only after a catastrophe occurs, without prioritizing proactive flood preparedness, mitigation, and other essential aspects of flood management (S. Duggal, 2019). This approach, characterized by minimal effort in terms of time and resources, only responds to emergencies rather than implementing comprehensive and sustainable flood management strategies.

In order to effectively address urban flooding, it is crucial to shift away from a passive approach and recognize the need for continuous adaptation and proactive strategies. As the saying goes, "Success is a success only when it is continuous," emphasizing the importance of continuously evolving flood management strategies in response to changing circumstances. One of the major challenges is poor implementation of flood management projects, often characterized by delays and non-adherence to ethical standards. This can

be attributed to various factors such as violations of laws and guidelines, corruption, fund diversion, and a lack of financial resources. Another critical aspect that needs attention is the absence of collaborative governance and inclusion in existing plans and policies. Currently, plans and policies in India are often developed in isolation by different departments, neglecting the multi-dimensional nature of flooding events.

To address this, it is essential for various organizations, departments, and agencies to work together towards a common goal. This collaborative approach ensures clarity of actions and steps to be taken during disasters, minimizing confusion and maximizing efficiency. Additionally, the inclusion of first responders and local expertise is vital. They possess valuable knowledge and strategies to deal with emergencies and should be actively involved in planning and capacity building efforts. Increasing awareness through initiatives such as awareness camps, promoting stakeholder engagement, improving communication, and teaching efficient resource management strategies are important steps towards building resilient and inclusive societies.

In summary, adopting a proactive approach, ensuring effective implementation, and promoting collaborative governance and inclusion are crucial for mitigating the impacts of urban floods. These measures require continuous adaptation, adherence to ethical practices, and the involvement of diverse stakeholders to create a resilient and sustainable flood management framework.

The management of urban floods in India has been plagued by various challenges, including improper management practices. Despite the presence of numerous management plans, both current and historical, they have proven to be ineffective in adequately addressing the issue. One of the reasons for this ineffectiveness is the failure to consider residual risks that can arise unexpectedly. These risks need to be accounted for in order to develop comprehensive and proactive flood management strategies.

Additionally, the lack of implementation of multiple steps within the management plans hinders their effectiveness. It is essential to ensure that all necessary measures are implemented in a coordinated manner to achieve the desired outcomes. Furthermore, the creation and maintenance of a shared database is crucial for effective flood management. Accessible and up-to-date data plays a vital role in decision-making and planning processes.

However, one of the most critical aspects of proper flood management is the ongoing management and maintenance of flood control infrastructure. Neglecting regular

maintenance activities can lead to the deterioration of infrastructure, rendering it ineffective during floods.

This highlights the importance of allocating sufficient resources and attention to the long-term management and maintenance of flood control systems. In summary, the improper management of urban floods in India can be attributed to the lack of consideration for residual risks, inadequate implementation of comprehensive strategies, the absence of a shared database, and insufficient management and maintenance of flood control infrastructure. Addressing these issues is crucial for improving the overall effectiveness of flood management plans and reducing the impacts of urban flooding.

1.5. Aim and Objectives

To develop a comprehensive methodological framework for urban flood mitigation in Hyderabad city.

The aim of this research is to develop a comprehensive methodological framework for urban flood mitigation in Hyderabad city. The framework will focus on integrating various strategies and measures to effectively reduce the impact of floods and enhance the city's resilience. The research will involve conducting a thorough assessment of flood risks, evaluating existing infrastructure, analysing urban planning practices, and exploring community engagement initiatives. The goal is to provide a systematic approach that addresses the specific challenges faced by Hyderabad, taking into account its geographical, environmental, and socio-economic factors. The framework aims to guide policymakers, urban planners, and stakeholders in implementing proactive and sustainable measures for flood mitigation in the city.

Objective 1: The first objective of this research is to analyze the flood risk characteristics of Hyderabad city. This involves studying historical flood events, rainfall patterns, topography, drainage systems, and other relevant factors to understand the vulnerability of different areas to flooding. The objective is to identify the most vulnerable areas in the city and assess the potential impact of floods on infrastructure, communities, and the environment.

Objective 2: The second objective is to assess the current flood mitigation practices in Hyderabad city and identify the gaps and shortcomings in the existing approach. This includes evaluating the effectiveness of flood control measures, early warning systems,

emergency response plans, and coordination among relevant authorities. The objective is to identify areas where the current practices are insufficient or ineffective in reducing flood risks and mitigating the impacts.

Objective 3: The third objective is to recommend strategies for the adoption of the proposed methodological framework in Hyderabad city. Based on the findings from the analysis of flood risk characteristics and assessment of current practices, this objective involves developing recommendations for improving flood mitigation in the city. These recommendations will align with the proposed methodological framework and address the identified gaps and shortcomings. The objective is to provide actionable strategies that can be implemented to enhance the city's flood resilience and reduce the adverse effects of flooding.

1.6. Scope

Existing flood management plans often neglect progressive measures and fail to integrate non-structural approaches alongside traditional structural measures. This research aims to emphasize the importance of incorporating non-structural measures and community involvement into flood control strategies.

By focusing on the wards that have experienced past flood events, the study will analyze the factors contributing to disparities in outcomes. The objective is to minimize casualties, economic losses, and resource wastage while enhancing community resilience. Furthermore, capturing real-life experiences and strategies adopted by communities will inform the development of a comprehensive flood management framework that integrates both non-structural and structural measures. This inclusive approach ensures efficient addressing of local issues and fosters resilience in the face of flooding.

To minimize losses and enhance efficiency in recovery, non-structural interventions play a crucial role in flood management. These interventions do not rely on physical infrastructure but instead focus on knowledge, practices, and understanding to mitigate disaster risks and impacts. Examples of non-structural measures include policies, regulations, public awareness campaigns, training programs, and educational initiatives.

By implementing non-structural strategies, such as land use regulations, flood forecasting and warning systems, flood-proofing techniques, and disaster mitigation and preparedness

mechanisms, the destructive effects of floods can be mitigated without disrupting the natural flow of water. These interventions have minimal environmental implications and should be actively considered as viable alternatives, either independently or in conjunction with structural flood management measures.

1.7. Limitations

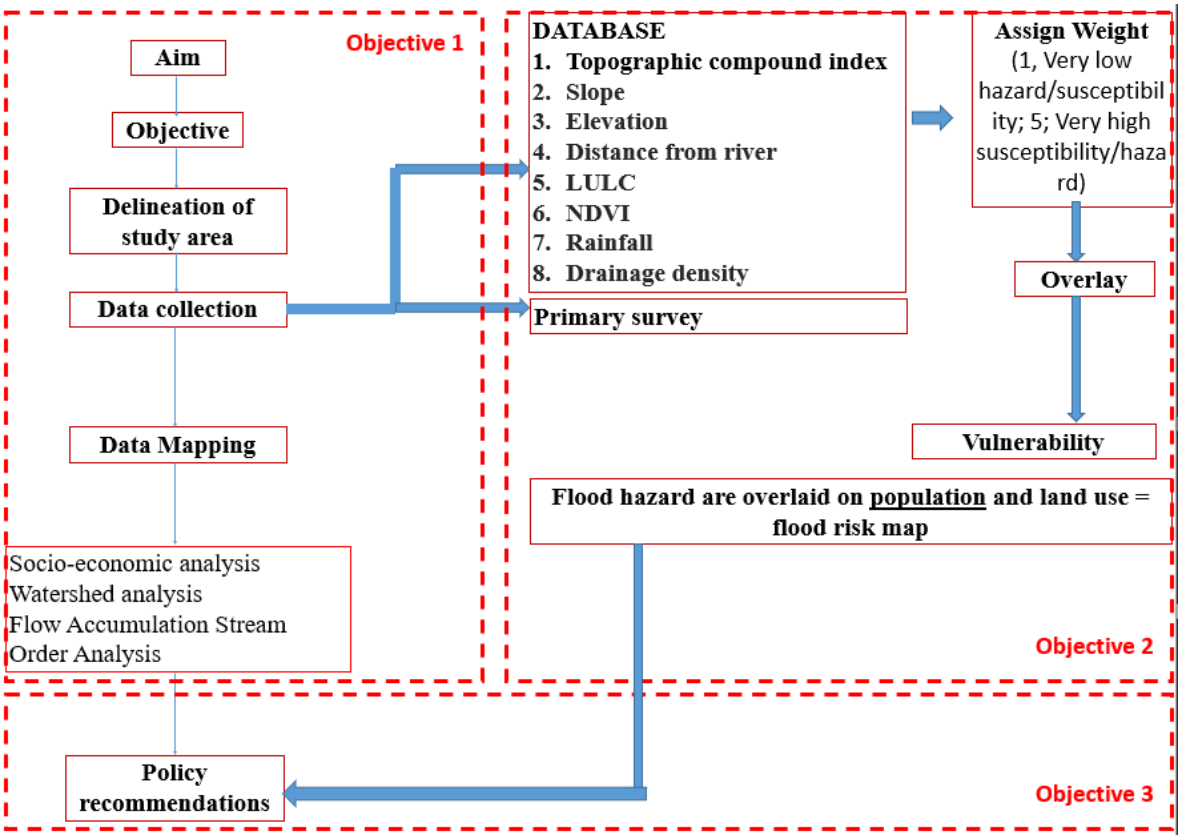
Due to time constraints, researchers are confronted with challenges in conducting a comprehensive study on the subject. Consequently, this study has certain limitations that need to be acknowledged, including:

a. The research does not encompass the examination of financial aspects directly or indirectly related to the study.
b. Flood events that occurred more than ten years ago will not be included in the analysis.
c. The primary focus of the study will be on the affected communities, neglecting other aspects associated with urban flooding.
d. The study will not delve into the detailed technical and structural aspects of the proposed framework.

It is important to recognize these limitations in order to have a clear understanding of the scope and boundaries of the research.

1.8. Methodology

Methodology serves as a roadmap for researchers, providing a clear outline of the steps that need to be followed in the research process. It plays a crucial role in ensuring the reliability and validity of the study and serves as a guide for future reference. The methodology outlines the research design, data collection methods, sampling techniques, and data analysis procedures that will be employed. It also addresses any ethical considerations, limitations, and potential biases. By following a well-defined methodology, researchers can conduct their study in a systematic and organized manner, enhancing the credibility and rigor of their findings.



1.9. Expected Outcomes

The outcome of this research will be a set of policies and interventions aimed at enhancing community engagement in flood prevention, preparedness, mitigation, recovery, as well as overall regeneration and growth processes. These measures will be focused on strengthening neighbourhood resilience and implementing spatial and policy strategies. By doing so, the research aims to foster greater community involvement and participation in tackling flood-related challenges. The implementation of these strategies will contribute to the development of more resilient and sustainable communities, capable of effectively addressing and adapting to flood risks.

2. LITERATURE REVIEW

This chapter provides an overview of the conceptual and theoretical foundations related to the chosen topic and theme. It incorporates a wide range of existing research, reports, documents, literature works, concepts, case examples, and frameworks that have enabled me to gain a comprehensive understanding of the relevance of the thesis title to current research. Despite the existence of numerous studies on the subject, this chapter highlights the need for conducting this specific study and justifies its importance in the present circumstances. It builds upon existing knowledge and identifies gaps that warrant further investigation, contributing to the existing body of literature on the topic.

2.1. Concepts

Flooding refers to the situation when water exceeds its normal boundaries and inundates land that is typically dry, with low-lying areas being particularly vulnerable. It can occur due to the overflow of rivers, lakes, or other water bodies, or due to uneven distribution of rainfall leading to water accumulation in specific areas. Regardless of the cause, flooding has severe implications for both human life and property.

The consequences of flooding can be devastating, resulting in loss of lives, damage to infrastructure, displacement of communities, and economic setbacks. Managing and mitigating the impacts of flooding is crucial to protect lives and minimize the destruction caused by such events.

2.1.1. Flood and its impacts

Floods have a significant impact on society, culture, economy, and the environment, particularly in developing countries with limited adaptation and mitigation measures. As highlighted in the IFRC's World Disaster Report, floods account for a significant portion of known disasters worldwide. Therefore, my study focuses on urban flooding and its associated issues, aiming to reduce their impact through a constructive and progressive approach.

Floods not only disrupt the daily lives of citizens but also have adverse effects on the environment, including damage to agricultural crops, disruption of transportation and communication networks, and other critical infrastructure. Flood victims face multiple challenges, including environmental issues, loss of life, and property. These crises

often leave them unable to adapt to the changing circumstances brought about by socio-political, economic, and cultural factors. Therefore, the study aims to address these complex problems and develop strategies to enhance resilience and mitigate the impacts of urban flooding.

Additionally, the study recognizes that urban flooding is not just a localized issue but also has broader implications. It affects the socio-economic fabric of communities, disrupts livelihoods, and hampers the overall development of urban areas. Therefore, it is crucial to adopt a comprehensive and integrated approach that takes into account various dimensions of flood management, including prevention, preparedness, response, and recovery.

2.1.1.1. Global Scenario

Floods are considered one of the most severe and frequent natural disasters, posing significant threats to human lives and causing extensive damage. With the increasing impacts of climate change, the incidence of urban flooding is on the rise worldwide. However, in many Asian cities, including Hyderabad, there is a lack of comprehensive urban flood-proofing and management strategies, demanding urgent attention from city councils and local governments.

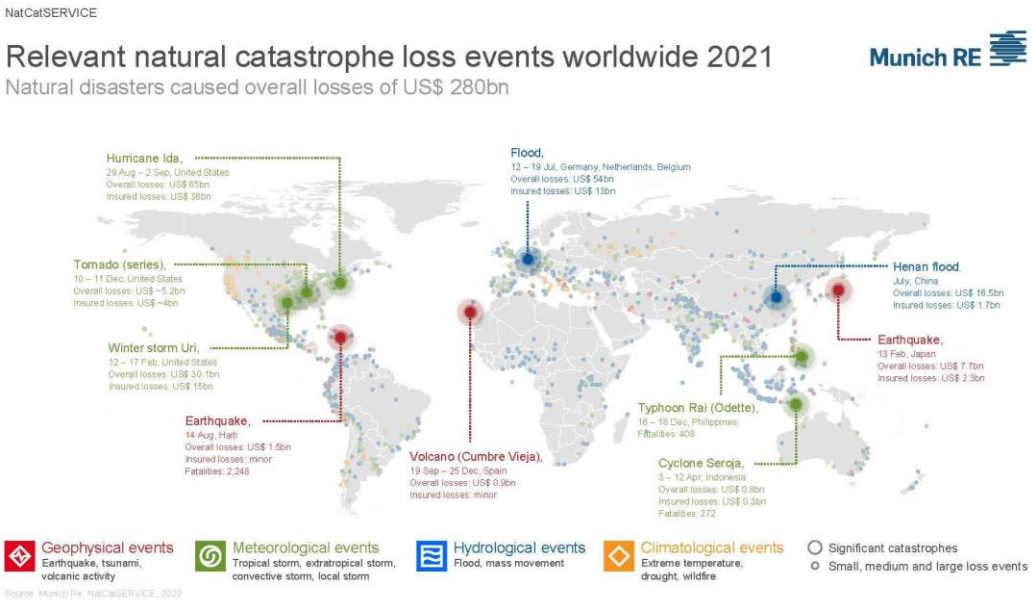
India, due to its geographical location and monsoon climate, has experienced severe economic losses due to floods. According to the Central Water Commission (CWC), flooding in India has resulted in the loss of approximately 1600 lives. The existing drainage systems often prove inadequate in handling excessive rainfall, leading to water overflow and the inundation of municipal infrastructure and buildings.

To address these challenges and ensure a better and safer future, it is crucial to implement effective urban flood-proofing and management strategies. This requires adopting a holistic approach that integrates both passive and progressive measures. Passive measures involve structural interventions such as improved drainage systems, embankments, and flood-resistant infrastructure, while progressive measures focus on non-structural interventions like community engagement, public awareness, and policy development.

The literature review conducted for this study will examine existing research, reports, and case studies from various sources. It will highlight successful urban flood

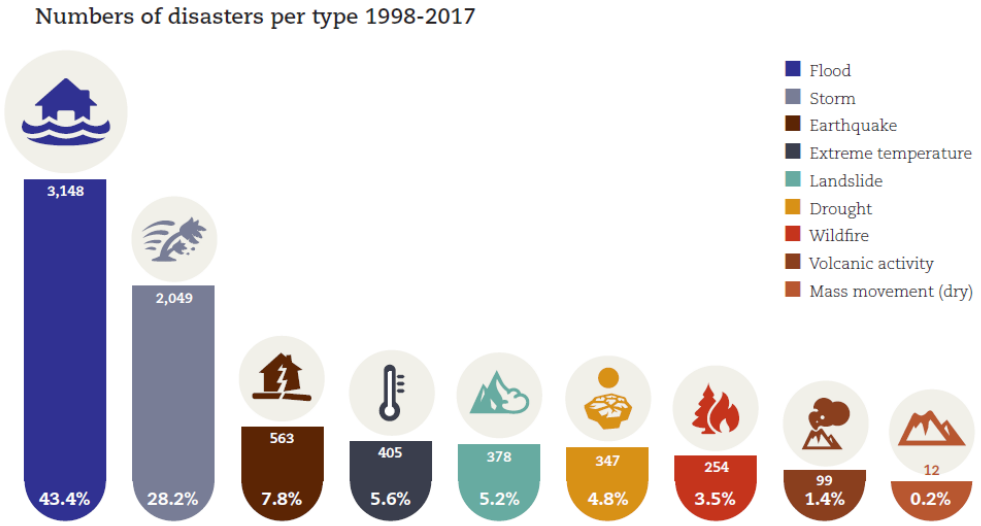
management approaches implemented in other cities around the world and identify the gaps and shortcomings in the current strategies. By synthesizing the findings, the study aims to develop a comprehensive framework tailored to the specific context of Greater Hyderabad, emphasizing the importance of both passive and progressive approaches to mitigate the impacts of urban floods.

Figure 1: Global Disaster Status 2021



Source: Eco Business News

Figure 2:Disaster occurrence and intensity of its impact

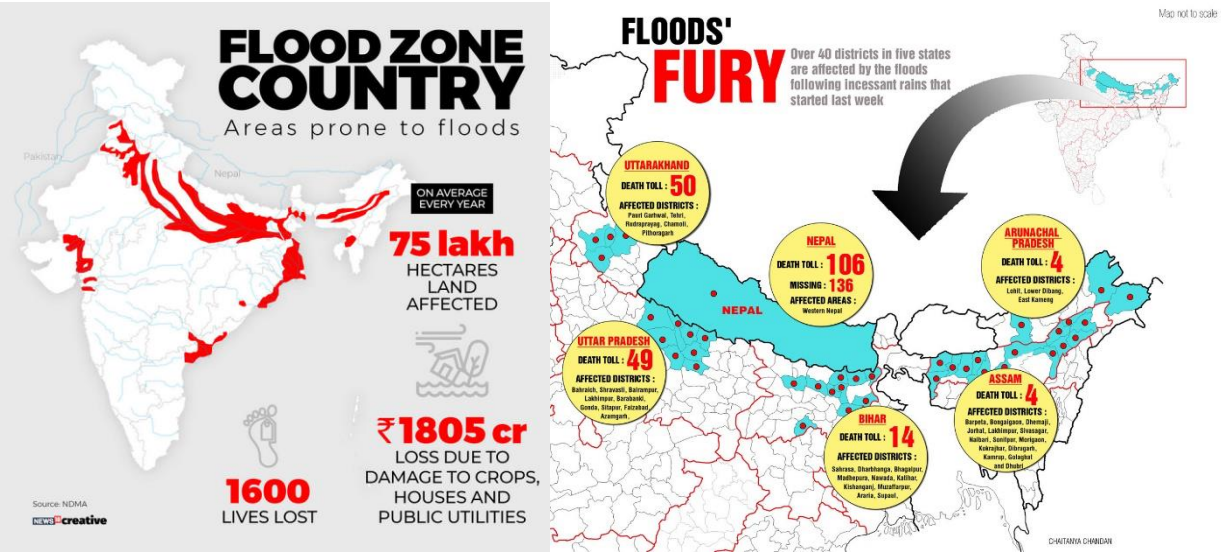


Source: Report on Global Disaster Statistics by CRED (Disasters, 2017)

2.1.1.2. Indian Scenario

The rapid urbanization phenomenon has given rise to a host of challenges, and the need for well-planned cities has become increasingly urgent. In the context of India, urban flooding has become a recurring problem, leading to substantial loss of life, property, and livelihoods. Floods in urban areas of India have become more severe, unpredictable, and difficult to manage. In 2018 alone, floods caused damages exceeding Rs. 950 billion in the country. The frequency of urban floods is attributed to inadequate drainage systems and the encroachment of water bodies in cities and towns. These factors contribute to the escalating occurrence of urban floods, necessitating effective measures to address this issue.

Figure 3:: National Disaster Status



Source: Annual National Disaster Report, 2019 (NDMA, 2019)

India, with its vast population of 1.38 billion people and its susceptibility to floods, faces a complex and challenging situation. Multiple agencies, authorities, and organizations have implemented various systemic and emergency management initiatives to reduce the likelihood of floods and mitigate their impacts.

However, the desired milestones in flood management have not yet been achieved. Despite the Indian Meteorological Department's prediction of a normal monsoon for the 2020 season, regional variations in rainfall have resulted in urban flooding. In recent decades, there has been an increase in severe rainfall events, characterized by irregular

and intense downpours in short intervals. Factors such as inadequate drainage systems, extensive concrete urbanization, encroachment of water bodies, and haphazard waste disposal have further worsened the situation.

While several organizations are involved in flood protection efforts, there is a significant lack of cooperation in flood prevention, as well as the exclusion of vulnerable communities. The valuable knowledge and insights of local communities are often ignored and unheard, as they are not actively included in the planning and management processes. This exclusion hampers their resilience. Therefore, public participation plays a crucial role in the planning and management of floods, as communities are the first responders and hold valuable vernacular wisdom that can contribute to effective flood mitigation strategies.

2.1.2. Urban Flooding

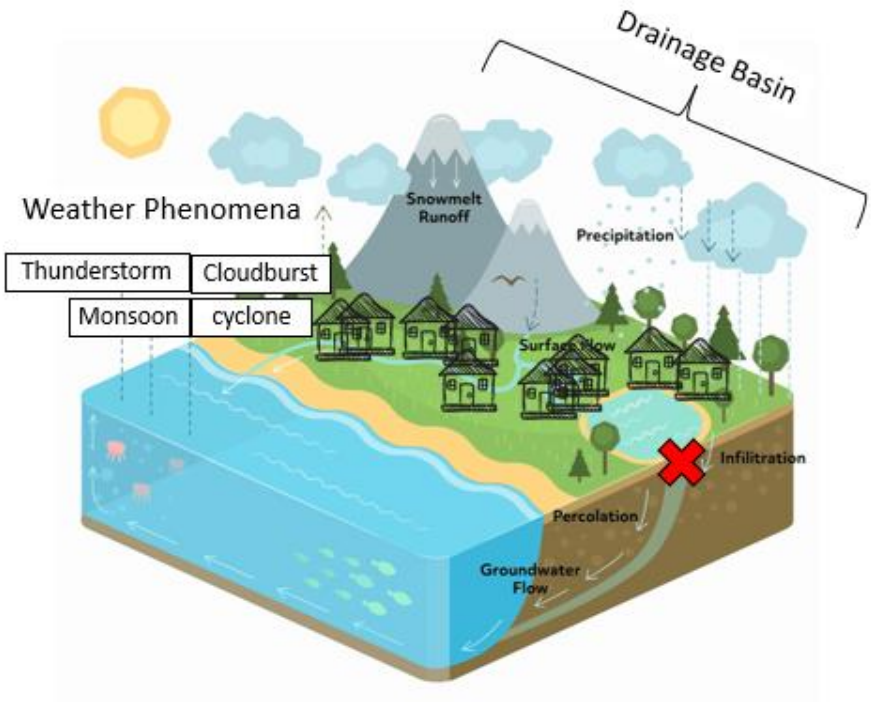
In recent times, urban floods in various Indian cities have garnered significant media attention due to the loss of lives and destruction of property, which has unfortunately become an annual occurrence in most cities. The onset of monsoon season in India has become more pronounced, leading to disruptions in the daily lives of the vast urban population. It is important to note that urban flooding is not unique to India but is a common phenomenon in cities worldwide.

India, being one of the most flood-prone nations, experiences approximately 60% of its flood damage from river floods, while cyclones and heavy rainfall account for the remaining 40% (NMMC, 2018). Urban flooding, caused by factors such as uneven distribution of rainfall, inadequate storm sewers, organic urbanization, encroachment on natural drainage channels, and the filling of urban reservoirs for urban development purposes, is a well-known occurrence in both India and the rest of the world. It differs significantly from rural flooding due to the impact of urbanization on existing catchments, resulting in increased flood peaks and volumes.

Furthermore, the loss of urban water bodies, including lakes, wetlands, springs, and rivers, is a growing concern for planners, officials, and politicians. Urbanization has led to over-exploitation, over-extraction, and encroachment on these water bodies. Illegal settlements and industrial discharge also contribute to their degradation. Preserving and restoring these natural water bodies is crucial for sustainable urban development and effective flood management.

Overall, urban flooding poses significant challenges to cities in India and globally. It is vital for policymakers, urban planners, and communities to address the underlying causes, such as inadequate infrastructure, unplanned urbanization, and encroachment, while also considering sustainable water management practices to mitigate the impacts of urban floods.

Figure 4:Factors contributing to the Floods



Source: Edited by author

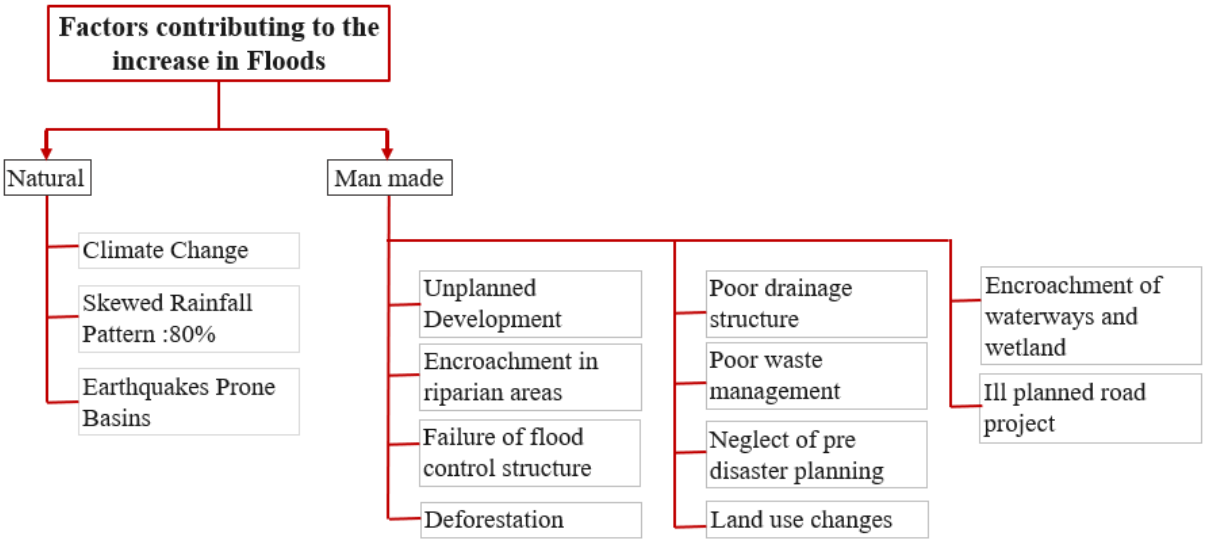
Urban flooding is influenced by a variety of factors that contribute to the increased risk and severity of floods in cities. These factors can be broadly categorized into natural factors, human factors, and infrastructural factors. Understanding these contributing factors is crucial for effective flood management and mitigation strategies. Here are some key factors that contribute to urban flooding:

Rainfall Patterns: Uneven or intense rainfall patterns, often associated with climate change, can overwhelm urban drainage systems. Sudden, heavy downpours or prolonged periods of rainfall can exceed the capacity of stormwater infrastructure, leading to water accumulation and flooding.

a. **Impermeable Surfaces:** Extensive urbanization results in the creation of impermeable surfaces such as concrete roads, pavements, and buildings. These surfaces prevent rainwater from infiltrating into the ground, causing rapid runoff and increased surface water flow into drainage systems.
b. **Inadequate Drainage Systems:** Insufficient or outdated drainage systems are unable to cope with the volume and intensity of rainfall. Inadequate capacity, blockages, and improper maintenance of drains, pipes, and culverts can impede water flow and contribute to urban flooding.
c. **Encroachment of Water Bodies and Floodplains:** Unplanned urban expansion often encroaches upon natural drainage channels, water bodies, and floodplains. The filling of wetlands, reclamation of rivers, and construction in flood-prone areas reduce the natural absorption and storage capacity of water, exacerbating flood risks.
d. **Urban Stream Channelization:** Straightening or channelizing natural streams and rivers to facilitate development can disrupt the natural flow dynamics and increase flood risks. This modification reduces the ability of water bodies to hold and convey excess water during heavy rainfall events.
e. **Land Use Changes:** Poor land use planning and zoning practices can contribute to urban flooding. Construction on slopes, hillsides, or in areas prone to flash floods can increase runoff and erosion, leading to localized flooding. Inappropriate land use decisions also result in the loss of natural water retention areas.
f. **Rapid Urbanization and Population Growth:** Unplanned and rapid urbanization often outpaces the development of adequate infrastructure. The rapid expansion of cities, accompanied by increased population density, places additional stress on existing drainage systems and increases the vulnerability to flooding.
g. **Poor Waste Management:** Improper disposal of solid waste and debris can clog drains, culverts, and waterways, impeding water flow and exacerbating flooding. Plastic waste, in particular, is a significant contributor to blockages in urban drainage systems.
h. **Climate Change:** Climate change, with its associated changes in weather patterns, including increased rainfall intensity and frequency, can amplify the risk of urban flooding. Rising sea levels can also lead to increased coastal flooding in low-lying urban areas.
i. **Lack of Public Awareness and Preparedness:** Insufficient awareness among residents regarding flood risks and inadequate preparedness measures can hinder effective response and exacerbate the impacts of urban flooding. Lack of education and

knowledge about flood risk reduction measures and early warning systems can result in increased vulnerability.

Figure 5: Factors contributing in floods



Source 1 Author

2.1.3. Floods and Urban Resilience

Illegal filling of urban water bodies is a prevalent issue in cities like Calcutta, Chennai, Delhi, Hyderabad, and others. Given India's susceptibility to annual floods and the resulting high losses and damages, it is evident that the country's adaptation and mitigation efforts are inadequate. There is a need for better disaster understanding, preparedness, management, and mitigation strategies.

While flood control is important, I believe that prevention holds greater significance, as disasters are unpredictable and their magnitude and intensity cannot be foreseen. Therefore, effective mitigation measures become crucial to minimize casualties and physical damage in urban areas.

The concept of urban resilience pertains to a city's ability to endure flooding, recover from physical and socio-economic disruptions, prevent loss of life and injuries, and maintain its socio-economic identity. It also involves the city's capacity to rebuild after a flood event and improve its functionality through a "build back better" approach. As cities become more concentrated with people and assets, they face a complex range of shocks and stresses. Urban resilience aims to help communities adapt to these changing

conditions and endure shocks while preserving essential functions. Disaster risk management and addressing the impacts of climate change have long been central to the concept of urban resilience.

Building urban resilience is an ongoing process that requires the engagement of all community members over time. It plays a critical role in ensuring urban protection and sustainability. As cities evolve and develop, their risk vulnerability profiles change as well. Therefore, continuous efforts must be made to enhance urban resilience in all aspects. This includes considering various dimensions such as physical infrastructure, social cohesion, economic systems, and environmental sustainability.

By prioritizing urban resilience, cities can effectively manage flood risks, adapt to climate change, and ensure sustainable development. This requires a comprehensive approach that integrates disaster risk reduction strategies, climate change adaptation measures, robust infrastructure planning, community participation, and effective governance. By fostering resilience, cities can withstand shocks and stresses, recover more quickly from flood events, and continue their developmental progress while reducing poverty and protecting their residents**.**

2.1.4. Public participation

While public involvement is crucial in post-disaster recovery planning, it is important to acknowledge that specific challenges and opportunities arise in such situations. The success of participation largely depends on the recovery policies and planning features that are implemented. This study aims to focus on an inclusive and transparent process that instills hope and encourages residents to become champions of recovery initiatives. However, it is essential to address certain issues such as unpreparedness in planning, participant homogeneity, and the tendency to bypass deliberation, as these factors can limit the voices of disadvantaged citizens and hinder the effective implementation of proposals.

One key aspect of this research is to explore the practices of community involvement in flood prevention worldwide. It is important to understand the difficulties faced by local governments in engaging communities in flood prevention efforts. By examining

different approaches and experiences, valuable insights can be gained to improve community participation in flood prevention and recovery processes.

To ensure equitable participation, economically disadvantaged populations that are under-represented should be actively included in all stages of recovery planning. This can be achieved through intentional outreach campaigns tailored to their specific circumstances. Meaningful engagement should go beyond simply seeking feedback and involve interested stakeholders in deliberative processes. This can be facilitated by experienced planners and technical experts who can guide and support the participatory preparation process in the post-disaster context.

By prioritizing inclusive community involvement in recovery planning, it becomes possible to harness the collective knowledge and experiences of residents. This can lead to more effective and sustainable recovery outcomes, as diverse perspectives are considered, and the needs of disadvantaged populations are addressed. Ultimately, through intentional and inclusive participation, the resilience and capacity of communities can be enhanced, enabling them to better cope with and recover from future flood events.

2.1.5. Community-based mitigation strategies

Even prior to the establishment of formal governance structures, communities have long relied on their own mitigation methods to address disaster risks. The concept of community-based disaster risk mitigation has emerged as a systematic approach to support societies in managing and reducing risks (Shaw, 2016). In the event of a disaster, two key actors play crucial roles: the local government and civil society. In India, with the projected increase in floods, people residing in low-lying coastal areas are expected to face heightened risks of displacement by the end of the century (IPCC, n.d.).

Recognizing that communities are often the first to experience and respond to any tragic or hazardous event, it is vital to engage them in disaster risk reduction (DRR) efforts. Community-based interventions have shown significant positive impacts wherever they have been implemented and embraced. By promoting community participation and ownership, these interventions contribute to safer conditions, more

secure livelihoods, and sustainable development, aligning with Sustainable Development Goal 11 of creating sustainable cities and communities.

By involving local communities in disaster risk mitigation strategies, their knowledge, experiences, and values can be leveraged to enhance resilience and foster sustainable growth. Community-based interventions not only empower individuals and communities to take proactive measures but also promote a sense of collective responsibility and solidarity. As a result, communities become better equipped to face future disasters, minimize risks, and adapt to changing circumstances.

The effectiveness of community-based approaches lies in their ability to integrate local perspectives, traditional knowledge, and social networks into disaster management processes. By bridging the gap between top-down governance and grassroots engagement, community-based interventions create a more inclusive and comprehensive approach to disaster risk mitigation. This collaborative effort between local governments, civil society, and communities establishes a foundation for building resilient societies that can withstand and recover from the impacts of floods and other disasters.

2.2. Case Examples

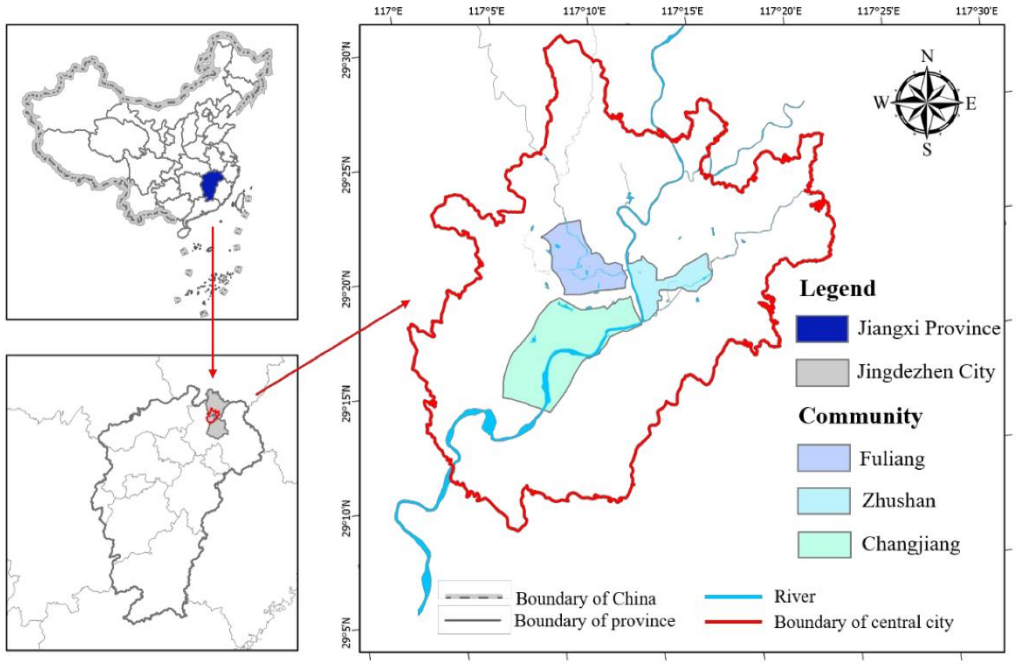
Case studies have long been used as a qualitative research tool in the social sciences. They provide in-depth insights into real-life situations and serve as a foundation for implementing ideas and methods. Case studies allow researchers to explore complex phenomena, understand practical implications, and bridge the gap between theory and practice. They inform decision-making, drive positive change, and contribute to knowledge advancement.

2.2.1. Global: Jingdezhen, China

Jingdezhen, located in Southeast China, is a populous city with approximately 1.8 million residents and a land area of about 400 square kilometres. It is situated along the Changjiang River, which flows from north to south, and is intersected by various tributaries such as the Sanlvmiao River and the Nanhe River. The city experiences frequent and severe flooding, resulting in significant economic

damage and widespread devastation. However, despite the recurring floods, Jingdezhen has gained renown as the "City of Chinaware" due to its expertise in producing exquisite porcelain artifacts. This unique artistic heritage has turned the city into a popular tourist destination, despite the ongoing flood challenges. Authorities and the government have focused primarily on flood control measures and addressing factors that contribute to flooding and associated losses. (Sources: Sun, 2017; Wang, 2018).

Figure 6: Study area of Jingdezhen City in Jiangxi Province, China. Three typical flood-prone communities of Fuliang, Changjiang, and Zhushan are selected in central Jingdezhen City.



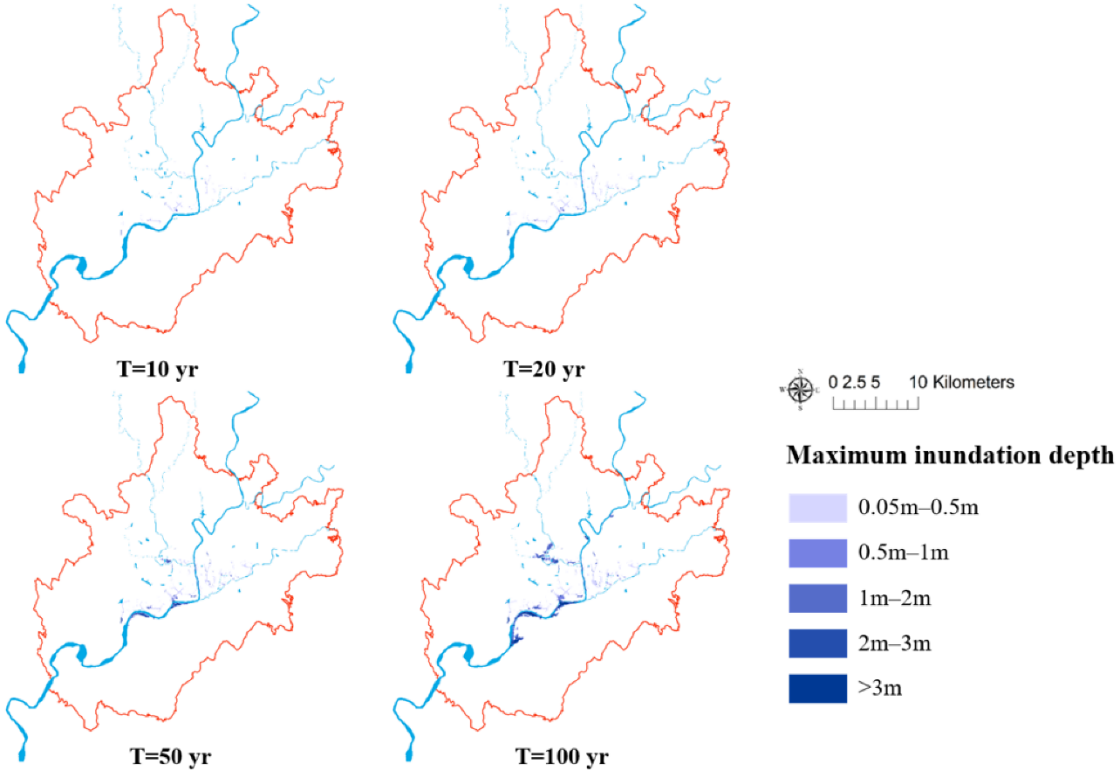
Source: Zhang, Jingxuan, Huimin Wang, Jing Huang, Dianchen Sun, and Gaofeng Liu. 2022. "Evaluation of Urban Flood Resilience Enhancement Strategies—A Case Study in Jingdezhen City under 20-Year Return Period Precipitation Scenario

The need for this study arises from several factors in the context of Jingdezhen:

a. Flash floods, particularly during extended storm periods in hilly areas of the city, result in significant water discharge. Additionally, when the Nanhe River reaches its maximum capacity, it adds to the flooding problem.
b. The situation is worsening over time due to population growth, while the existing storm drainage systems are inadequate to handle the current population size.
c. During heavy rainfall and exceptional monsoon seasons, low-lying areas are at a higher risk of flooding compared to other parts of the city.

d. The absence of advanced hydrological and hydraulic models hampers effective management of storm runoff.

Figure 7:Maximum inundation depth map with four return periods in Jingdezhen city.



Source: Zhang, Jingxuan, Huimin Wang, Jing Huang, Dianchen Sun, and Gaofeng Liu. 2022. "Evaluation of Urban Flood Resilience Enhancement Strategies—A Case Study in Jingdezhen City under 20-Year Return Period Precipitation Scenario

Figure 8 : Picture illustrating the situation during flood &Community participation in rescue process

Source: (Zhang, 2020)

Causes of flooding in Jingdezhen city include:

a. Inadequate preparedness for severe and extreme flood events, as the city's approach lacks measures to address the severity and intensity of floods.
b. Encroachment on low-lying areas along the Changjiang River contributes to the flooding problem.
c. Inefficient and insufficient sewage and stormwater drainage systems are also factors leading to annual flooding in the city.

Inferences:

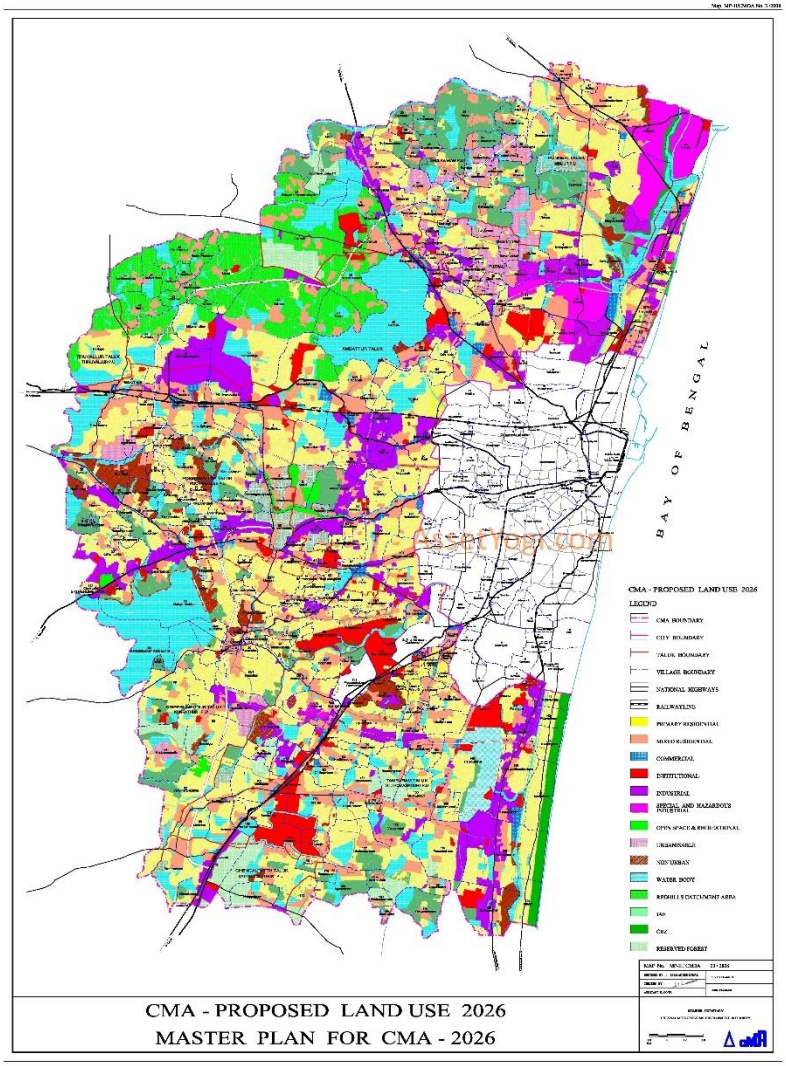
a. The identification of vulnerable areas using modern tools and models is crucial in reducing the risk of flooding. Embracing technological solutions can provide valuable assistance in addressing traditional flooding challenges.
b. To safeguard against flooding, it is essential to prioritize the regular maintenance and upgrading of drainage systems, sewers, and water channels, particularly in low-lying regions that are most susceptible to inundation.
c. The dissemination of basic awareness and preparedness measures among vulnerable communities can have a profound impact on saving lives and reducing flood-related losses.
d. A holistic approach to flood-proofing and management necessitates the integration of both structural and non-structural measures. By considering all available strategies, a comprehensive flood mitigation strategy can be achieved.

2.2.2. National: Chennai, India

Chennai, formerly known as Madras, holds the status of being the commercial hub and one of the prominent ports in South India. Over time, it has transformed into a bustling metropolis and currently stands as the fourth largest city in India. Situated on the coast, Chennai boasts the second largest beach in the world, adding to its allure. This culturally vibrant city, known for its grace and charm, serves as the capital of Tamil Nadu and serves as a convergence point for various South Indian cultures. The origins of Chennai can be traced back to its development as a fishing town during the British colonial era.

In 2015, Chennai, a city known for its beauty, cleanliness, architectural marvels, and green spaces, faced a devastating flood. The calamity was triggered by Cyclone Vardah, which had weakened into a Severe Cyclonic Storm. On December 12, the cyclone made landfall near Chennai, Tamil Nadu, with winds reaching speeds of 65 miles per hour (105 kilometres per hour). The impact of the cyclone resulted in widespread destruction and severe flooding, causing immense hardship and damage to the city and its residents.

Figure 9:Chennai Metropolitan City



Source: Chennai Master Plan 2026

The Chennai floods of 2015 were deemed a man-made tragedy due to the rapid urbanization that took place in the city over a span of just four decades, resulting in a nearly 20-fold increase in urban development (IISC, 2014). Wetlands, which played a crucial role in natural drainage and flood control, were converted for other purposes with relative ease until the Tamil Nadu Town and Country Planning Act was amended to prohibit such conversions. Under the amended act, permission for converting wetlands to alternative uses, including residential, could only be granted by the district collector and not the local tehsildars. However, there are claims from the public that even with these measures in place, wetlands continued to be encroached upon, leading to the exacerbation of the flood situation in Chennai.

Study Objectives:

a. To assess the current state of lakes, rivers, marshes, tanks, canals, and other water bodies in Chennai city, considering their historical and contemporary infrastructure, and identify the need for new systems and interventions.
b. To evaluate the effectiveness of natural drainage systems in Chennai in terms of their ability to protect the city against floods, taking into account both current and past scenarios.
c. To provide recommendations for enhancing the functioning and maintenance of Chennai's natural drainage systems through the use of maps, as well as social, economic, and legal processes, while also emphasizing the importance of community participation in flood management initiatives.

Causes of Urban Flooding in Chennai:

a. Encroachment on marshes and mangroves leading to pollution and congestion of natural drainage systems, causing damage to water sources and biodiversity.
b. Combined impact of natural factors such as sea-level rise and man-made factors including inefficient drainage systems and inadequate coastal protection measures.
c. Decrease in the capacity of natural drains due to encroachment on age-old systems, Ecologically Sensitive Areas (ESA), wetlands, and permeable/open areas.
d. Fragmentation of existing channels and water bodies due to the presence of informal and unauthorized settlements, disrupting the natural flow of water.

Figure 10:Picture illustrating the situation during flood &Community participation in rescue process

Source: dnaindia.com report-chennai-rains-inundation-annual-affair-for-many-grim-reminder-of-2015-floods

Role of Communities in Chennai Floods:

During the 2015 Chennai floods, communities played a crucial role in providing assistance and support to those affected by the disaster. Their efforts were instrumental in saving lives and facilitating the recovery process. Here are some examples:

a. Young individuals and specially trained fire officials rescued vulnerable individuals such as patients, infants, women, the elderly, and pets.
b. Chennai's fishermen group provided mechanized boats to various agencies and departments, aiding in rescue operations.
c. Private enterprises, including restaurants, taxi companies, and car repair shops, collaborated with the government to assist flood victims.
d. Kola Pasi, a Chennai-based restaurant, transformed into a temporary food distribution centre, providing meals to those in need.
e. Private media outlets used their platforms to raise funds and awareness about the situation, garnering support from people of all ages.
f. Community-based organizations like Oxfam offered assistance by supplying electricity and fuel to households.
g. Private companies and unaffected citizens provided rehabilitation kits to slum dwellers, manual laborers, and villagers in the worst-hit areas. These kits included essential items such as kerosene stoves, water filters, utensils, disinfectants, and composters.

h. Volunteers from different communities actively participated in rescue, relief, recovery, and restoration efforts.

These community-driven initiatives demonstrated the collective strength and resilience of the people of Chennai in overcoming the challenges posed by the floods and supporting one another in times of crisis.

2.3. Existing Framework

Frameworks are invaluable tools that provide guidance and structure throughout a process, making it more manageable and efficient. They serve as roadmaps, helping us navigate complex tasks and decisions by offering a set of principles, concepts, and steps to follow. Frameworks bring clarity and consistency to our approach and enable us to achieve better outcomes.

2.3.1. The Hyogo Framework for Action

The International Strategy for Disaster Reduction (ISDR) was adopted by the United Nations in 1999 to guide global efforts in reducing disaster losses and building resilient communities. This strategy marked a shift from response-focused approaches to a more comprehensive risk reduction approach. The Hyogo Framework for Action (HFA) 2005-2015, adopted at the World Conference on Disaster Reduction, aimed to integrate disaster risk considerations into sustainable development strategies and emphasized disaster avoidance, mitigation, preparedness, and vulnerability reduction.

The HFA outlined five action priorities:

a. Make disaster risk reduction a national and local priority, establishing a solid foundation for implementation.
b. Enhance early warning systems by identifying, assessing, and monitoring disaster threats.
c. Promote a culture of resilience through education, expertise, and creativity at all levels.
d. Address underlying risk factors and reduce their impact on communities.

e. Strengthen disaster preparedness to ensure an effective response.

Recent international agreements and commitments on risk mitigation and climate change, along with the Sustainable Development Goals, provide an opportunity for countries like India to pursue long-term transformative growth while reducing losses and damages. The Sendai Framework for Disaster Risk Reduction, adopted in 2015, succeeded the Hyogo Framework and further guides global efforts in disaster risk reduction. Given India's vulnerability to natural and man-made disasters, it becomes crucial for planners and policymakers to consider these frameworks in their strategies and decision-making processes.

2.3.2. The Sendai Framework for Disaster Risk Reduction

a. The Sendai Framework for Disaster Risk Reduction (SFDRR) aims to significantly reduce disaster risk and losses in various aspects, such as lives, livelihoods, health, and the environment, over the next 15 years.
b. The SFDRR provides a comprehensive structure with achievable goals and serves as a guiding instrument based on legal foundations for disaster risk reduction.
c. The framework emphasizes the shared responsibility and accountability of various stakeholders, including the private sector, government, and other relevant actors.
d. It recognizes the interconnectedness of human health, climate change, disaster risk reduction, and sustainable development, highlighting their common concerns.
e. The project's objective is to enhance understanding of disaster risk and improve governance mechanisms to effectively manage and reduce disaster risks.
f. The SFDRR emphasizes the importance of enhancing disaster preparedness and ensuring an efficient response, recovery, restoration, and rehabilitation in the aftermath of a disaster.

2.3.3. New Urban Agenda

The New Urban Agenda (NUA) serves as a visionary document aiming to create a prosperous, equitable, clean, inclusive, and resilient future for all people in cities. However, it lacks specific goals and clear guidance for effective implementation.

The NUA is structured into six thematic fields, ten policy units, and 22 issue papers. The policy unit on 'Urban Ecology and Resilience' recognizes the challenges posed by climate change and rapid urbanization, as well as the potential opportunities in developing the 70 percent of urban infrastructure that is expected to be built by 2030. While the NUA provides a broad vision, further refinement and specific actions are needed to ensure its successful implementation.

2.3.4. 2030 Sustainable Development Goals Agenda

In contrast to climate action, disaster risk reduction does not have a single target or goal. Instead, it encompasses various objectives such as addressing the exposure and vulnerability of marginalized communities, ensuring resilient infrastructure and practices, and enhancing adaptive capacities. This approach has both advantages and disadvantages that influence people's motivation to take action. Integrating risk reduction into all aspects of sustainable development, especially in urban areas (as outlined in Goal 11 of the SDGs), allows for a comprehensive approach. However, the specific and distinct nature of disaster risks is often not adequately recognized or emphasized, resulting in their co-occurrence with other development challenges.

Figure 11: Sustainable Development Goal 2015

Source: United Nations Department of Economic and Social Affairs

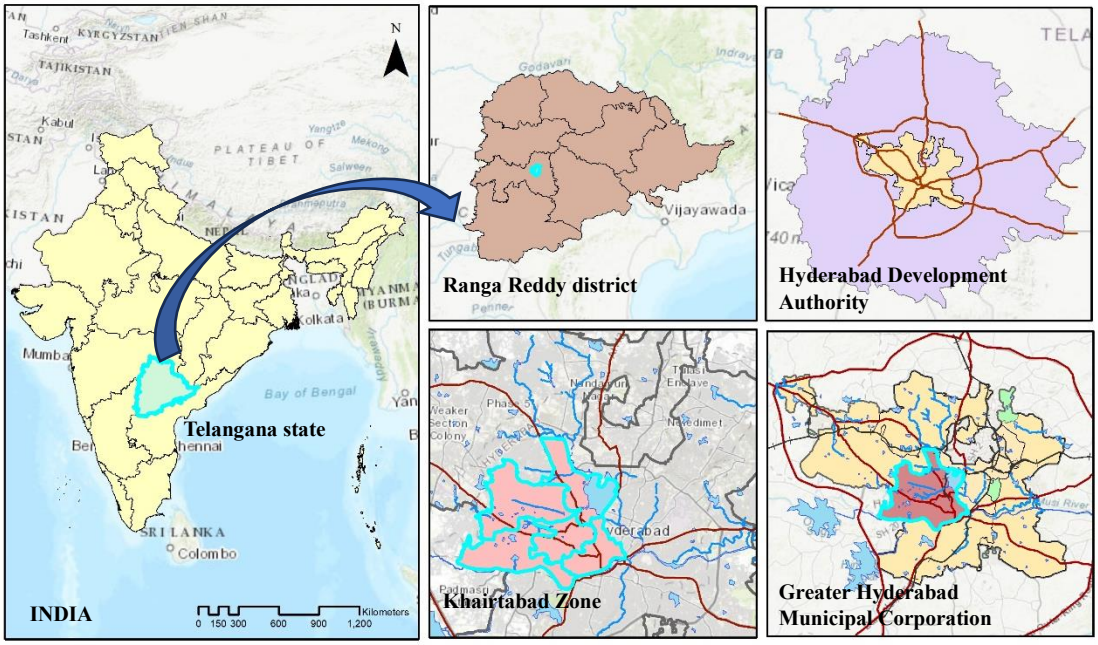
3. STUDY AREA

This section focuses on the site selection criteria and provides an overview of the study area, including its topography, slope, growing conditions, demographic profile, and transportation and communication infrastructure. It is essential to have prior knowledge and a comprehensive understanding of the study area to gain insights into its characteristics and context. This knowledge helps researchers and stakeholders to better comprehend the site and its specific circumstances, enabling them to conduct a more informed and effective study.

3.1. City Introduction

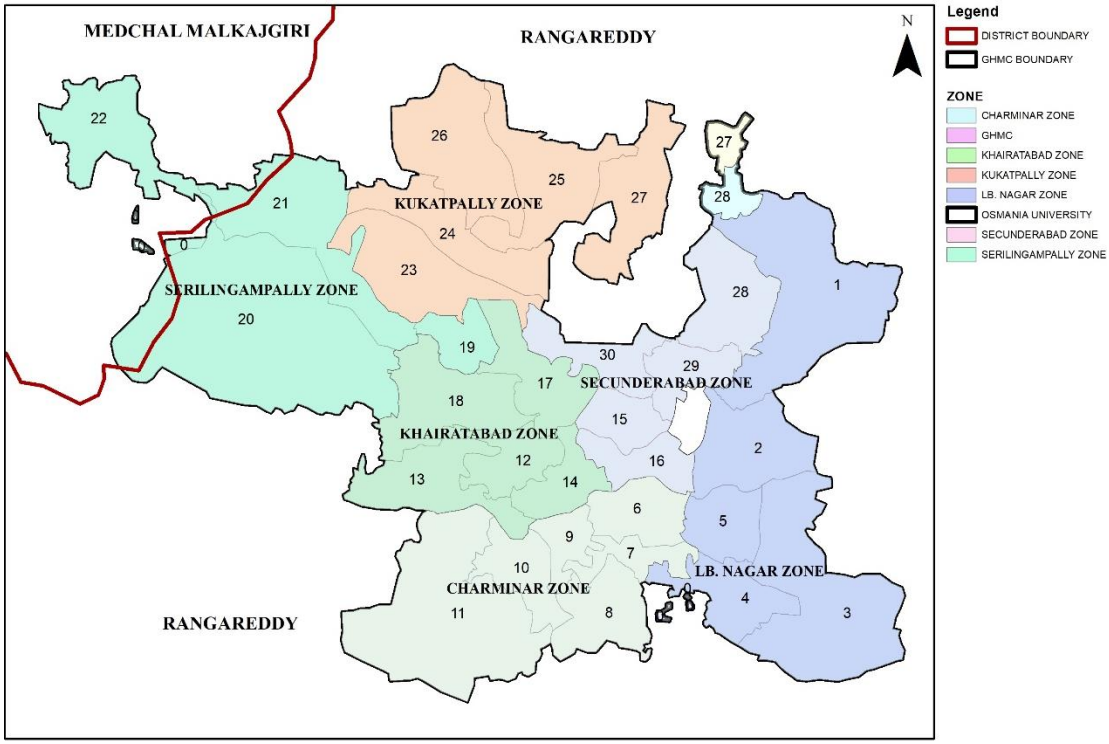
Telangana is a state located in southern India, known for its rich history spanning 400 years. The state's capital and largest city is Hyderabad. Hyderabad is situated along the banks of the Musi River and is divided into two portions by the river: Musi and Easi catchment. The northern bank of the river is at a lower level compared to the southern bank. The Greater Hyderabad Municipal Corporation (GHMC) covers a larger area of 650 square kilometres, encompassing three cities: Hyderabad, Secunderabad, and Cyberabad.

Map 1: Study area



Source: Author

Map 2:: Hyderabad Zone and Circle Map



Source: Author

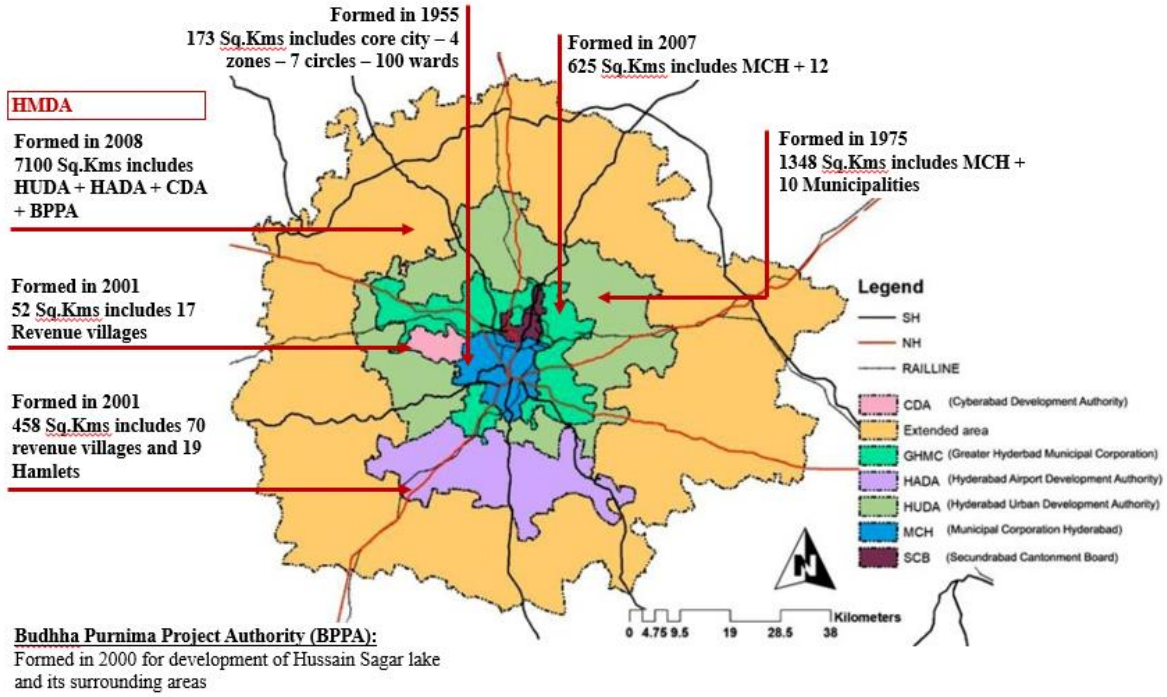
According to the 2011 Census, the population of Hyderabad is over 3.9 million, with the entire population residing in urban areas and no rural population. This is a result of the merger of three cities, Hyderabad, Secunderabad, and Cyberabad, under the Greater Hyderabad Municipal Corporation (GHMC). The merger made Greater Hyderabad a fully urban area, and the outlying and rural areas became part of the Rangareddy district under GHMC jurisdiction. Hyderabad is located in the southwestern part of Telangana state, specifically in the northern region of the Deccan Plateau. It is known as a developed IT and knowledge hub of India. The city has a unique landscape with undulating topography and impressive rock formations, which are estimated to be over 2500 million years old. Hyderabad falls under seismic zone 1, which is the least vulnerable to earthquakes.

3.1.1. Administration

The spatial context and administrative structure of the area being discussed in the report. It highlights boundaries, administrative centres, and other key features that are important for understanding the administrative framework within which the study is conducted.

The civic administration and infrastructure development in the Hyderabad city is being taken care by the municipal authority of the city – **GHMC (erstwhile MCH).**

Figure 12: Administration bodies in Hyderabad city



Source: Research Paper Research Paper, HMDA Master Plan 2031

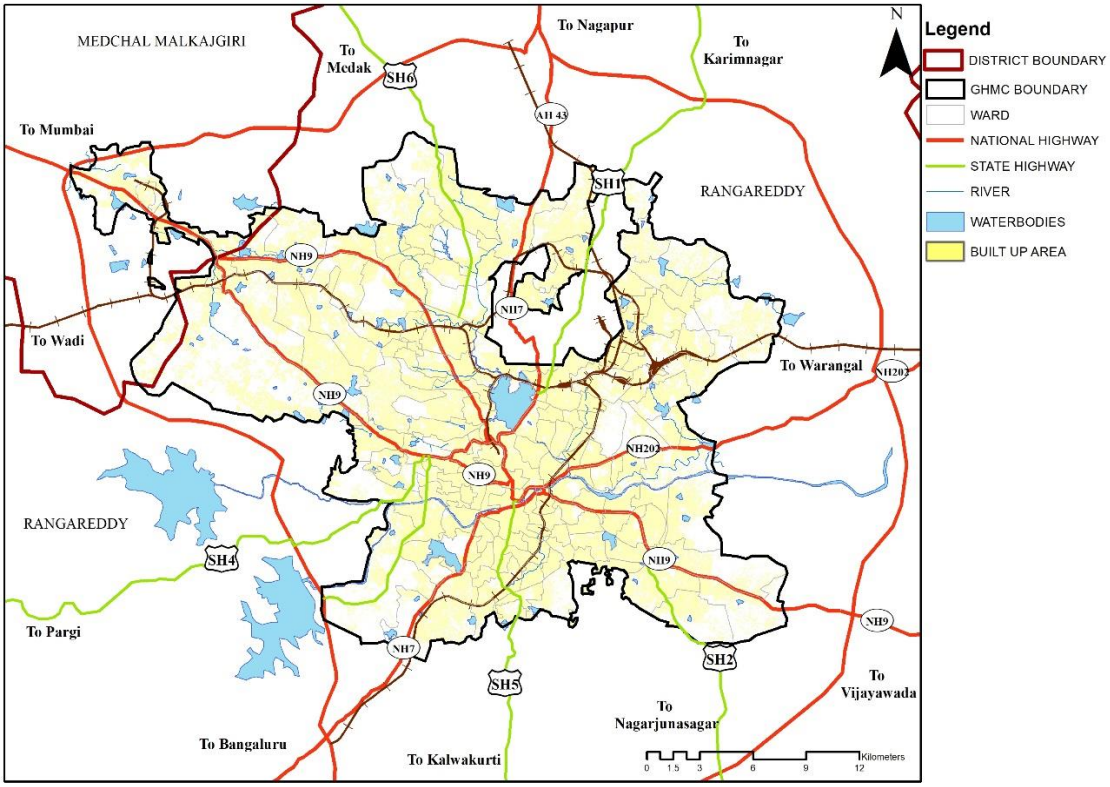
3.2. Regional Setting

Hyderabad, renowned for its vibrant history, diverse culinary traditions, and multicultural community, is a city that harmoniously blends geography and culture. Nestled along the banks of the Musi River, Hyderabad boasts iconic landmarks such as Charminar, Falaknuma Palace, Chowmallah Palace, and Makkah Masjid, which collectively form the enchanting old town.

Hyderabad and Secunderabad, often referred to as twin cities, are distinguished by the magnificent man-made lake constructed by Ibrahim Qutb Shah in 1562, known as Sagar Hussain. These two towns are connected by the famous "Tank Bund" road. Positioned on the Deccan Plateau, Hyderabad enjoys an average elevation of 536

meters. The city is geographically located at 17°23'2.58"N latitude and 78°27'22.9"E longitude.

Map 3: Regional base map for study area



Source: Author

3.2.1. Location

The Greater Hyderabad region encompasses Hyderabad city along with certain areas of Rangareddy district. It is situated in the southwestern region of the state of Telangana.

3.2.2. Connectivity

The Greater Hyderabad area enjoys excellent connectivity with neighbouring cities, districts, and states. It is served by various state highways (SH) and national highways (NH) that facilitate easy travel and transportation.

SH-1 runs through the city, connecting Hyderabad to Shamirpet, Karimnagar, Peddapalli, and Ramagundam. SH-4 links Hyderabad to Chevella, Parigi, and Kodangal. SH-5 connects Hyderabad to Dundigal, Narsapur, Medak, Yellareddy, Banswada, and Bodhan. SH-19 connects Hyderabad to Ibrahimpatnam, Peddavoora, and Nagarjuna Sagar.

In addition to state highways, Hyderabad is also connected to the rest of India through major national highways such as NH-7, NH-9, and NH-202.

The robust transportation network is crucial for the city's economic activities, and ensuring the safety and continuity of this network is essential to prevent any disruptions and associated economic losses**.**

Table 1: State Highway connectivity

S.No.	Highway	Cities
01.	SH-1	Hyderabad- Shamirpet- Karimnagar Peddapalli- Ramagundam
02.	SH-2	Hyderabad- IbrahimpatnamPeddavoora- Nagarjuna Sagar
03.	SH-4	Hyderabad- Chevella- Parigi Kodangal
04.	SH-5	Hyderabad- Dundigal- Narsapur- Medak- YellareddyBanswada- Bodhan

Source: Author

3.3. City Profile

Each city possesses unique qualities that set it apart from others, including its demographic makeup, physical attributes, historical background, and various factors that shape its identity and reputation. These distinguishing features contribute to the distinctiveness and recognition of the city among its counterparts.

3.3.1. Demographic profile

The Greater Hyderabad Metropolitan Corporation (GHMC) area encompasses a significantly larger area than Hyderabad city alone, extending beyond the boundaries of the Hyderabad district. It is a continuously growing urban region, with a 100 percent urban population ratio, indicating ongoing urbanization.

The current population of the city has surpassed 10.2 million, experiencing a gradual increase from 10 million in 2020 and 9.7 million in 2019. The city has exhibited an average annual growth rate of 2.7 percent, which can be attributed to factors such as immigration and the city's emergence as an IT hub over the past 15 years, attracting individuals from other districts.

The sex ratio in Hyderabad is commendable and exceeds the national average, reflecting a positive reputation for the city and indicating strong representation of women in society. It is believed that a higher number of women in a community leads to enhanced social well-being and prosperity.

The city boasts a high literacy rate, signifying the status and opportunities available to women in society. The literacy rate in Greater Hyderabad surpasses the national average. However, despite the high literacy levels, the job rate stands at 36 percent, indicating that a significant proportion of literate individuals, both men and women, are still unemployed. This issue was also reflected in primary surveys, which highlighted the presence of literate but unemployed individuals actively seeking employment opportunities.

Table 2: General city profile

Greater Hyderabad Area	650 sq. km
Population	1.02 crore
Population Density	15,385 people/ sq. km
Sex Ratio	954:1000
Literacy Rate	73.34% (77,34,000 literates)
Working Population	36% (Main and Marginal Workers)

Source: Preparing a framework to mitigate impacts of urban floods: A case of Greater Hyderabad) report 2020

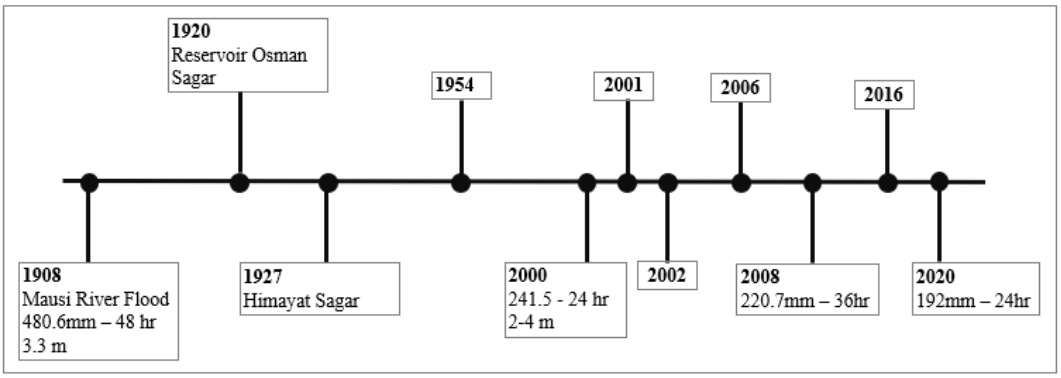
3.3.2. Flood profile

The southern banks of the Musi River, developed by Muhammad Quli Qutub Shah, are historically known as the 'Old City,' while the urbanized areas on the northern banks are referred to as the 'New City.' Several river bridges connect the old and new cities, with the oldest among them being the 'Purana Pul.' Hyderabad and Secunderabad are twin cities situated on either side of the Hussain Sagar Lake. Together, they form the Greater Hyderabad municipal unit.

Historical records indicate that Hyderabad has witnessed eight major floods in the past century. These floods affected approximately one-third of the city's land area,

particularly impacting the low-lying regions. Over the last two decades, the frequency and severity of flooding have increased, leading to significant destruction. Despite not being located in a designated major flood zone according to meteorological organizations, Hyderabad has faced urban and seasonal flooding, resulting in adverse consequences for the public and their immediate surroundings. These repeated flooding events have had long-lasting effects on the affected residents and their communities.

Figure 13:Hyderabad Floods: Timeline



Source: Research Paper, NIUA report on Urban flooding,2016

Urbanization poses numerous challenges for city leaders, planners, and policymakers, and one of the rapidly emerging challenges is urban flooding. Urban flooding occurs due to inadequate management of stormwater drains, inappropriate planning practices, encroachment on drains and water bodies, filling up of low-lying areas, alteration of catchments, and the impacts of climate change. Urban flooding is characterized by certain common features, including:

a. Significant increase in flood peaks, often ranging from 2 to 8 times higher than normal.
b. Considerable rise in flood volumes, reaching up to 6 times greater than previous levels.
c. Reduced time required for floodwaters to reach their peak levels, leading to faster onset and intensity of flooding.
d. Severe economic losses, including loss of life, damage to properties, disruption of livelihoods, and decreased productivity.

Addressing these characteristics of urban flooding is crucial for city stakeholders as they strive to develop effective strategies to mitigate the impacts of floods, protect communities and infrastructure, and ensure sustainable urban development.

3.4. Site Selection and Justification

Hyderabad has witnessed rapid and extensive urban expansion in all directions over the past decade, making it a recurrent site for urban flooding. This expansion has resulted in significant changes in land use and land cover, with a notable increase in impervious surfaces at the expense of green and blue areas. Interestingly, while Hyderabad is not located within or near the officially demarcated flood zones on India's map, it has consistently experienced flooding, highlighting the urgency for planners and responsible citizens to address this issue.

Among the various metropolitan cities in India, Hyderabad stands out for three key reasons:

a. The city's expansion has been multidirectional, extending beyond the boundaries of the Hyderabad district.
b. Observable changes in land cover, including the proliferation of impervious surfaces, can be analysed to understand the transformation.
c. Despite its distance from designated flood-prone areas, Hyderabad has consistently experienced flooding, making it crucial to address this issue effectively.

These factors make Hyderabad a significant case for studying and implementing measures to mitigate the impacts of urban floods, ensuring the city's resilience and the well-being of its residents.

4. DATA COLLECTION

The primary objective of data collection is to gather comprehensive and accurate information from diverse sources, including primary and secondary sources. This data is collected with the aim of conducting statistical analysis and making research decisions based on evidence. By collecting data, we can gather and analyze crucial information about the study area, including its current population and potential residents. Furthermore, data collection techniques that employ larger sample sizes and effective research methods contribute to enhancing the reliability of the data gathered.

4.1. Method of Data Collection

A perception study has been implemented to gain insights into the experiences of individuals affected by flooding on an annual basis. The purpose of this study is to assess the alignment between the actions claimed to be taken by the government and the actual support and assistance received by the affected people. By conducting this study, the aim is to identify any discrepancies or gaps that exist between the government's claims and the ground reality in terms of flood response and relief efforts**.**

4.1.1. Primary Data Collection

The primary survey holds significant importance in various studies, research endeavours, and similar processes. It provides a comprehensive understanding of the ground reality and helps uncover previously unknown information.

Nature of Questions

i. General details/ profile (to know the socio-economic status)
ii. How long did the water stay in your area during the flood?
iii. How long did the water stay in your area during the flood?
iv. Level of inundation?
v. Do you know where the flooding comes from?
vi. Did the flood cause damage to roads, bridges, or buildings in your area? Please rate the severity of the infrastructure damage on a scale of 1-5, with 1 being minimal/no damage and 5 being severe damage.

vii. Were utilities (electricity, water supply, sewage) affected by the flood in your locality? Please rate the severity of utility disruption on a scale of 1-5, with 1 being minimal /no disruption and 5 being severe disruption.

viii. Did the flood cause damage to buildings or structures in your area? Please rate the severity of building/structure damage on a scale of 1-5, with 1 being minimal/ no damage and 5 being severe damage.

ix. Did the flood cause damage to buildings or structures in your area? Please rate the severity of building/structure damage on a scale of 1-5, with 1 being minimal/ no damage and 5 being severe damage.

x. Any evacuation shelter provided by the govt. /authorities during flood?

xi. How would you rate the organization and effectiveness of the evacuation procedures?

xii. Did you receive any assistance (food, shelter, medical aid) during the flood or post-flood period?

xiii. Did you receive flood warning on time?

xiv. How would you rate the government's response to the flood situation in Hyderabad?

xv. Are you aware of any ongoing or proposed initiatives for flood mitigation in your area?

4.1.2. Secondary Data Collection

A wealth of data and information has been sourced from numerous agencies and organizations, significantly enhancing the scope of advanced analysis. GHMC's SNDP section has provided valuable and reliable data pertaining to plans, policies, and infrastructure. This data has been instrumental in analysing crucial aspects such as drainage availability, drainage density, and flood vulnerability. The inclusion of such authentic data has greatly contributed to the accuracy and depth of the analysis conducted.

5. DATA ANALYSIS

This chapter focuses on the analysis of the collected data to identify gaps and loopholes in the current scenario. By understanding the ground reality, relevant suggestions can be formulated and implemented in the subsequent chapter. This is crucial for addressing and rectifying issues related to flood vulnerability, as well as the impact on the economy, healthcare, and other critical aspects of the city. Data interpretation and analysis, which involve organizing, structuring, and extracting meaningful insights from the data, play a vital role in spatial planning and decision-making for the area's growth and development. The research conducted in this section contributes to achieving objectives and goals related to flood mitigation and overall improvement.

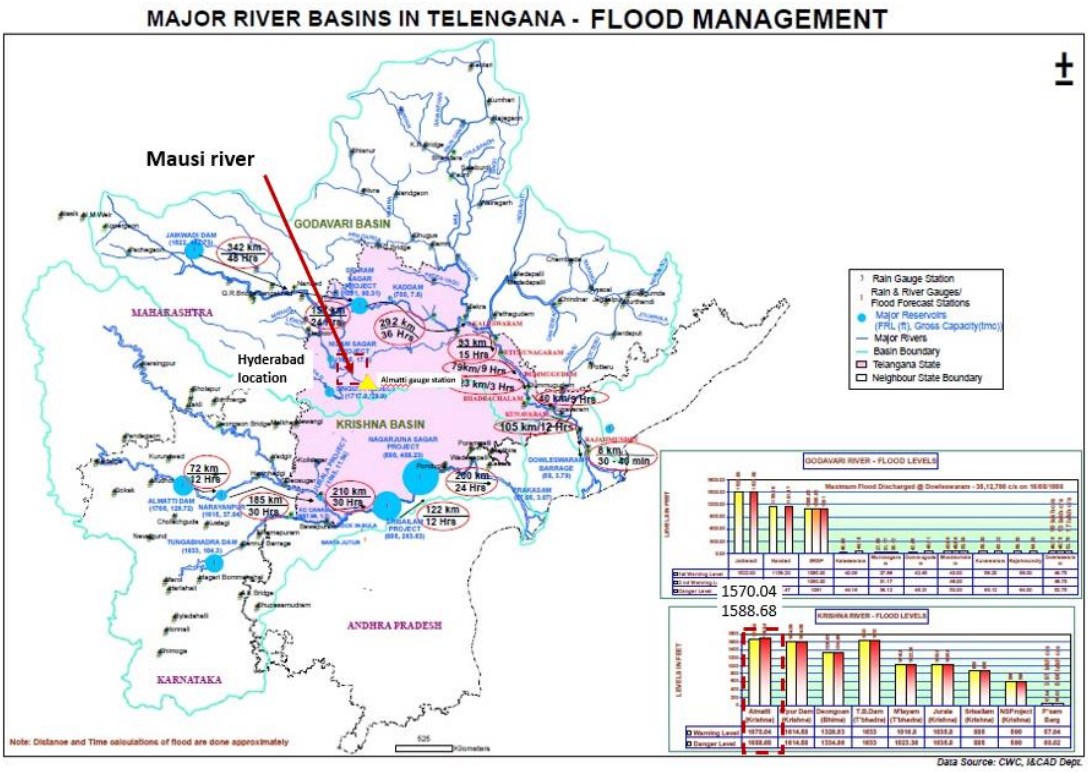
5.1. Physical Profile

Hyderabad, known for its geographical and cultural significance, has a rich history, diverse culinary traditions, and a multicultural society. Initially, the city was established on the banks of the Musi River. Today, it is situated on the southern bank of the river and encompasses the historic old town, home to iconic landmarks such as Charminar, Falaknuma Palace, Chowmallah Palace, and Makkah Masjid. Hyderabad and Secunderabad, the twin towns, are separated by the man-made lake of Ibrahim Qutb Shah, constructed in 1562, and connected by the famous "Tank Bund" road. The city is located on the Deccan Plateau, with an average elevation of 536 meters above sea level. Its geographical coordinates are approximately 17.366 degrees N latitude and 78.476 degrees E longitude. The city of Hyderabad has a distinct demographic profile, with the lower or southern part experiencing higher population density. This can be attributed to two main factors. Firstly, the core city or the old city area consists of wards located on the southern bank of the Musi River, which naturally attracts a higher concentration of residents. Secondly, the relatively lower land prices in this area make it more affordable and accessible for immigrants and individuals seeking affordable housing options.

Hyderabad is in between the system of catchments:

The map below shows that the western edge is in the Godavari River basin, To the east, it’s in the Krishna River basin and Hussain Sagar Lake in the middle of the city. Musi river(overflowing) is going through the city connecting waters of several lakes.

Figure 14: River Basin



Source: Government of Telangana Irrigation & CAD Department

5.1.1. Rainfall Data

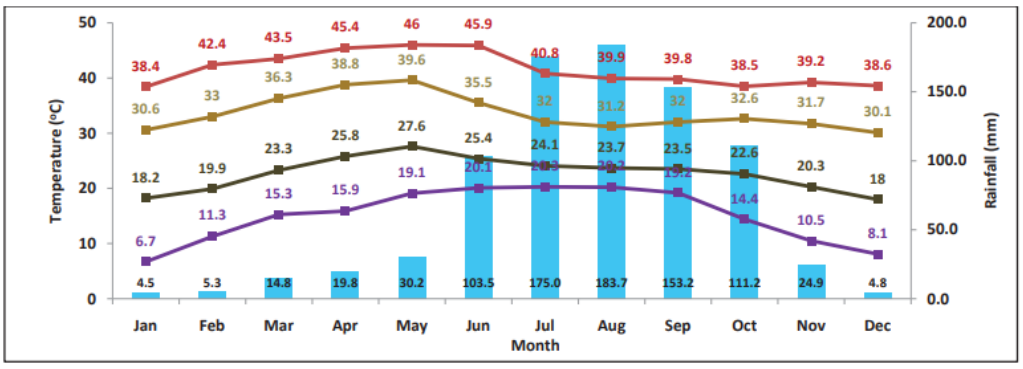
Hyderabad, the capital city of Telangana, experiences a moderate annual rainfall of 830.8 mm. The city witnesses an average of 52 rainy days and 277 dry days throughout the year, highlighting the prevalence of a distinct wet and dry season. The climatic pattern in Hyderabad is characterized by a significant variation in rainfall across different months.

The month of August receives the highest mean monthly rainfall, with an average of 183.7 mm. This indicates that the city experiences heavy rainfall during this period, which contributes to the overall annual precipitation. On the other hand, January records the lowest mean monthly rainfall, with an average of only 4.8 mm. This suggests that the city encounters drier conditions during the winter months. It is worth mentioning that Hyderabad has witnessed extreme weather events in the past. On October 14, 2019, Musheerabad (M) in Hyderabad recorded the heaviest rainfall ever observed in a 24-hour period, reaching a staggering 258.3 mm. This intense rainfall event resulted in significant impacts on the local infrastructure and caused disruptions in the daily lives of the residents.

Hyderabad experiences two major monsoon seasons, namely the Southwest Monsoon (SW Monsoon) and the Northeast Monsoon (NE Monsoon). During the SW Monsoon, the city receives an average rainfall of 615.4 mm, accompanied by 39 rainy days. This monsoon season contributes significantly to the overall annual rainfall in Hyderabad. In contrast, the NE Monsoon brings relatively less rainfall, with an average of 140.9 mm and 7 rainy days.

Figure 15: Climate of District

	Temperature (°C)			Average Relative Humidity (RH%)			
	Avg. Annual Temp.	Mean Hottest / Coldest Month	Ever Recorded Max/Min Temp in 24 hrs	SWM	NEM	Winter	Summer
Max	33.6	39.6 in May	46.0 on 23-05-2015 at Mondamarket(M)	85	82	77	65
Min	22.7	18 in December	6.7 on 12-01-2015 at Maredpally (M)	56	43	31	26



Month wise average Rainfall; Temperature - Extreme Max, Min (24hrs) Avg Max, Avg Min

Source: Government of Telangana ground water department, 2022

These climatic conditions have a significant impact on various aspects of life in Hyderabad. The rainfall patterns influence agricultural activities, water availability, and overall ecosystem dynamics in the region. Adequate rainfall during the monsoon seasons is crucial for sustaining agricultural productivity and ensuring water security for the city's growing population.

In conclusion, Hyderabad experiences a moderate annual rainfall of 830.8 mm, with distinct wet and dry seasons. The city receives the highest mean monthly rainfall in August and the lowest in January. Extreme rainfall events have been recorded in the past, with the heaviest 24-hour rainfall reaching 258.3 mm. The SW Monsoon brings the majority of the rainfall, while the NE Monsoon contributes comparatively less precipitation. Understanding the city's rainfall

patterns is essential for effective water management, urban planning, and disaster preparedness in Hyderabad.

Figure 16:Mandal wise Monthly Normal based on the last 33 years data (1989-90 to 2021-22) Rainfall (mm) Hyderabad District

S.No	Mandal	Jun	Jul	Aug	Sep	SWM	Oct	Nov	Dec	NEM	Jan	Feb	Winter	Mar	Apr	May	Hot Period	Annual
1	Shaikpet	102.7	175.5	172.9	150.3	601.4	110.4	25.3	4.7	140.4	3.9	5.8	9.7	14.8	18.0	29.9	62.7	814.2
2	Ameerpet	105.3	187.1	197.4	159.7	649.5	109.7	27.9	5.3	142.9	4.6	5.3	9.9	15.2	23.2	32.6	71.0	873.3
3	Secunderabad	108.4	178.8	187.8	152.3	627.3	111.5	26.0	4.5	142.0	5.5	6.3	11.8	15.1	22.2	30.5	67.8	848.9
4	Tirumalgiri	107.9	177.3	190.7	154.6	630.5	107.7	27.5	5.6	140.8	3.9	5.6	9.5	15.8	21.1	29.7	66.6	847.4
5	Maredpally	105.0	176.9	190.5	149.8	622.2	108.0	26.5	5.4	139.9	5.8	6.1	11.9	15.1	21.2	28.4	64.7	838.7
6	Musheerabad	108.7	176.1	183.0	165.5	633.3	116.5	24.1	4.9	145.5	4.3	5.0	9.3	15.2	23.6	29.7	68.5	856.6
7	Amberpet	101.4	173.1	187.0	162.7	624.2	113.5	22.6	4.8	140.9	5.4	4.1	9.5	14.7	21.2	29.8	65.7	840.3
8	Himayatnagar	102.1	173.0	184.4	153.4	612.9	111.7	25.5	5.3	142.5	4.9	4.3	9.2	13.9	21.6	31.5	67.0	831.6
9	Nampally	105.0	174.6	178.7	149.4	607.7	107.9	24.2	4.4	136.5	3.6	6.0	9.6	13.7	17.8	31.7	63.2	817.0
10	Khairatabad	105.8	181.1	191.6	158.2	636.7	112.0	25.9	5.1	143.0	4.4	7.4	11.8	15.6	23.2	31.2	70.0	861.5
11	Asifnagar	102.5	178.0	179.2	151.3	611.0	111.1	24.3	4.6	140.0	4.0	5.7	9.7	14.5	17.9	29.7	62.1	822.8
12	Golkonda	104.1	173.9	178.9	148.9	605.8	108.3	25.0	3.9	137.2	4.2	5.6	9.8	15.4	17.0	30.0	62.4	815.2
13	Bahadurpura	97.4	169.0	175.1	144.2	585.7	106.4	22.9	4.2	133.5	3.8	4.5	8.3	14.4	16.2	29.2	59.8	787.3
14	Bandlaguda	96.6	165.7	177.2	143.8	583.3	110.0	22.8	4.6	137.4	3.7	4.3	8.0	13.6	15.8	30.7	60.1	788.8
15	Charminar	101.1	169.8	189.6	151.0	611.5	117.2	24.8	4.7	146.7	4.3	4.8	9.1	15.1	17.3	29.2	61.6	828.9
16	Saidabad	101.3	170.1	175.9	155.7	603.0	117.0	23.6	4.2	144.8	5.1	4.1	9.2	14.4	19.5	30.0	63.9	820.9
	District	**103.5**	**175.0**	**183.7**	**153.2**	**615.4**	**111.2**	**24.9**	**4.8**	**140.9**	**4.5**	**5.3**	**9.8**	**14.8**	**19.8**	**30.2**	**64.8**	**830.8**

Source: Government of Telangana ground water department, 2022

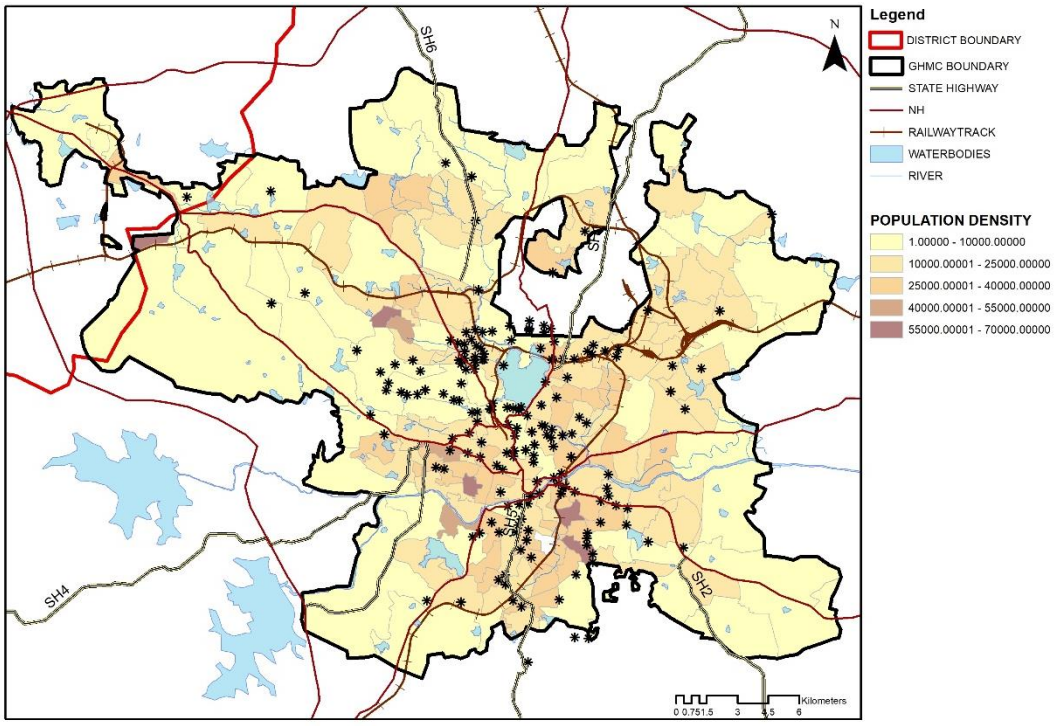
5.1.2. Population Density

Population density plays a crucial role in the planning and development of an area, providing valuable insights into its future prospects. The density of a population in a particular place reflects the preferences and choices of the people regarding their habitat and work environments. When a place exhibits low population density over an extended period, it indicates a lack of attraction for individuals to settle or work in that area. This could be due to various factors such as limited amenities, inadequate infrastructure, or unfavourable living conditions.

Conversely, a place with a higher population density signifies the public's preference and prioritization of that particular area. It suggests that the area offers

desirable opportunities, amenities, and a conducive environment that attract people to reside or engage in activities there. Understanding population density is essential for urban planners and policymakers as it helps them assess the demand for resources, infrastructure, and services in a given area. It aids in making informed decisions regarding the allocation of resources, land use planning, transportation systems, and the provision of social amenities to meet the needs of the population.

Map 4: Population Density



Source: Author

Population density is influenced by various factors, including access to basic services, connectivity, distance from workplaces, safety, and security (D. Debbarma, 2019). As depicted on the map, the southern part of the city, which encompasses the old and core areas, exhibits a high population density.

The population density map reveals points indicating water accumulation. It can be inferred that areas with higher population density are more prone to water accumulation, leading to significant impacts during flooding events. Therefore,

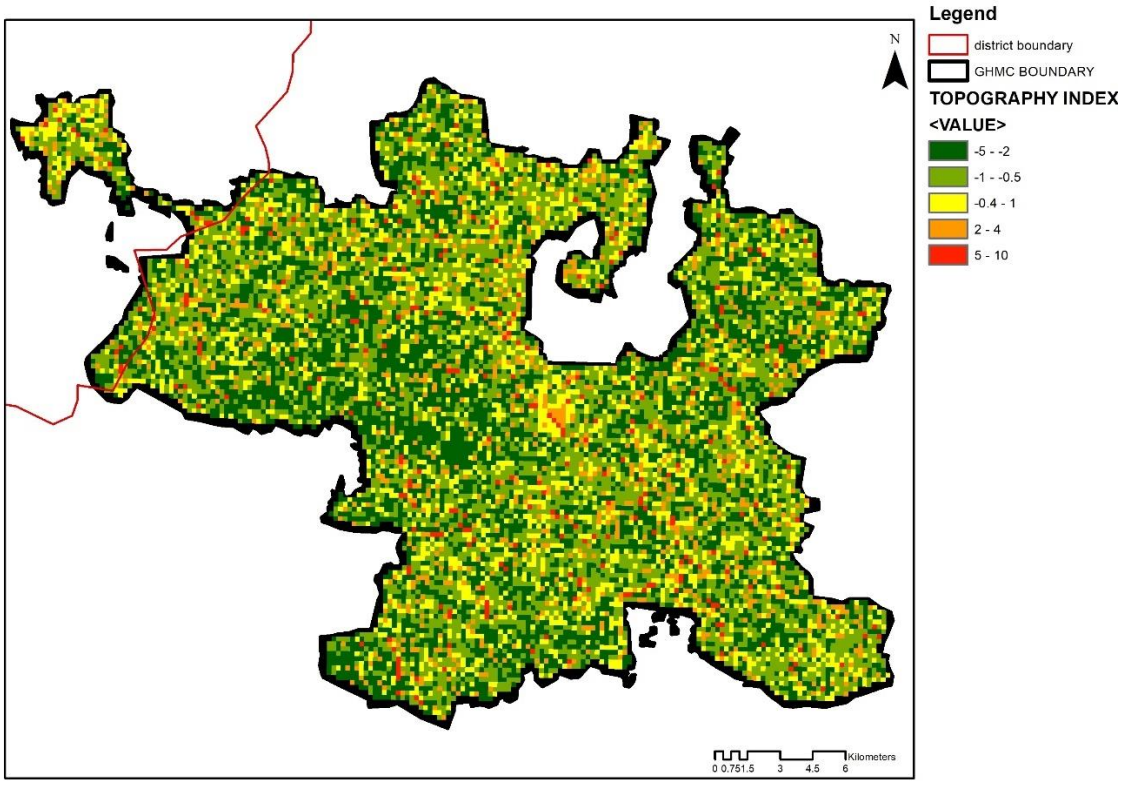
the objective of this research is to mitigate these impacts, reducing the potential loss of life and property.

By addressing the factors contributing to population density and understanding their relationship with flood vulnerability, appropriate measures can be implemented to improve the living conditions and resilience of the affected population.

5.1.3. Topography Wetness Index

The topography wetness index (TWI) is a measure that assesses the wetness of the land surface based on slope and water accumulation. It helps identify areas prone to water accumulation and potential flooding. High TWI values indicate greater water-holding capacity, while low values indicate better drainage. TWI assists in land management, planning, and flood risk assessment.

Map 5: Topography Wetness Index - Hyderabad City

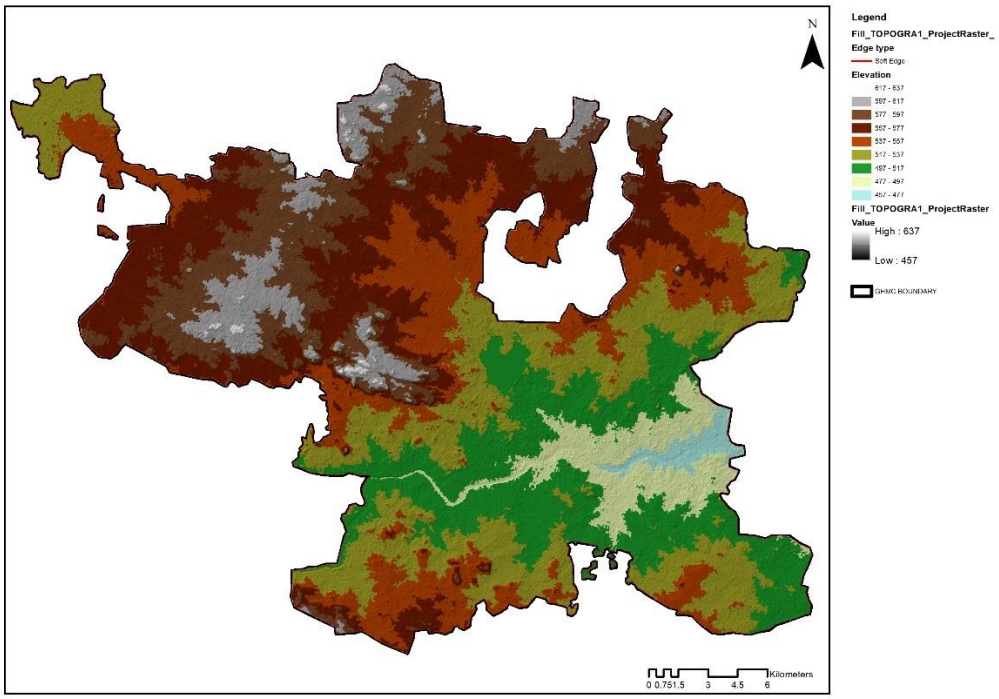


Source: Author

5.1.4. Topography

Topography plays a crucial role in flood dynamics. The elevation and slope of the land determine how water flows and accumulates during a flood event. Low-lying areas and areas with gentle slopes are more prone to flooding as they have limited natural drainage capacity. On the other hand, areas with higher elevation and steeper slopes are less susceptible to flooding as water can quickly flow away. Analysing the topography of a region helps in identifying flood-prone areas, designing effective drainage systems, and implementing appropriate flood mitigation measures.

Map 6: Topography -Hyderabad City



Source: Author

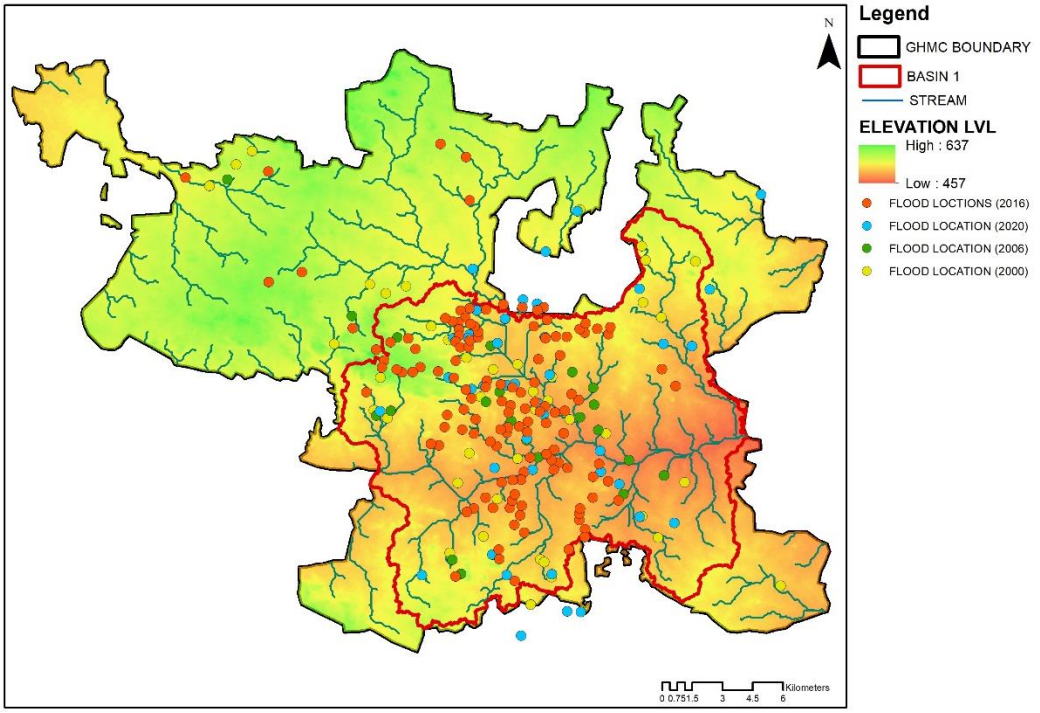
The topography of the study area, as depicted in the map, is a critical factor influencing water flow patterns. It has a direct impact on various aspects, including drainage systems, stormwater management, and domestic water supply. The map clearly indicates that water accumulation points are predominantly found in low-lying areas of the city. This highlights the importance of effective planning and rectifying any existing flaws to prevent and control flooding incidents.

Addressing the issues related to topography and implementing appropriate measures will be instrumental in mitigating flood risks.

5.1.5. Watershed

Watershed mapping and analysis contribute to natural resource studies and resource-centric planning, fostering nature-centric development. By understanding the characteristics of a watershed, decision-makers can make informed choices regarding water management and conservation, promoting sustainable development and preserving the environment.

Map 7: Watersheds - Hyderabad city



Source: Author

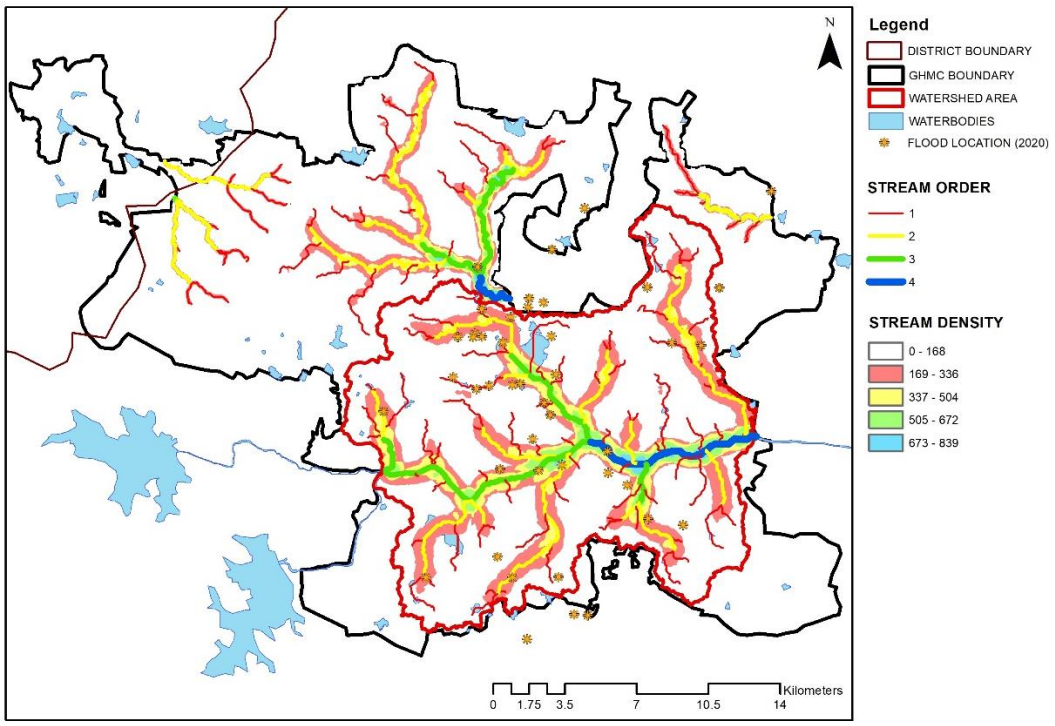
The city consists of 18 watersheds, and out of these, 13 watersheds exhibit water accumulation points, indicating organic development and inadequate land use planning. This situation arises due to illegal encroachment and unplanned growth. Wards located within these watersheds, whether fully or partially, are at higher risk of flooding and waterlogging until proper infrastructure is implemented.

Therefore, addressing waterlogging and flood risks should be prioritized to ensure the safety and well-being of the affected areas.

5.1.6. Drainage density

The analysis of drainage density assists in identifying areas with high imperviousness and concrete cover along water channels. This information helps in determining locations where water percolation and infiltration capacity is low. Typically, areas with high drainage density exhibit reduced percolation capacity. As a result, water tends to accumulate or flow rapidly through narrow or confined spaces, leading to situations resembling floods.

Map 8: Drainage density - Hyderabad city



Source: Author

The provided map illustrates the drainage density in the study area. It is notable that the fifth and fourth order streams primarily consist of the Musi River or its tributaries, resulting in high drainage density along these streams. However, on the ground, water accumulation occurs in areas with third order streams. Even moderate drainage density can lead to severe flood conditions. Therefore, it is

crucial to take prompt and effective measures to mitigate the severity of floods as much as possible.

The studied basin has an area of 257.23 square kilometres and a total stream length of 210.80 kilometres. By calculating the drainage density, which is the ratio of total stream length to basin area, it is determined that the drainage density of the basin is 0.81. This indicates a low density of streams within the basin.

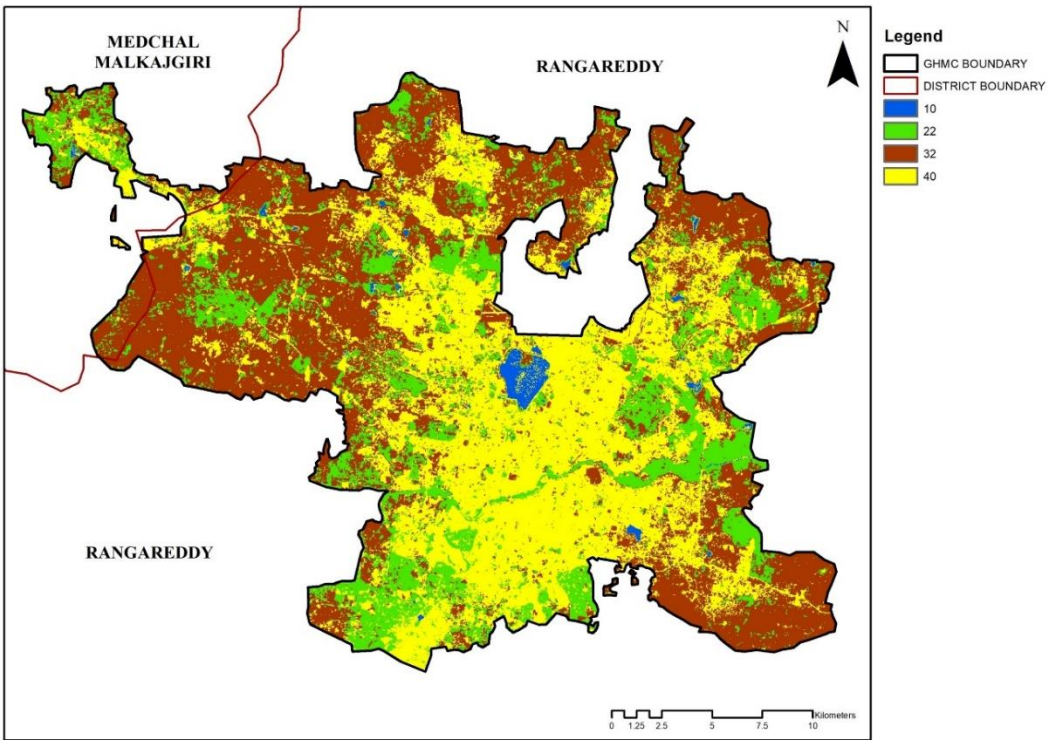
Although the drainage density of the studied basin is low, indicating a relatively spread-out network of streams, it is important to note that flooding is still occurring in the area. Despite the low density, other factors such as land use patterns, urban development, and the capacity of the existing drainage infrastructure may contribute to the flooding issue. It suggests that even with a low drainage density, certain areas within the basin may experience water accumulation and subsequent flooding due to local conditions.

5.1.7. Land Use Land Cover

Land use land cover (LULC) analysis is a valuable technique for monitoring changes in our surrounding environment, particularly on land. It provides insights into long-term transformations that have taken place. With rapid urbanization being a significant concern today, where resources are limited but needs are abundant, LULC analysis becomes crucial. It allows us to track and understand the patterns of change occurring in our surroundings. By taking responsible and sustainable actions based on LULC analysis, we can work towards securing a better future for all.

The LULC map for 2003 provides valuable insights into the land cover pattern of the area. The map indicates that a significant portion of the land is occupied by built-up areas, including residential, industrial, and commercial structures. Following built-up areas, there are substantial areas of barren land and green patches. Moreover, the map reveals the presence of vacant or barren land at the city's periphery, which holds potential for future growth and development. The LULC mapping allows for a comprehensive understanding of the land cover dynamics and assists in identifying areas of change and potential for future land use.

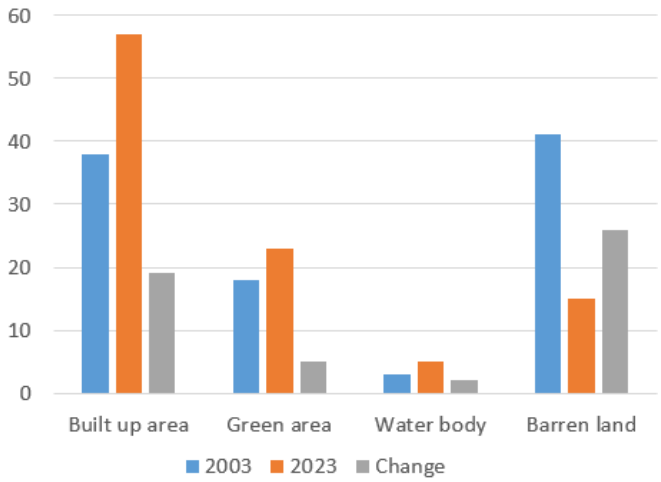
Map 9:LULC 2003 - Hyderabad City



Source: Author

The LULC map for 2023 reveals a significant transformation in the city's land cover. The majority of the land is now occupied by built structures, indicating extensive urban development. Over the past decade, peripheral areas have experienced rapid development, resulting in the disappearance of vacant land that was present in 2003.

Figure 17: Comparative Analyses LULC of 2003 &2023



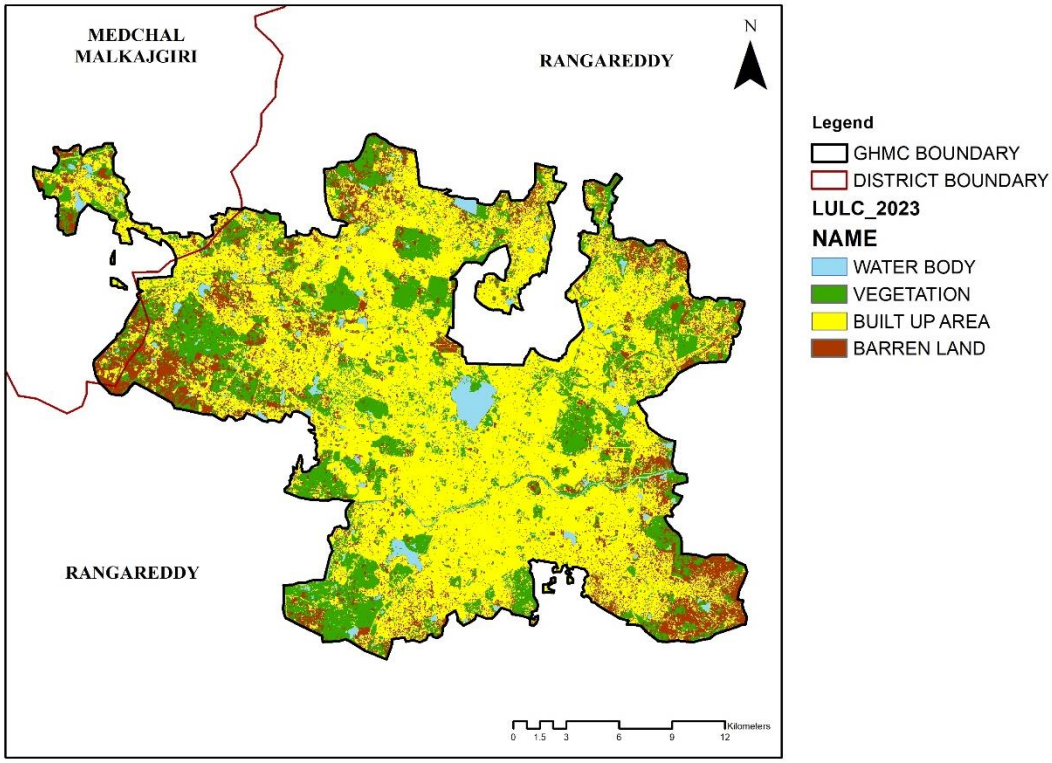
Source: Author

Only a few areas in Cyberabad remain vacant, primarily due to commercial zoning regulations and restrictions on construction activities. The map highlights the south-eastern part of the city as undergoing the most significant change, with the conversion of previously vacant and green spaces into residential buildings.

It can be inferred that the Mausi river has transformed the in terms of land cover change (from water and green spaces to build forms). Urban growth has resulted in encroachment of riparian corridors, which poses flood risk to areas.

With the rapid urban expansion administration neglect has allowed construction on increasingly reclaimed wetlands, flood plains and low lands of the city as these areas have a cheaper land rate.

Map 10: LULC 2023-Hyderabad City



Source: Author

5.1.8. Flood Susceptibility Mapping Using Multi-Criteria Analysis

Flood susceptibility mapping using multi-criteria analysis is a valuable approach in assessing areas that are prone to flooding. This method involves the integration of various factors and criteria to determine the vulnerability of a particular area to floods. The process involves analysing multiple parameters such as topography,

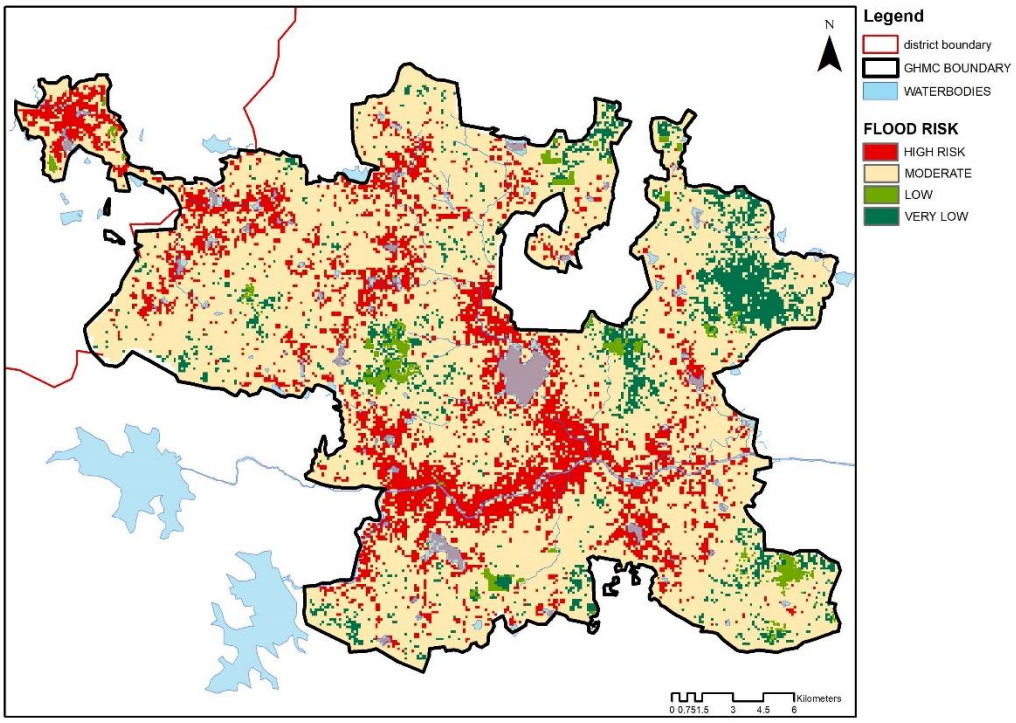
land use, hydrological characteristics, rainfall patterns, and infrastructure conditions.

By considering these different criteria and assigning weights to each, a comprehensive assessment can be made to identify areas with a higher susceptibility to flooding. The multi-criteria analysis takes into account the interactions and dependencies between these factors, allowing for a more accurate prediction of flood-prone areas.

This mapping technique helps in prioritizing mitigation and adaptation measures, as well as in land use planning and decision-making processes. By identifying high-risk areas, appropriate measures can be implemented to minimize the impact of floods, such as the construction of flood control infrastructure, land use regulations, and early warning systems.

Overall, flood susceptibility mapping using multi-criteria analysis is a valuable tool in understanding and managing the risks associated with floods. It provides a systematic and holistic approach to assess and prioritize areas for flood management strategies, enhancing the resilience of communities and infrastructure in flood-prone regions.

Map 11: Flood risk -Hyderabad City



Source: Author

The vulnerability map of Hyderabad city, generated using the weighted overlay technique in ArcGIS, provides valuable insights into the areas at high risk of flooding. The map highlights that the southern part of the city is particularly susceptible to flood hazards due to several factors. These factors include the presence of large low-lying areas, high population density, and significant water accumulation in wards located in the southern region. Additionally, the higher drainage density in these areas indicates that the excessive concentration of concrete structures has hindered proper surface drainage, leading to increased flood risk.

The weights assigned to different criteria in the weighted overlay analysis were based on extensive research. The land use and land cover (LULC) parameter were assigned a weight of 10%, while both watershed and stream order were given weights of 15% each. Factors such as slope, flow accumulation, and drainage density were assigned higher weights of 20% each, reflecting their significant influence on flood vulnerability.

5.1.9. Comparative Analysis of Waterbody

A comparative analysis of water bodies for flood detection is a valuable approach in assessing their effectiveness in mitigating flood risks. By examining different types of water bodies, such as natural lakes, reservoirs, retention ponds, and drainage channels, their roles in flood prevention and management can be evaluated.

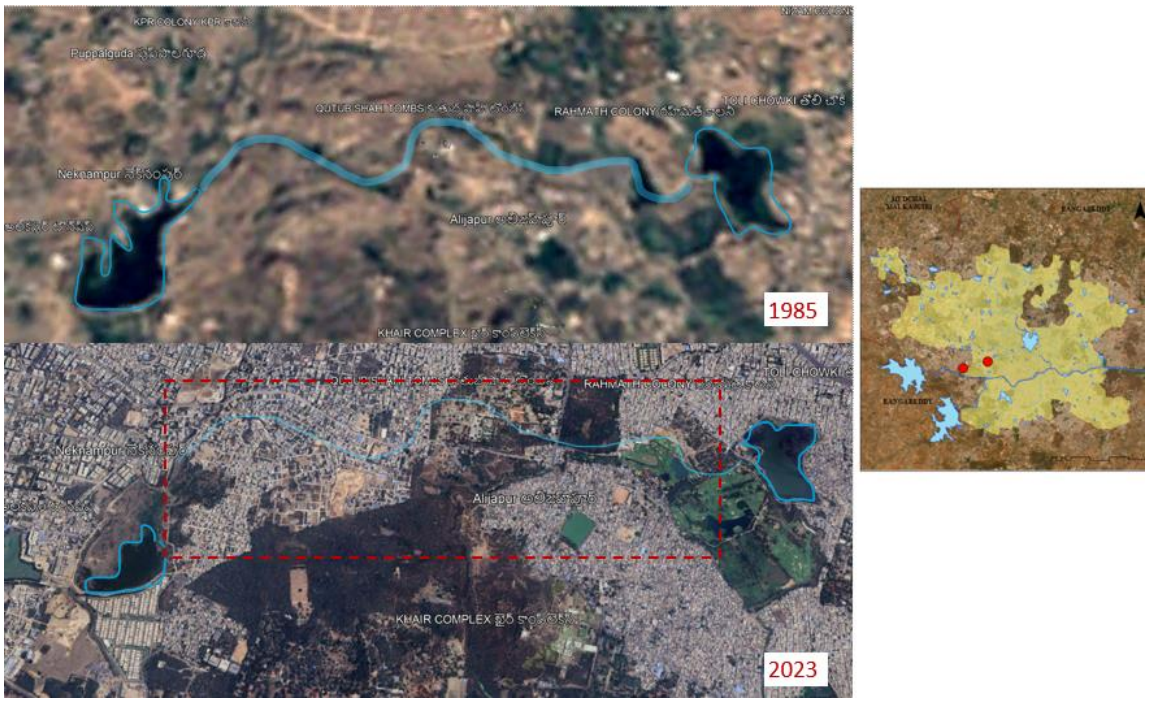
One aspect of the comparative analysis is the capacity of water bodies to store excess water during heavy rainfall events. Reservoirs and retention ponds, designed specifically for flood control, are expected to have a significant impact in reducing flood risk by storing and slowly releasing water. Comparing their storage capacities and efficiency in flood control can provide insights into their effectiveness. Another aspect to consider is the connectivity of water bodies with natural drainage systems. Effective flood detection requires the timely identification of rising water levels and the ability to divert excess water to appropriate outlets. Assessing the connectivity of water bodies with drainage

channels and their ability to effectively channel water away from vulnerable areas is crucial in flood detection and mitigation efforts.

Several buildings and houses have been built without taking into account the floodwater Nala there, effectively closing the space for the exit of water from the city.

This situation has occurred due to those hundreds of lakes which were connected by water channels in the past & those, which typically lie in the valley areas now encroach upon by the buildings.

Figure 18:Comparative analysis of waterbodies



Source: Google Earth

5.2. Socio-Economy Profile

To understand the socio-economic profile related to urban flooding in Hyderabad, a survey can be conducted to gather relevant data. The key aspects that the survey cover:

a. Demographics: Collect information about the demographic characteristics of the affected population, including age, gender, income levels, education levels, and occupation. This will help in understanding how different socio-economic groups are affected by urban flooding.

b. Infrastructure: Evaluate the condition of infrastructure in flood-prone areas, including roads, bridges, drainage systems, and stormwater management facilities. Identify areas with inadequate infrastructure that contribute to flooding and assess the impact on socio-economic activities.

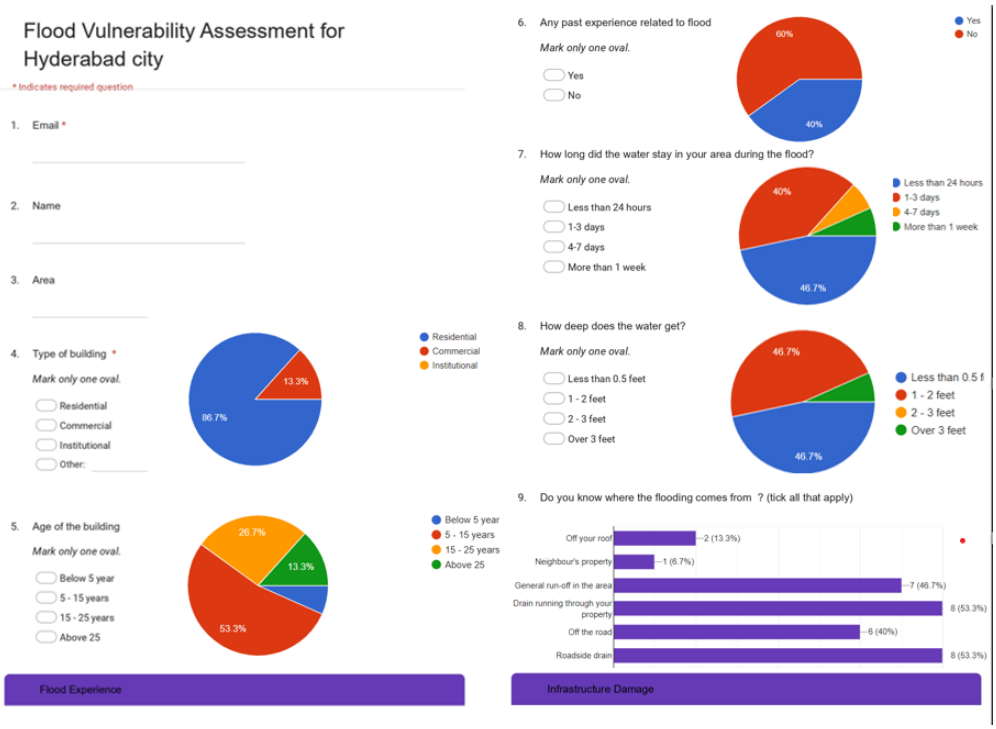
c. Vulnerable Groups: Identify vulnerable groups such as low-income households, elderly individuals, children, persons with disabilities, and marginalized communities.

d. Health and Education: Assess the impact of urban flooding on public health, including the spread of waterborne diseases, sanitation, and access to healthcare facilities.

e. Resilience Measures: Determine the level of awareness and adoption of resilience measures among the affected population. This can include early warning systems, disaster preparedness, community-based initiatives, and government interventions to mitigate the impact of urban flooding.

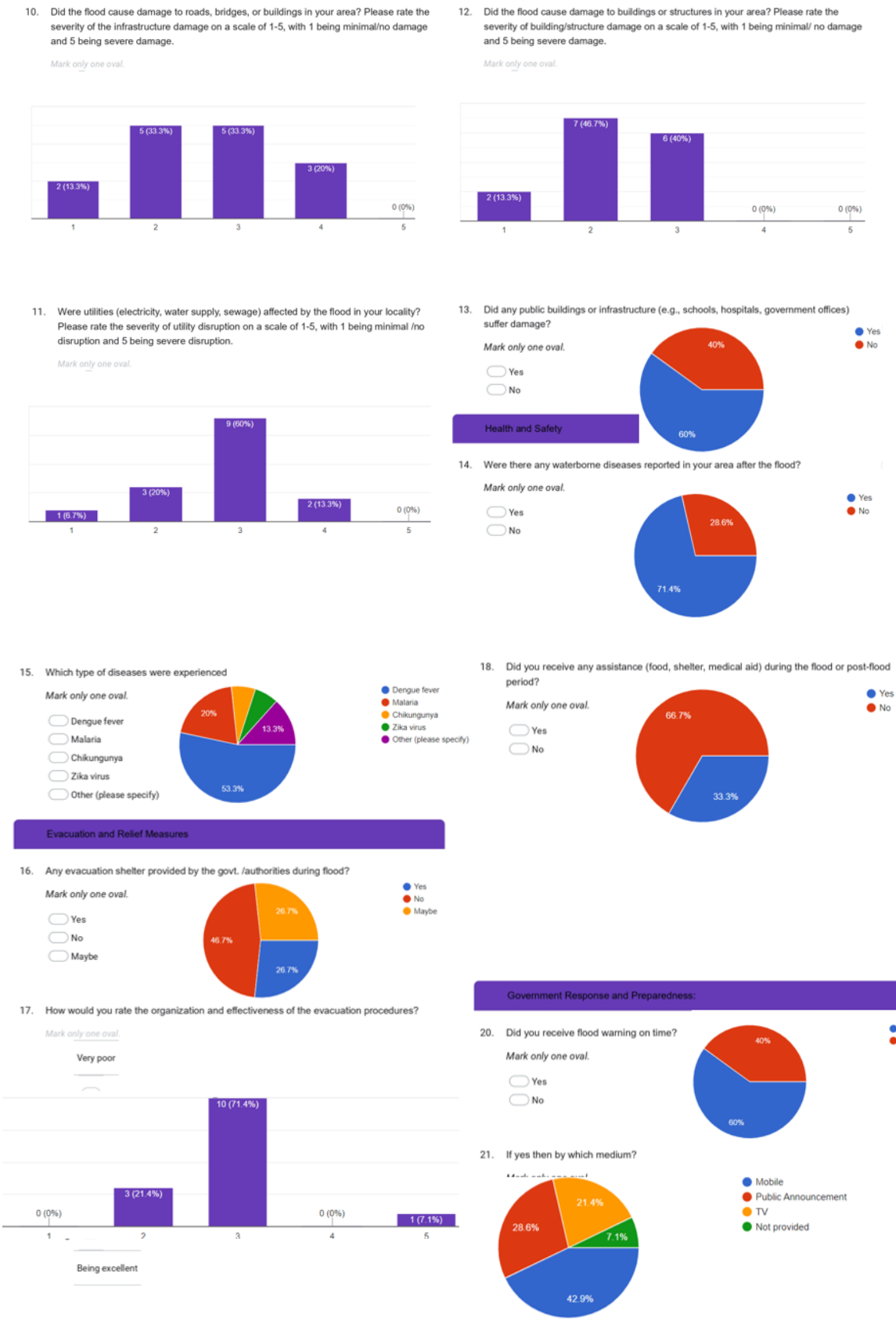
By conducting a survey on these aspects, policymakers, urban planners, and relevant stakeholders can gain insights into the socio-economic factors associated with urban flooding in Hyderabad.

Figure 19: Result of survey



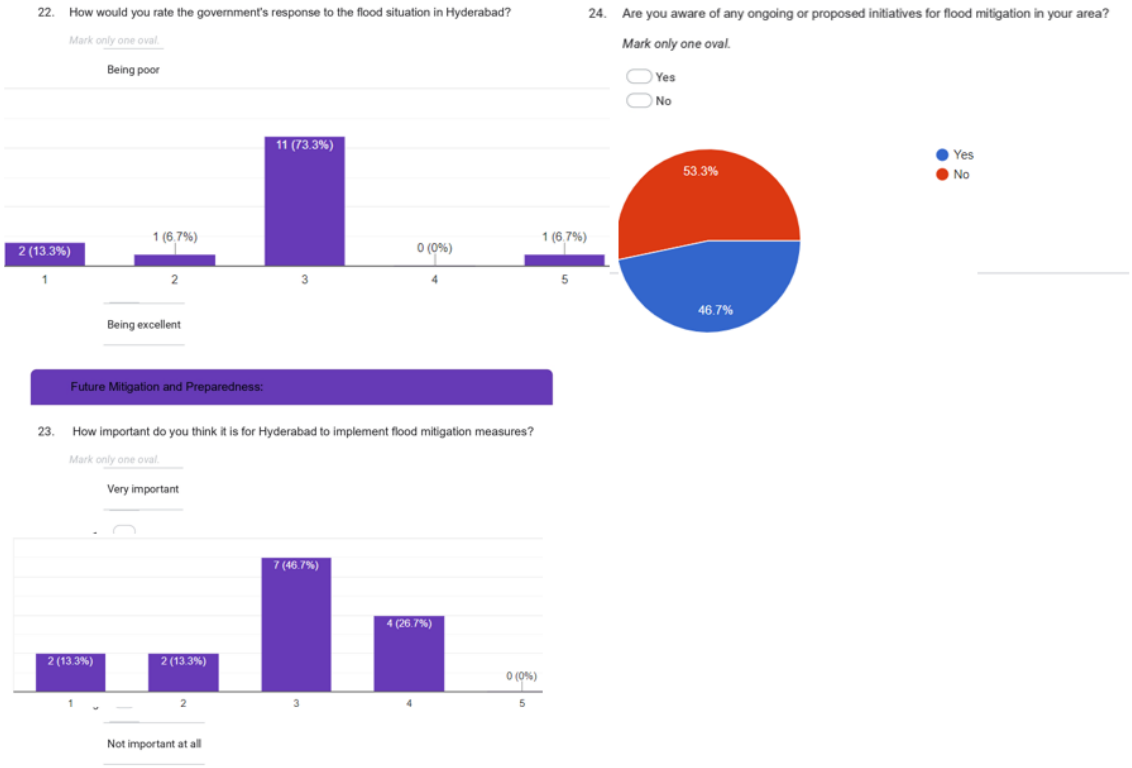
Source: Author

Figure 20: Result of survey



Source: Author

Figure 21: Result of survey



Source: Author

6. SWOT

STRENGTH

- Hyderabad benefits from its central location in Telangana, making it easily accessible for implementing flood mitigation strategies.
- The city can leverage advanced technologies like remote sensing, GIS mapping, and real-time data monitoring to enhance flood forecasting
- The local government has shown commitment to addressing flood-related issues and has implemented various initiatives to mitigate urban flooding.

WEAKNESS

- The rapid growth and urbanization of Hyderabad have led to increased impervious surfaces, reducing natural drainage
- Some areas, including the Khatirabad zone, may have insufficient or outdated drainage infrastructure, leading to inadequate floodwater management.
- Encroachments and Unauthorized Constructions

OPPORTUNITIES

- Hyderabad can adopt an integrated approach that combines flood management with sustainable water resource management, including rainwater harvesting and groundwater recharge.
- Investing in green infrastructure, such as permeable pavements, urban green spaces, and rooftop gardens, can help absorb and retain rainwater, reducing the risk of urban flooding.

THREATS

- Changing weather patterns, including increased rainfall intensity and frequency, pose a significant threat to flood management efforts in Hyderabad.
- The scarcity of available land can restrict the implementation of large-scale flood mitigation infrastructure .
- The continuous growth of the population and urban sprawl can exacerbate flood risks and put additional pressure on existing flood mitigation measures.

7. KEY FINDINGS AND PROPOSAL

The chapter will provide a range of spatial and policy-level recommendations aimed at reducing the risk of flooding and enhancing community resilience. These recommendations will involve strategic measures to modify the microclimate and ensure that communities are better informed and prepared for future flood events. By implementing these recommendations, the objective is to enhance adaptability among residents and make the city more resilient to flooding, ultimately working towards a flood-proof future.

7.1. Key Finding

a. While most parts of the city are connected to the municipal drainage network, certain areas in Cyberabad, which is a recently developed part, lack efficient infrastructure that can effectively handle heavy water flow.
b. The southeastern part of the city is particularly susceptible to flooding due to its natural topography, characterized by lower elevation. Consequently, excess water tends to flow and accumulate in this area.
c. The duration of inundation during flooding events ranges from 30 to 45 days.
d. Unreported deaths and missing persons cases indicate a lack of institutional efficiency, with responsible agencies lacking documentation and records of such incidents.
e. In the initial stages, communities primarily rely on each other for assistance during flood events, highlighting the importance of local support networks.
f. The areas that have been significantly affected by flooding experience a wide range of land prices for constructed properties, varying from 1800 to 10,000 per square foot.
g. It is crucial to integrate technology with the existing systems to enhance community resilience in the face of floods.
h. With the city's population growth rate in mind, there is an urgent need to extend the drainage network to effectively manage increasing water flow.
i. Plantation drives should be implemented to offset the increase in impervious surfaces and promote better water absorption and management.

7.2. Recommendations

The study findings indicate several gaps in the existing literature, highlighting the need for specific recommendations to be implemented in strategies, practices, concepts, or future studies. These recommendations aim to address these gaps and make meaningful contributions to the field of planning. The actions or directions proposed are based on the study's findings, providing guidance on the steps that should be taken to mitigate flood risks and enhance overall preparedness. By implementing these recommendations, we can work towards more effective planning approaches and fill the existing gaps in the literature.

7.2.1. Riparian Buffer to control and prevent flood occurrences

A riparian buffer refers to a vegetated strip of land adjacent to a stream, which serves as a protective barrier against the impacts of surrounding urban, commercial, or agricultural activities. These areas play a crucial role in providing essential resources such as food, shelter, and water to a diverse range of species. Riparian buffers also serve as migration corridors and resting places for wildlife. They are characterized by high soil moisture, are susceptible to flooding, and support a rich biodiversity that has adapted to living alongside water bodies. The presence of trees, grasses, and other vegetation in riparian areas helps stabilize stream banks, reducing the velocity of floodwaters and mitigating downstream flood peaks. Additionally, riparian buffers are highly effective in mitigating non-point source pollution and improving water quality. The vegetation in these buffers acts as a natural filter, preventing erosion and purifying the water as it flows through.

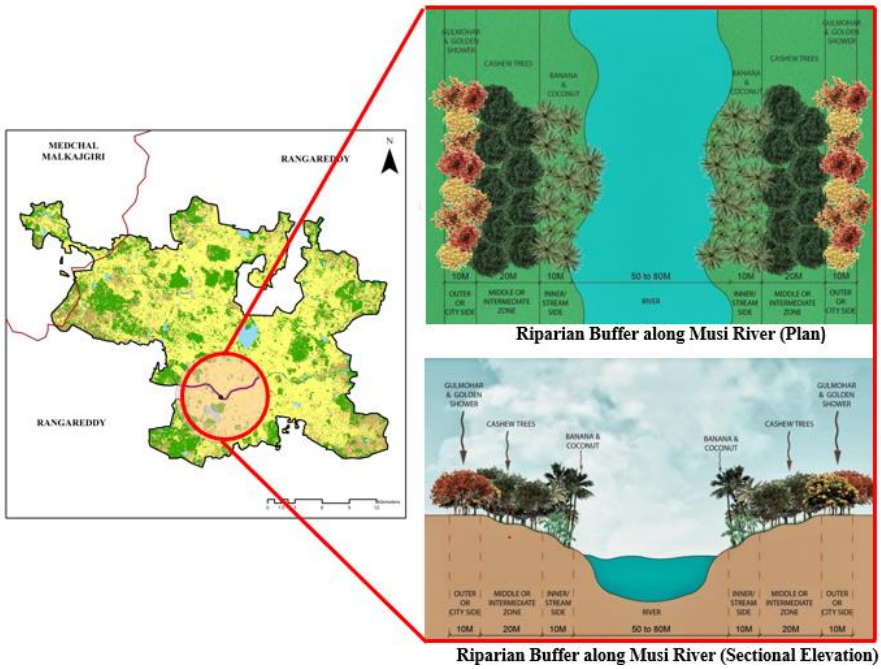
The implementation of riparian buffers offers numerous benefits, including:

a. Improved water quality: Riparian buffers act as natural filters, effectively removing pollutants and contaminants from water bodies, resulting in cleaner and healthier water.
b. Pollution reduction: By trapping and absorbing excess nutrients, sediments, and chemicals from runoff, riparian buffers help to reduce non-point source pollution, improving the overall water quality.

c. Erosion control: The presence of vegetation in riparian areas helps stabilize soil and prevent erosion, protecting stream banks from being washed away.
d. Flood mitigation: Riparian buffers help to regulate and slow down the flow of floodwaters, reducing both the frequency and intensity of flooding events.
e. Micro-climate improvement: The vegetation in riparian buffers contributes to a more balanced and improved micro-climate by providing shade, reducing temperature extremes, and increasing humidity.
f. Habitat provision: Riparian areas serve as valuable habitats for a wide range of plant and animal species, providing food, shelter, and breeding grounds.
g. Groundwater replenishment: Riparian buffers help recharge groundwater by allowing water to infiltrate the soil, replenishing underground aquifers.

These initiatives will be implemented under the National Mission on Sustainable Habitat, aiming to promote integrated water management and address water scarcity issues. The mission will also work towards reversing land use transitions along a 20 km stretch, with potential expansion in the future.

Figure 22: Location of Buffer Riparian



Source: Edited Author

The Plant for Permit scheme encourages public participation by requiring citizens to contribute one plant before receiving birth and death certificates. This innovative approach not only ensures public involvement but also reduces the financial burden on the corporation. By actively engaging citizens in this manner, these initiatives aim to raise awareness, promote a sense of responsibility, and foster an informed and environmentally conscious community.

7.2.2. Integrating grey and green infrastructure

Urbanization in Hyderabad has led to the siltation and clogging of streams and nallas, resulting in increased flood risks and losses. To address these challenges, it is essential for the government to collaborate with NGOs and civil society and adopt an inclusive approach that aligns with nature and natural features, rather than altering or harming them.

Nature-based solutions and green infrastructure offer effective approaches to address both development challenges and ecosystem degradation.

Green infrastructure aims to strategically preserve, enhance, or restore natural systems such as forests, agricultural land, floodplains, riparian areas, and coastal forests. It combines these natural elements with grey infrastructure to create more resilient and cost-effective services. This approach, also known as engineering with nature or natural infrastructure, promotes the integration of built solutions such as reservoirs, pipes, pumps, embankments, and water treatment systems with the hydrological and environmental characteristics of river basins, watersheds, wetlands, and coastal ecosystems.

By leveraging nature's natural capacity, Hyderabad can reduce flood risks and enhance the overall resilience of the city. This can be achieved through a combination of preserving and restoring natural systems, implementing green infrastructure practices, and optimizing the efficiency of grey infrastructure. By adopting these nature-based solutions and green infrastructure strategies, Hyderabad can create a more sustainable and resilient urban environment while safeguarding its ecosystems.

Nature-based solutions (NBS) encompass a range of actions aimed at preserving, restoring, and sustainably managing natural ecosystems to effectively address

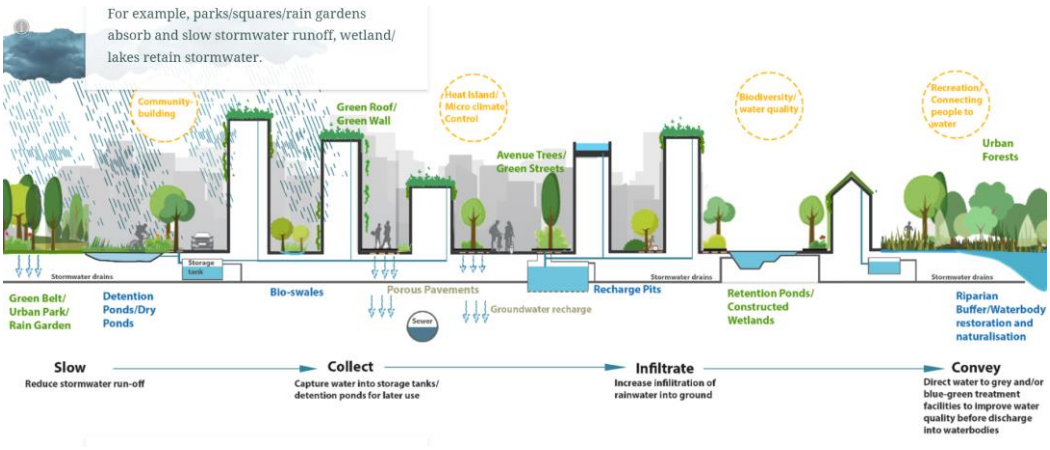
societal problems while benefiting both human well-being and ecosystems. These solutions leverage the buffering capacity of ecosystems to mitigate the impacts of extreme rainfall or drought events, thereby increasing climate and urban resilience.

In the context of Hyderabad, NBS can be successfully applied to maintain and extend existing infrastructure. Here are some recommendations:

a. **Cleaning and Maintenance of Drainage Network:** Regular cleaning and maintenance of the existing drainage network within the city limits is crucial. Additionally, there should be a plan to extend the drainage network in areas that are highly or very highly vulnerable to floods. This will help in controlling the severity and frequency of floods.
b. **Adoption of Blue-Green Infrastructure:** Implementing blue-green infrastructure practices can provide eco-friendly and sustainable solutions. This includes the establishment of bio-swales, roof gardens, pervious pavements, and community-level rainwater harvesting systems. These measures enhance water absorption, reduce surface runoff, and promote groundwater recharge.
c. **Regular Drain Cleaning and De-silting:** To prevent water overflow, it is important to regularly clean and de-silt the drains and channels. This will ensure unobstructed flow and minimize the risk of flooding.
d. **Use of Mesh/Jalis for Drain Covering:** Installing mesh or jalis to cover the drains can help prevent debris and solid waste from blocking the drainage system. This will maintain the efficiency of the drains and reduce the chances of waterlogging.
e. **Establishment of Riparian Buffers:** Along the river Musi, it is advisable to create riparian buffers by planting native species. Riparian vegetation helps enhance water quality, stabilize stream banks, and provide habitat for diverse species. These buffers contribute to water retention and improve overall ecosystem health.

By implementing these nature-based solutions, Hyderabad can effectively manage flood risks, enhance water resilience, and promote the sustainable development of the city while preserving and restoring its natural ecosystems.

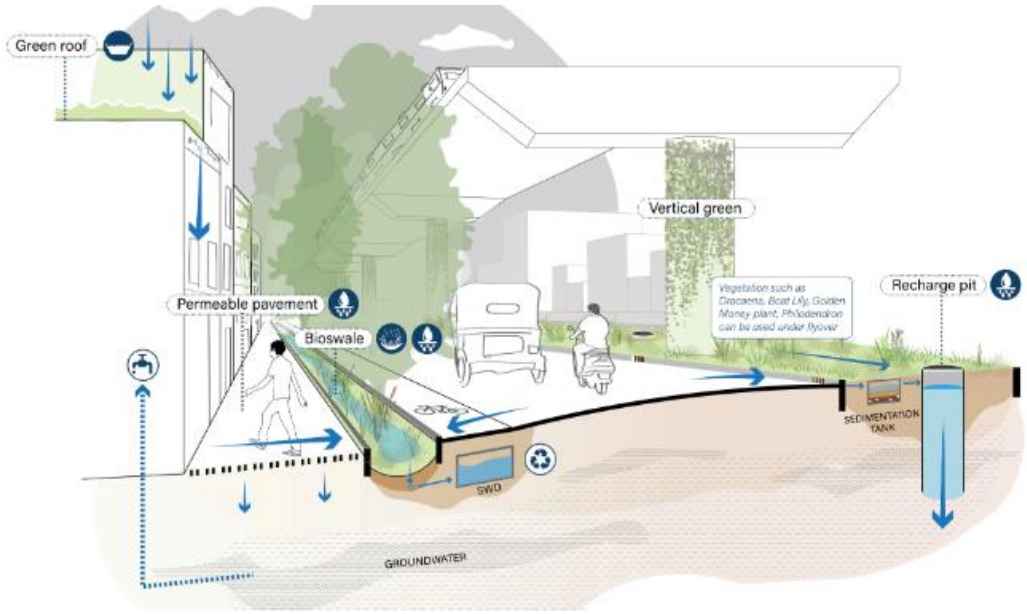
Figure 23: NBS



Source: Urban Flooding: Insights from Hyderabad

Increased onsite stormwater absorption can be achieved through the implementation of nature-based solutions (NBS) for urban flooding. These solutions are most effective when integrated into systematic urban planning at various scales, ranging from individual buildings to the larger landscape or regional level. They are often used in combination with both NBS and grey infrastructure components to maximize their efficiency.

Figure 24:Interlinking transit corridors, building roof, and neighbouring unused urban spaces for systemic capture of rainwater and recharge of ground



Source: Urban Flooding: Insights from Hyderabad

a. Green roofs are a prime example of NBS that minimize stormwater runoff by allowing rainwater to infiltrate through the structure's roof. They can retain a significant portion, ranging from 50% to 100%, of the rainfall they receive. While the initial installation costs of green roofs may be higher compared to conventional roofs, they prove to be cost-effective over their lifespan due to their durability and energy-saving benefits.
b. Pervious concrete, asphalt, or interlocking pavements are another NBS option that enables rainwater to permeate the surface, reducing stormwater runoff. Although the installation costs of these permeable surfaces are generally two to three times higher than standard asphalt or concrete, they have demonstrated a substantial reduction of up to 90% in runoff volumes.
c. Rain gardens and bio-swales are bio-retention areas designed to capture and treat runoff at specific locations. These vegetated trenches can effectively filter contaminants and remove up to 90% of heavy metals from stormwater while controlling peak flows.
d. Strategic placement of parks and greenways can serve as catchment areas for water from upstream basins and surrounding regions. The cost of creating open spaces for this purpose varies depending on land prices and design layout. A notable example in Beijing, China, showcased substantial benefits equivalent to the annual water needs of the city's urban ecological landscape.
e. Constructed wetlands provide another means of capturing and retaining stormwater, facilitating further water infiltration. These wetlands are generally more cost-effective compared to traditional grey infrastructure solutions for the same purpose, although the costs can vary significantly depending on land prices. An acre of wetland has the capacity to hold between 3.8 and 5.7 million liters of floodwater, reducing peak loads on wastewater and stormwater systems.

Implementing these nature-based solutions can enhance stormwater management, reduce runoff, and contribute to the overall resilience of urban areas.

7.2.3. Improving adaptive capacity

a. Enhancing adaptive capacity can be achieved through a flood mitigation skill development program.
b. Sharing traditional techniques and knowledge to cope with floods can be a valuable strategy.
c. It is important to ensure that people living in vulnerable areas have access to hazard insurance. Individuals categorized under MIG/HIG could purchase insurance, while those falling under EWS/LIG should receive subsidies to make it affordable.
d. Developing evacuation and rehabilitation plans is crucial to be prepared for future similar situations.
e. Including disaster programs and education in schools and public areas can effectively raise awareness and sensitize the general public.
f. Social inequality should be addressed through appropriate policies, schemes, and subsidies, ensuring that vulnerable populations have equal access to resources and support.

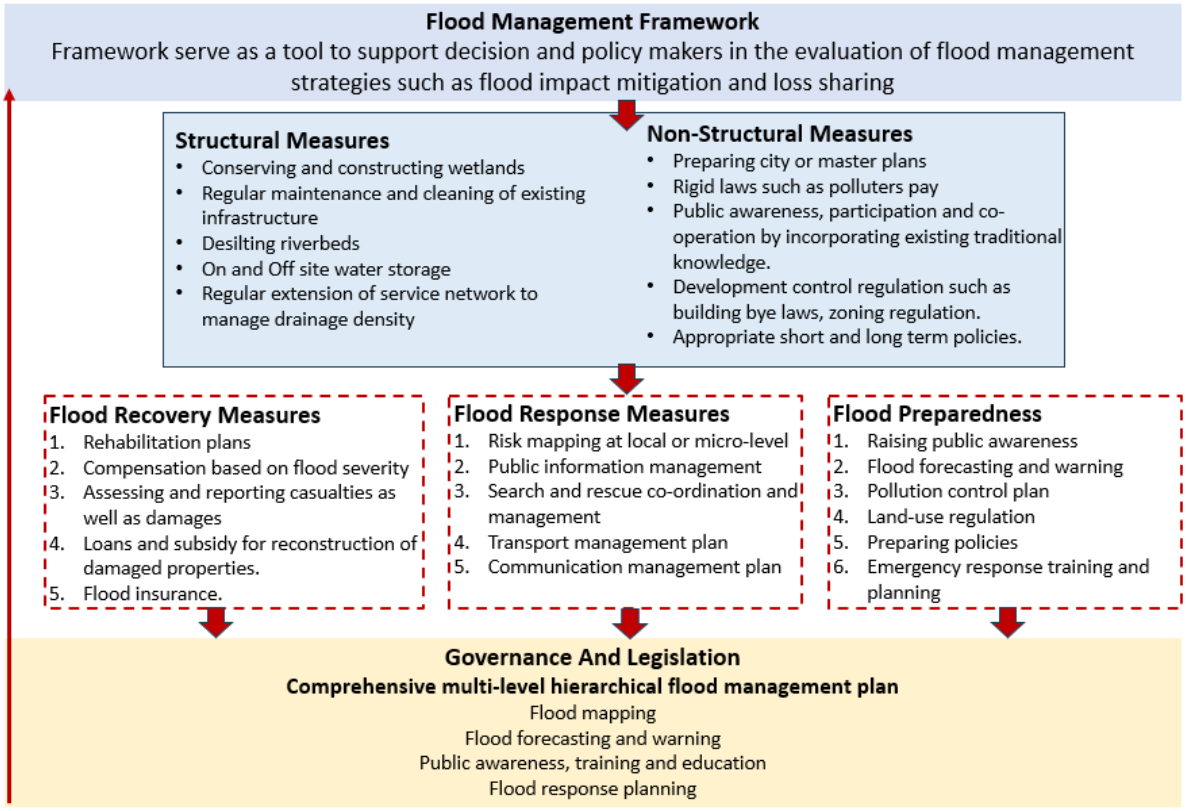
7.2.4. Framework for an inclusive planning process

a. It is important for responsible agencies and authorities to collaborate with citizens in developing a comprehensive flood mitigation plan.
b. Building codes and zoning regulations should be localized to address specific flood mitigation needs of the area.
c. Plantation drives should be initiated to compensate for or reverse the loss of green spaces caused by development.

7.2.5. Integrating technology with the system

a. Implementing an early warning system through SMS or other alert systems can significantly reduce the risk of loss of life and property during floods.
b. To enhance efficiency, it is advisable to decentralize forecasting and alerting centres into zonal units.

Figure 25:Framework for an inclusive planning process



Source: Author

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