

Mainstreaming Disaster Risk Reduction in Spatial Plans: A Comprehensive Guide for Urban Heat and Urban Flooding

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By

NATIONAL INSTITUTE OF URBAN AFFAIRS



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The document is developed on the basis of the review of available secondary sources and expert consultations. This is an open-source publication and can be used for reference purposes. Text from this document may be quoted, provided proper references are given and the source is duly acknowledged. It is intended as a compilation of learnings and recommendations on integrating disaster risk reduction into spatial planning and urban governance, with the aim of disseminating relevant practices and approaches for building resilient cities. The content has been developed primarily through information collated from desk research and related knowledge resources.

Mainstreaming Disaster Risk Reduction in Spatial Plans: A Comprehensive Guide for Urban Heat and Urban Flooding

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NATIONAL INSTITUTE OF URBAN AFFAIRS

Foreword



Dr Debolina Kundu
Director, NIUA

As Indian cities continue to urbanise at an unprecedented pace, the challenges posed by climate change are becoming increasingly acute. Urban flooding and urban heat events have emerged as critical threats, disrupting lives, livelihoods, and infrastructure, and disproportionately affecting the most vulnerable populations. The urgency to mainstream disaster risk reduction (DRR) into spatial planning is therefore greater than ever.

This document, *Mainstreaming Disaster Risk Reduction in Spatial Plans: A Comprehensive Guide for Urban Heat and Urban Flood*, is a timely contribution that bridges the gap between policy intent and practical implementation. It captures the global and national discourse on DRR while contextualising it for Indian cities. Importantly, it translates these frameworks into strategies, tools, and spatial planning interventions that can be embedded in city master plans and governance systems.

The document underscores that building resilience is not only about managing risks but also about shaping urban spaces that are safer, equitable, and sustainable. It calls upon city leaders, administrators, and practitioners to adopt an integrated and forward-looking approach, one that leverages data, technology, and community knowledge while ensuring inclusivity in decision-making.

We hope this document serves as a practical reference for urban planners, policymakers, and researchers to support Indian cities in building resilience against disasters, safeguarding lives and assets, and advancing the larger vision of climate-resilient urban planning.

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Executive Summary

Recent statistics underscore the urgency of this effort: India faced 23 major natural disasters in 2019, resulting in over 1,600 deaths and affecting millions of people (World Bank, 2020). Between 2003 and 2022, the country incurred losses of approximately ₹4.23 lakh crore due to floods and heavy rains, accounting for 83% of rain-related losses over the past seven decades (NDMA, 2023). Furthermore, projections suggest that urban heat days could increase by 7-17 days by 2100, significantly amplifying the challenges faced by urban populations (IPCC, 2021).

This document provides a comprehensive guide on mainstreaming disaster risk reduction (DRR) in spatial plans, focusing specifically on the critical issues of urban flooding and urban heat within Indian cities. As climate change and urbanization intensify these challenges, the need for effective spatial planning interventions has never been more pressing. This study highlights the substantial economic losses, public health risks, and social inequalities exacerbated by urban flooding and heat, particularly affecting vulnerable populations.

The document begins with an overview of disaster management principles as defined by the Disaster Management Act of 2005, outlining the importance of preparedness, mitigation, response, and recovery. It then discusses the current global and Indian contexts, emphasizing the unique vulnerabilities of Indian cities, including geographic, demographic, and economic factors that heighten disaster risks.

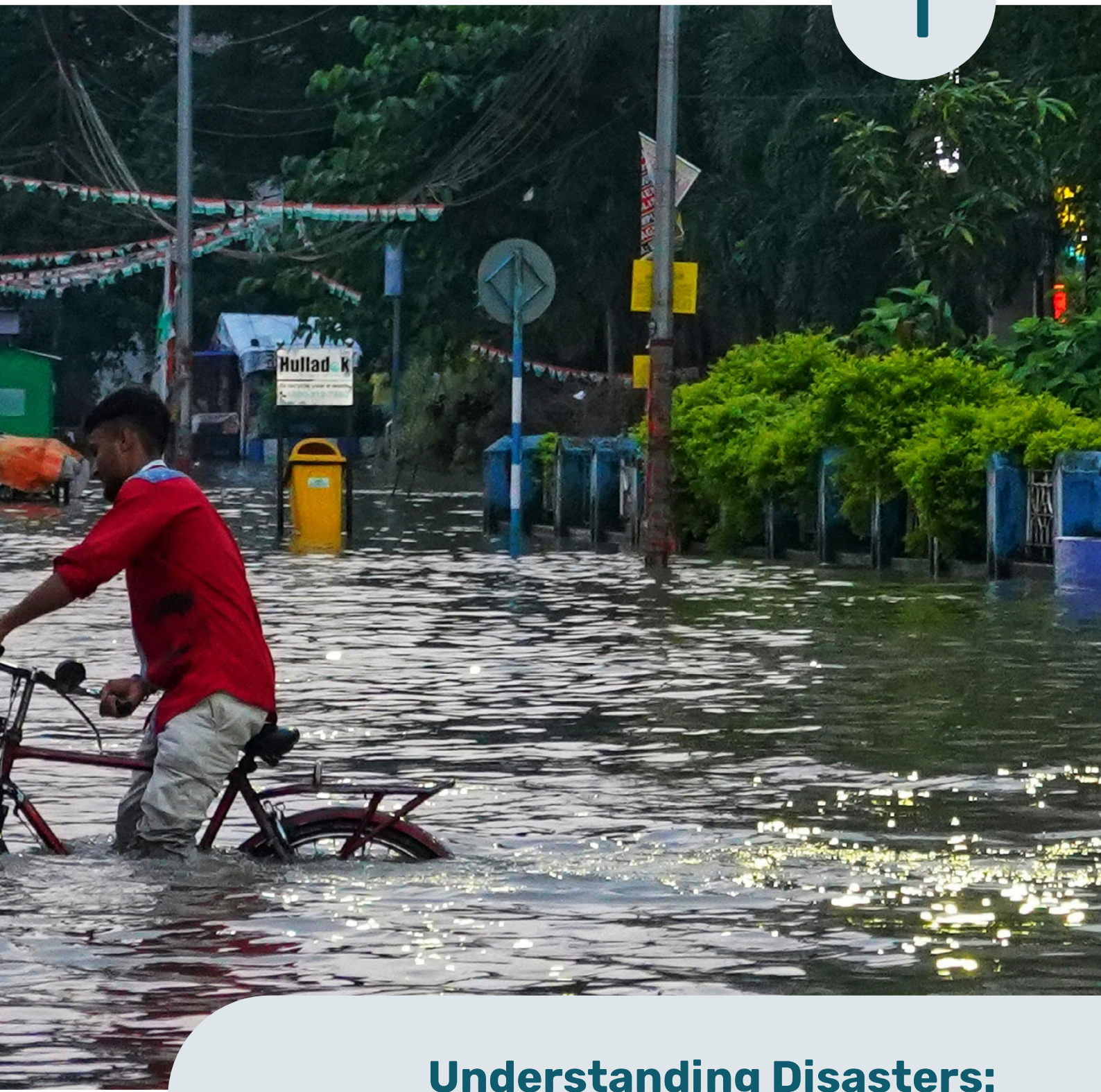
In examining existing policy and regulatory frameworks, the document analyses both global initiatives—such as the Hyogo and Sendai frameworks—and national policies, including the National Disaster Management Act and the National Disaster Management Policy. This context underscores the necessity for coordinated action at multiple governance levels to enhance disaster resilience.

Focusing on urban flooding and urban heat, the study outlines the interconnected nature of these hazards and their compounded effects on urban environments. It explores issues such as housing vulnerability, health implications, and economic impacts, providing a rationale for prioritizing these two disasters in urban planning.

The recommendations section presents actionable strategies for city officials, including the development of flood risk-informed master plans, hazard mapping, and land use planning to reduce flood risks. For urban heat, it emphasizes urban green infrastructure, heat hazard mapping, and the integration of passive cooling techniques in building designs. These strategies aim to create more resilient urban environments by addressing the immediate and long-term challenges posed by climate-induced disasters.

In conclusion, this document serves as a crucial resource for urban planners, policymakers, and stakeholders, offering practical tools and frameworks to mainstream disaster risk reduction in spatial planning. By adopting these recommendations, Indian cities can significantly enhance their resilience to urban flooding and heat, ultimately protecting lives, livelihoods, and the environment in the face of growing climate risks.





Understanding Disasters: An Overview

1. Understanding Disasters: An Overview

.....

1.1 Introduction

Natural disasters pose a significant threat to communities worldwide, frequently resulting in severe consequences for human life, infrastructure, and economic stability. An effective understanding of disaster vulnerability necessitates a comprehensive analysis of both the physical risks associated with specific hazards and the underlying socio-economic conditions that predispose certain populations to heightened exposure. Vulnerable groups, particularly those living in poverty, encounter amplified challenges during such events, often experiencing disproportionately severe impacts.

Several interrelated factors contribute to this vulnerability. A lack of access to early warning systems frequently leaves individuals in at-risk communities without timely alerts regarding impending disasters, rendering them unprepared for emergencies. Furthermore, the resilience of infrastructure in these areas is often inadequate; critical physical structures—such as homes, roads, and bridges—are typically not designed to withstand extreme weather events, leading to extensive damage and prolonged recovery periods.

Inadequate disaster preparedness exacerbates these vulnerabilities, as many households may lack access to essential resources or training necessary for effective crisis response. Post-disaster recovery is further hindered by insufficient financial resources, which significantly impede the ability of affected communities to rebuild their lives and regain stability.

Disaster risk management is essential for addressing these vulnerabilities and mitigating the impacts of disasters. Effective strategies encompass risk assessment, preparedness, response, recovery, and long-term mitigation efforts aimed at reducing exposure and enhancing community resilience. Additionally, climate change intensifies these vulnerabilities by increasing the frequency and severity of extreme weather events, thereby posing further challenges to existing disaster management frameworks.

1.2 Disaster and Its Components

As per the Disaster Management Act, 2005 of India, a **disaster** is defined as a catastrophe, mishap, calamity, or grave occurrence in any area, arising from natural or man-made causes, or by accident and negligence, which results in substantial loss of life, human suffering, damage to property, or degradation of the environment, and is of such a nature or magnitude as to be beyond the coping capacity of the affected community. In response to such events, disaster management encompasses a coordinated series of actions aimed at minimising the impact of disasters on people, infrastructure, and the environment. It involves response, recovery, preparedness and mitigation, efforts, ensuring that communities are equipped to handle both immediate and long-term effects of disasters. Effective disaster management requires collaboration among government agencies, local authorities, communities, and other stakeholders to strengthen resilience, improve early warning systems, and facilitate swift and efficient recovery. Through well-structured planning and proactive measures, disaster management seeks to reduce risks, enhance the capacity to cope with future disasters, and ultimately protect lives and livelihoods.

1.2.1 Hazard

A **hazard** is any potential occurrence of a natural or human-induced physical event that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, and environment (ISDR, 2007)¹. More simply, any condition, material, process or event having the potential to cause harmful effects is understood as a hazard.

Hazards are generally classified into **natural hazards**, **human-made (or technological) hazards** and complex hazards, although in urban areas, the impact of human-made hazards can often be exacerbated by environmental factors or by the sheer scale of human activity.

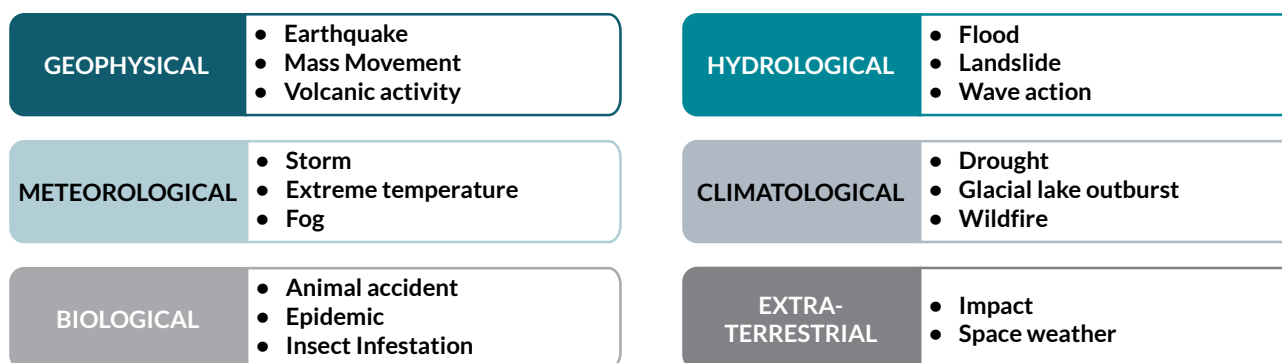


Figure 1: Natural Hazards Subgroups and Types in the IRDR Peril Classification and Hazard Glossary²

- **Natural Hazards:** These are hazards that arise from natural processes or environmental conditions. India is prone to a wide range of natural hazards, such as cyclones, floods, heatwaves, landslides, earthquakes, wildfires, likewise. In addition, Indian cities also face air quality deterioration, flash floods and urban heating.
- **Human-Made Hazards:** These hazards arise due to human activity, industrial processes, or accidents. This includes, chemical hazards, fires, technological and infrastructure failures likewise.
- **Complex Hazards:** It is where multiple hazards interact with each other, amplifying their impact. For example, an earthquake may trigger landslides or fires, or a heatwave may exacerbate air pollution, leading to public health crises.

1.2.2 Vulnerability

Vulnerability means the characteristics of a person, group of persons (community) or their resources (property, infrastructure, environment or ecosystems) and the concerned situation that influences their capacity to anticipate, cope with, resist and recover from the impact of a natural or anthropogenic hazard.

It involves a combination of factors that determine the degree to which someone's life, livelihood, property, ecosystems and other assets are put at risk by a discrete and identifiable event in nature and society. Social vulnerability enumerates upon the fact that in our society some groups are more prone to damage and losses in context to different hazards. The vulnerability could be divided into four types, viz:

- Physical vulnerability:** Physical vulnerability includes the risk to the tangible things having physical structure or configuration, such as infrastructure, amenities, houses, buildings, bridges, and other assets which can be directly hit by a hazard event. For example, in case of an earthquake, old and structurally weak buildings are vulnerable to damage or collapse.
- Environmental vulnerability:** Environmental vulnerability represents the risk to land and landscape, land-use, existing ecological settings including natural resources and ecosystem services, and thereby, also referred to as underlying causes of socio-economic vulnerability. For example, urban activities on the coastline of

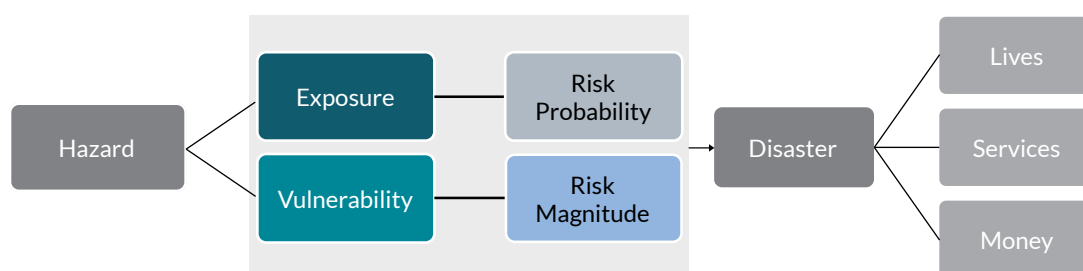


Figure 2: Relationships between hazard, risk and disaster

cities like Mumbai make the mangrove vegetation cover recede. This environmental vulnerability increases the chances and impact of urban flooding, and causes further socio-economic vulnerability in urban coastal communities and slum areas.

- c. **Socio-economic vulnerability:** Social vulnerability means the threat to life and livelihood based on factors like caste, ethnicity, age, gender, ability, health status, etc due to a hazard. Key variables explaining the variation of impact include class, occupation, caste, ethnicity, gender, disability and health status, age and immigration state and social networks.
- d. **Systemic vulnerability:** Systemic vulnerability represents the state of intactness in the governance and administration against the risk of disaster incidents. This includes management and inter-relationship between different levels of governments, and within and among organizations, agencies and, thus, represents the effectiveness of coordination even during a disaster situation.

1.2.3 Exposure

Exposure is one of the key components of disaster risk, referring to the presence of people, property, infrastructure, and other assets in hazard-prone areas, which are subject to potential damage from a disaster event. According to the **International Strategy for Disaster Reduction (ISDR)**, exposure

is defined as “the presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; and built structures, services, and infrastructure in areas that could be adversely affected by hazard events” (ISDR, 2009)³. In simple terms, exposure quantifies the extent to which an area or population is physically exposed to a potential hazard, such as floods, earthquakes, or cyclones.

In disaster risk assessment, the weightage or significance of each component differs depending on the context. For example:

- a. **High Exposure with Low Vulnerability:** In this case, even though a large number of people or assets are exposed to hazards (e.g., a floodplain or coastal city), the impact may be mitigated due to strong infrastructure, early warning systems, and effective response measures. This scenario typically results in fewer casualties or less damage despite significant exposure.
- b. **High Exposure with High Vulnerability:** This is often the most concerning scenario. If a large population or critical infrastructure is exposed to frequent or severe hazards (e.g., an earthquake-prone city with poorly constructed buildings), the risk of loss and destruction increases dramatically. High vulnerability compounds the exposure, leading to devastating consequences in terms of human casualties, economic loss, and

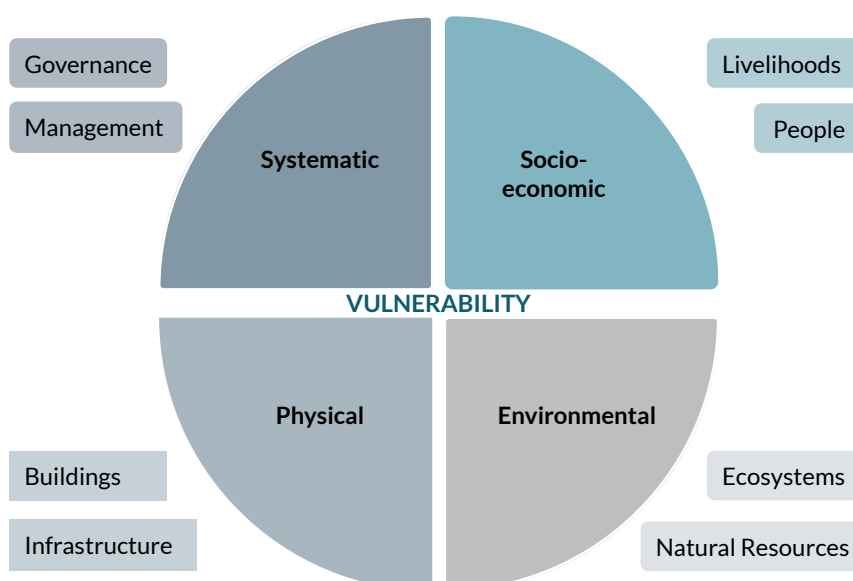


Figure 3: Disaster Vulnerability classification, Source: Authors

environmental degradation.

- c. **Low Exposure with High Vulnerability:** Even when fewer people or assets are exposed to hazards, the vulnerability of the exposed group may lead to significant impacts. For instance, a rural community in an isolated area may not be directly exposed to frequent hazards, but limited access to resources, poor infrastructure, and low resilience can make them highly susceptible to harm when a disaster strikes.
- d. **Low Exposure with Low Vulnerability:** In this situation, there is minimal risk due to both low exposure and low vulnerability. Areas that are both geographically distant from hazard zones and have strong infrastructure and social systems tend to experience less significant impacts from disasters.

Exposure, along with **hazard** and **vulnerability**, determines the overall level of disaster risk. Understanding and addressing exposure involves not only identifying hazard-prone areas but also considering the spatial distribution of vulnerable populations and assets. For example, rapid urbanization and unplanned settlements in flood-prone areas increase exposure, while weak building codes, inadequate emergency services, and limited social safety nets increase vulnerability.

In conclusion, while **hazard** and **vulnerability** are critical in assessing disaster risk, **exposure** plays a crucial role in determining the scale and severity of the impacts. Reducing exposure through better urban planning, land-use policies, and relocation strategies can significantly lower disaster risks, especially in areas with high vulnerability. This holistic approach to disaster risk management ensures that all components—hazard, vulnerability, and exposure—are addressed to build resilient communities.

1.3 Disaster Risk

Disaster Risk is an indicator of the probability of occurrence of a hazardous event and the extent of its damage in terms of lives lost, persons injured, damage to property, environment, infrastructure and disruption of economic activity.

Underlying drivers of disaster risk refer to processes or conditions—often linked to development—that

exacerbate the level of exposure, vulnerability, and reduce the capacity of communities to cope with disasters. These drivers, sometimes called **underlying disaster risk factors**, include systemic issues such as poverty, inequality, climate change, and unplanned urbanization. These factors contribute to a higher level of **exposure**, by increasing the number of people and assets located in hazard-prone areas, and to greater **vulnerability**, by limiting the ability of individuals and communities to prepare for or recover from disasters.

1.4 Disaster Management

Disaster Management means a continuous and integrated process of planning, organizing, coordinating and implementing measures that are necessary or expedient for implementing the following actions (Ministry of Law and Justice, 2005):

- a. Prevention of danger or threat of any disaster
- b. Building capacities within governments and citizens.
- c. Mitigation or reduction of risk of any disaster or its severity or consequences
- d. Prompt response to any threatening disaster situation or disaster
- e. Preparedness to deal with any disaster
- f. Assessing the severity or magnitude of effects of any disaster
- g. Evacuation, rescue and relief
- h. Rehabilitation and reconstruction

1.4.1 Four Phases of Disaster management

Disaster management is typically divided into four key phases: mitigation, preparedness, response, and recovery.

Disaster management is a comprehensive and systematic approach aimed at reducing the impact of disasters, enhancing community resilience, and ensuring a coordinated response during times of crisis. The process begins with **mitigation**, which focuses on reducing or eliminating the risks of disasters before they occur. Mitigation efforts include both **structural** and **non-structural measures**. Structural mitigation involves physical interventions such as **retrofitting**, **protective structures**, and **reinforcing infrastructure** to reduce exposure to hazards like floods, earthquakes, or cyclones. Non-

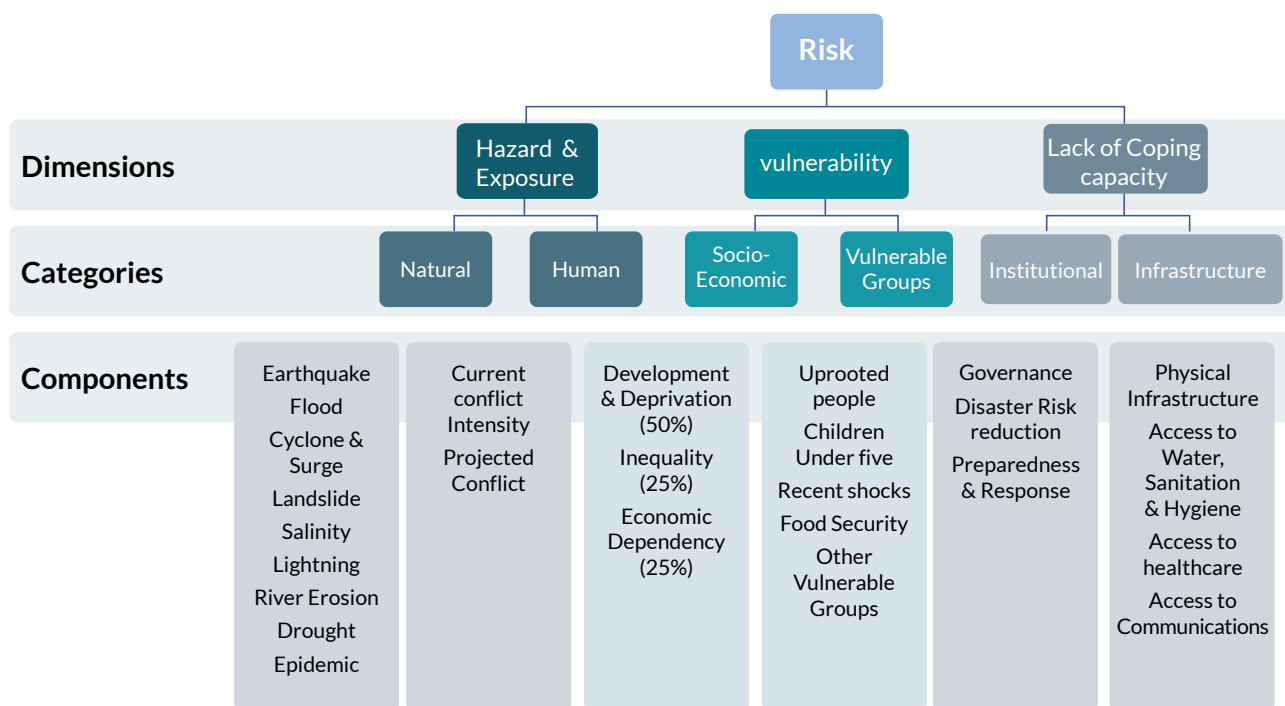


Figure 4: Components of Disaster Impact,

Data Source: UNDRR⁴

structural mitigation, on the other hand, includes actions like **environmental conservation**, land-use planning, policy development, and community awareness programs. The goal is to minimize risks by addressing the underlying causes of vulnerability and exposure, such as encouraging sustainable practices and reducing human encroachment in disaster-prone areas.

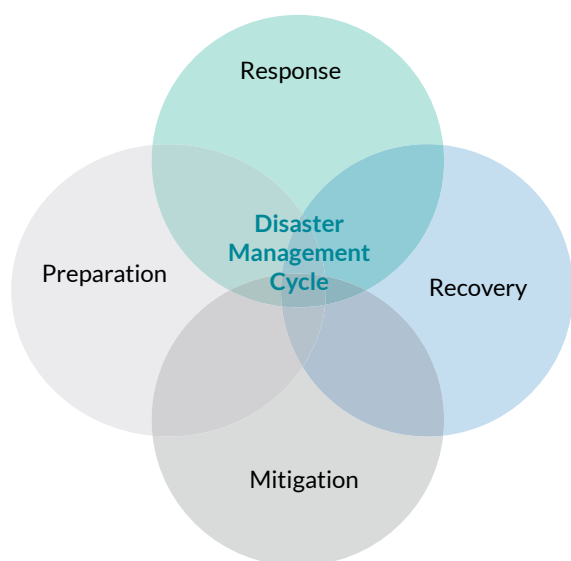


Figure 5: Four phases of Disaster Management

The **preparedness** phase of disaster management is crucial for ensuring communities are ready to respond effectively to disasters, following mitigation efforts. This involves planning and organizing resources, **training first responders**, conducting **regular drills**, establishing early warning systems, and ensuring emergency services are equipped for quick action. **Capacity building** is also essential, as it educates local communities and authorities on disaster response and provides them with the necessary tools to handle emergencies. Complementing this is the incorporation of **pre-impact** measures focused on **disaster risk reduction (DRR)**, which emphasizes preventive strategies such as integrating early warning systems, improving urban planning to avoid high-risk areas, and fostering community engagement to cultivate a culture of preparedness. Together, these efforts aim to minimize loss and disruption by enhancing community resilience and reducing the potential severity of disaster impacts when they occur.

Once a disaster occurs, the **response** phase takes precedence. This phase involves immediate actions to protect lives, property, and infrastructure, such as **emergency evacuations**, providing **medical aid**, and conducting **rescue operations**. During this phase,

effective coordination among local authorities, government agencies, and humanitarian organizations is critical to ensure a rapid and organized response. The main objective is to save lives and prevent further damage by ensuring that the necessary resources are mobilized quickly and efficiently.

Once the immediate danger has passed, the **recovery** phase begins, focusing on restoring normalcy and rebuilding the affected community. This phase includes repairing damaged infrastructure, restoring essential services like water, electricity, and healthcare, and providing **financial support** and **psychological counselling** to those impacted. The recovery process can last from months to years, depending on the scale of the disaster. It also offers an opportunity to **learn from the event** and improve future disaster risk reduction strategies, ensuring that recovery efforts help communities become more resilient to future disasters.

In parallel to recovery, **restoration** and **reconstruction** efforts are vital to rebuilding infrastructure and revitalizing the community. These processes are focused not only on rebuilding homes, schools, and hospitals but also on ensuring that future structures are designed with greater resilience in mind. It is crucial that reconstruction efforts integrate lessons

learned from the disaster, ensuring that the rebuilt community is better prepared for future challenges. The reconstruction phase also offers an opportunity to address systemic vulnerabilities that contributed to the disaster's impact, such as by improving building codes, updating land-use policies, or restoring natural barriers like wetlands to reduce flood risk.

Ultimately, disaster management is a dynamic process that involves a range of activities designed to mitigate risks, prepare communities for disasters, ensure an effective response during crises, and support recovery efforts. By addressing disaster risks through both structural and non-structural measures, and focusing on capacity building and resilience, communities can significantly reduce their vulnerability to hazards. Effective disaster management not only helps save lives during an event but also ensures that communities can recover quickly and build back better, ultimately reducing future risks and strengthening the overall resilience of the urban environment.

1.5 Disaster Resilience

The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the

OneNYC

New York City's OneNYC plan integrates equity, climate resilience, and long-term sustainability into urban governance to provide sustainable and resilient city for all its residents. The plan set out with an ambition to build a thriving, equitable, resilient and sustainable city, recognizes that social and environmental vulnerabilities are deeply intertwined. It aims to tackle systemic inequality while preparing the city for the dual challenges of climate change and rapid urbanization.

OneNYC operationalises this through a series of investments in climate-resilient infrastructure, including the upgrading of transportation networks, coastal defences, upgrading aging water and energy infrastructure to withstand climate shocks, investing in green infrastructure like rain gardens and bioswales to manage stormwater, and setting greenhouse gas emission reduction targets aiming for 80% reduction by 2050. The city also launched Resilient Neighbourhoods and Community Preparedness Initiatives, prioritising historically underserved areas for adaptation planning. Early results have shown measurable progress: emissions declined by over 15% since 2005, hundreds of thousands of residents gained access to affordable housing units, and flood protection infrastructure was expanded in high-risk zones such as the Lower East Side. The plan has since evolved into OneNYC 2050, building on its integrated approach and placing greater focus on climate justice, workforce equity, and inclusive economic recovery.

preservation and restoration of its essential basic structures and functions through risk management (UNDRR)⁵.

A resilient community or city can absorb shocks and stresses, ensuring that essential functions continue even during and after a disaster. The concept of resilient cities focuses on integrating disaster risk reduction (DRR) into urban planning, development, and governance to create urban environments that can withstand and recover from various disasters, including floods, earthquakes, heatwaves, and cyclones.

One of the key frameworks for resilient cities is the **Sendai Framework for Disaster Risk Reduction 2015-2030**, which emphasizes the importance of building resilience in urban areas by adopting risk-informed development. It highlights the need for cities to focus on risk reduction through **climate adaptation**, **inclusive planning**, and **sustainable urbanisation** to avoid the amplification of vulnerabilities. The framework also calls for integrating **ecosystem-based approaches** to reduce disaster risks and enhance resilience by preserving natural buffers like wetlands, mangroves, and forests that provide essential services in times of disaster.

Urban resilience is particularly important in the context of climate change, which is expected to

increase the frequency and intensity of extreme weather events such as storms, floods, and heatwaves. According to the **UN-Habitat**, cities are highly vulnerable to climate change, particularly in developing countries where urban populations are growing rapidly and informal settlements are common. As a result, there is an urgent need to develop resilient urban strategies that not only reduce the risks posed by climate change but also enhance the adaptive capacity of cities to future shocks (UN-Habitat, 2020)⁶.

A **resilient city** is one that can **anticipate, prepare for, respond to, and recover from** disaster events with minimal disruption. This includes investing in **green infrastructure**, improving the **capacity of local institutions**, and fostering **community participation** in disaster risk management. For example, **New York City's "OneNYC"** plan aims to integrate climate resilience into urban development by upgrading infrastructure, reducing emissions, and ensuring that the most vulnerable populations are protected from disaster impacts (City of New York, 2015)⁷.

The Ten Essentials for Making Cities Resilient were developed by the Sendai Framework for Disaster Risk Reduction actions. Under each essential, key actions have been identified in the framework. These essentials are mapped across three layers i.e. corporate governance, integrated planning,

- 1  Organise for disaster resilience
- 2  Identify, understand and use current and future risk scenarios
- 3  Strengthen financial capacity for resilience
- 4  Pursue resilient urban development and design
- 5  Safeguard natural buffer to enhance the protective functions offered by natural ecosystems
- 6  Strengthen institutional capacity for resilience
- 7  Understand and strengthen societal capacity for resilience
- 8  Increase infrastructure resilience
- 9  Ensure effective disaster response
- 10  Expedite recovery and build better

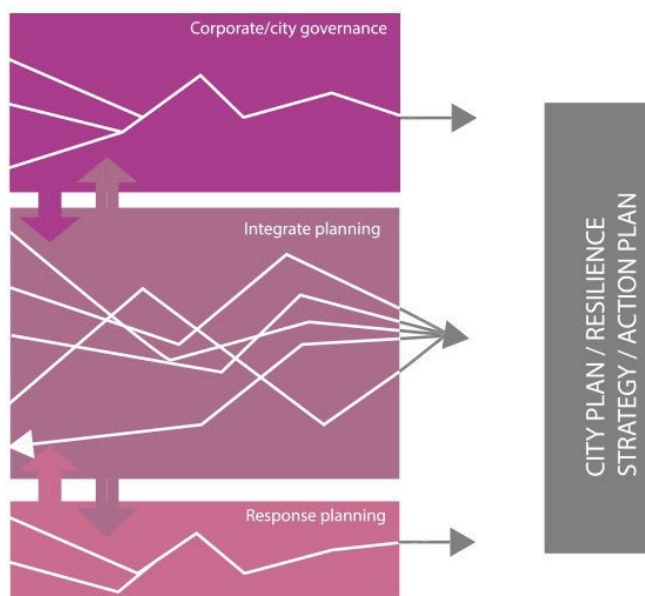


Figure 6: The 10 essentials for making cities resilient⁸

As per the National Institute of Disaster Management (NIDM), a disaster-resilient city:

- a. Is one where disasters are minimised because the population lives in homes and neighbourhoods with organized services and infrastructure that adhere to sensible building codes.
- b. Has an inclusive, competent and accountable local government that is concerned about sustainable urbanization and that commits the necessary resources to develop capacities to manage and organize itself before, during and after a natural hazard event.
- c. Is one where the local authorities and the population understand their risks and develop a shared, local information base on disaster losses, hazards and risks, including who is exposed and who is vulnerable.
- d. Is one where people are empowered to participate, decide and plan their city together with local authorities and value local and indigenous knowledge, capacities and resources.
- e. Has taken steps to anticipate and mitigate the impact of disasters, incorporating monitoring and early warning technologies to protect infrastructure, community assets and individuals, including their homes and possessions, cultural heritage, environmental and economic capital, and can minimize physical and social losses arising from extreme weather events, earthquakes or other natural or human-induced hazards.
- f. Can respond, implement immediate recovery strategies and quickly restore basic services to resume social, institutional and economic activity after such an event.
- g. Understands that most of the above are also central to building resilience to adverse environmental changes, including climate change, in addition to reducing greenhouse gas emissions

and response planning, ensuring that resilience is embedded into all aspects. Together, they can help guide the formulation of a comprehensive City Resilience Strategy or Action Plan that enables cities to better anticipate, absorb, and recover from disaster risks.

In conclusion, disaster resilience is a multidimensional concept that requires collaboration across various sectors—urban planning, governance, infrastructure, and community engagement. Building resilient cities is an ongoing process that requires not only immediate action to mitigate risks but also long-term strategies to adapt to future challenges. As cities continue to grow and face increasing disaster risks, fostering resilience through risk-informed policies and investments will be critical to safeguarding lives and livelihoods.

1.6 Interlinkages between Climate Change and Urbanisation

The relationship between climate change and rapid urbanization presents a multifaceted risk landscape that significantly heightens vulnerabilities to disasters. As urban areas evolve and expand, they are projected to house approximately 68% of the

global population by the year 2050. This substantial increase in population density exacerbates the exposure of these regions to various climate-induced hazards, such as extreme weather events, rising sea levels, and heat waves.

The rapid growth of cities often leads to environmental degradation, including deforestation, loss of green spaces, and increased air and water pollution, which further contribute to their vulnerability. Additionally, inadequate infrastructure and limited resources in many urban areas pose challenges in disaster preparedness and response. As a result, it is crucial for policymakers and urban planners to implement sustainable practices and devise strategies that enhance resilience against the growing threats posed by climate change in these densely populated environments. The IPCC's Sixth Assessment Report emphasizes that urban systems are particularly susceptible to compound and cascading risks due to their concentrated populations and interconnected infrastructure networks (IPCC, 2022)⁹. In India, an estimated 24.1 million children are impacted by floods, cyclones, heatwaves and other emergencies every year¹⁰. Climate change, combined with environmental degradation, is increasing the

frequency, severity and overall impacts of these kinds of hydro-meteorological hazards.

Urbanization patterns in developing countries, including India, often exhibit unplanned growth and informal settlements in hazard-prone areas. Rapid urbanisation has led to the expansion of cities and encroachment on natural water bodies and floodplains. The rapid growth of urban areas, exacerbated by the impacts of climate change, generates complex risk scenarios that traditional planning strategies are ill-equipped to handle. Addressing these challenges is essential for sustainable development and safeguarding communities.

The incorporation of disaster risk reduction into spatial planning has emerged as an essential strategy for developing resilient urban systems. This approach involves systematically analysing and addressing potential hazards in urban design and land use decisions. Research has shown that cities with well-established spatial planning frameworks that explicitly integrate considerations of disaster risk tend to exhibit significantly higher resilience in the face of extreme events, such as natural disasters or climate-related crises. Furthermore, these cities often experience lower recovery costs after such events, as proactive planning allows for better preparedness and more efficient response measures, ultimately safeguarding infrastructure, protecting lives, and reducing economic losses. By prioritizing disaster risk reduction within the framework of urban planning, cities can create safer and more sustainable environments for their residents (World Bank, 2024)¹¹.

1.7 Scope of the study

This study will concentrate exclusively on urban flooding and urban heat in Indian cities, emphasizing the urgent need for effective spatial planning interventions. Given the significant impacts of these disasters—including substantial economic losses, public health risks, and the exacerbation of inequalities—this research serves as a critical response to the challenges posed by climate change. The selection of these two hazards stems from their growing significance and the escalating threats they pose, particularly amid rapid urbanization, climate change, and insufficient infrastructure. As these

hazards become increasingly frequent and severe, their impacts disproportionately affect vulnerable populations, often exacerbating each other's effects and leading to considerable economic and social disruptions. This report delves into the integration of disaster risk reduction (DRR) strategies within the framework of Indian city master plans and policy guidelines, aiming to identify and propose spatial planning tools and strategies that city officials can suitably implement to mitigate the challenges posed by urban flooding and heat. By focusing on these targeted recommendations, the study aims to yield immediate benefits and enhance the resilience of urban environments.

1.8 Structure of Document

This document is organized into six main sections, each addressing critical aspects of disaster risk management and resilience in the context of urban flood and urban heat.

- a. **Understanding Disasters: An Overview:** This section provides foundational knowledge about disasters, including definitions, the concept of disaster risk, and an overview of disaster management and resilience. It also explores the relevance of these concepts in relation to climate change and urbanization.
- b. **Current Scenario: Global & Indian Context:** Here, the document examines disaster vulnerability from both global and Indian perspectives. It details geographic and demographic vulnerabilities, as well as the economic impacts of disasters, establishing a comprehensive understanding of the current disaster landscape.
- c. **Policy and Regulatory Frameworks:** This section outlines existing frameworks that guide disaster risk management, both globally and nationally. It reviews significant global initiatives, such as the Hyogo and Sendai frameworks, and discusses India's national policies and acts, including the National Disaster Management Act and the National Disaster Management Policy.
- d. **Climate Disasters: Urban Flood & Urban Heat:** Focused on specific climate-related disasters, this section delves into urban flooding and urban heat. It justifies the selection of these two disasters for study and discusses their interconnected nature, setting the stage for in-depth analysis.

- e. **Recommendations:** This critical section provides actionable recommendations for addressing urban flood and heat risks. It includes strategies for flood risk reduction and urban heat management, encompassing urban planning, infrastructure development, and community resilience initiatives.
- f. **Conclusion:** The document concludes with a summary of key findings and insights, emphasizing the importance of integrating disaster risk

reduction strategies into urban planning and policy frameworks to enhance resilience in the face of climate change.

Each section is designed to build upon the previous one, leading to a comprehensive understanding of disaster risk management and the necessary strategies for enhancing resilience in urban environments.





Evolving Realities in Climate and Urban Development: Global & Indian Outlook

2. Evolving Realities in Climate and Urban Development: Global & Indian Outlook

2.1 Disaster vulnerability in global context

The occurrence of natural disasters has been on the rise globally, with climate change significantly amplifying the associated risks. Between the years 2000 and 2019, the world recorded a staggering total of 7,348 major disaster events. These catastrophic events resulted in the tragic loss of 1.23 million lives and profoundly impacted the lives of approximately 4.2 billion people around the globe. The economic losses during this period amounted to approximately US\$ 2.97 trillion (UNDRR, 2021)¹². In the first half of 2024, global disaster losses were driven by severe thunderstorms, flooding, and two major earthquakes, resulting in an estimated total loss of US\$ 120 billion. Insured losses for this period amounted to US\$ 62 billion, which is significantly higher than the ten-year average. Notably, 68% of overall losses and 76% of insured losses were attributable to severe thunderstorms, flooding, and forest fires. One of the

most devastating events was an earthquake in Japan on New Year's Day, causing US\$ 10 billion in losses and more than 200 fatalities. The United States experienced a severe thunderstorm season, with 1,250 tornadoes reported, leading to US\$ 45 billion in losses. Additionally, global temperatures reached record highs, exacerbating the risk of heatwaves, forest fires, and hurricanes. This trend emphasizes the critical need for societies, economies, and the insurance sector to adapt to evolving climate risks and implement effective disaster risk reduction strategies.¹³

Statistics indicate that the low-income and lower middle-income countries experience significant economic challenges, losing an average of 0.8% to 1% of their national GDP annually due to disasters. In comparison, the high-income and upper middle-income countries are far less affected, with losses of only 0.1% and 0.3% of their GDP, respectively.

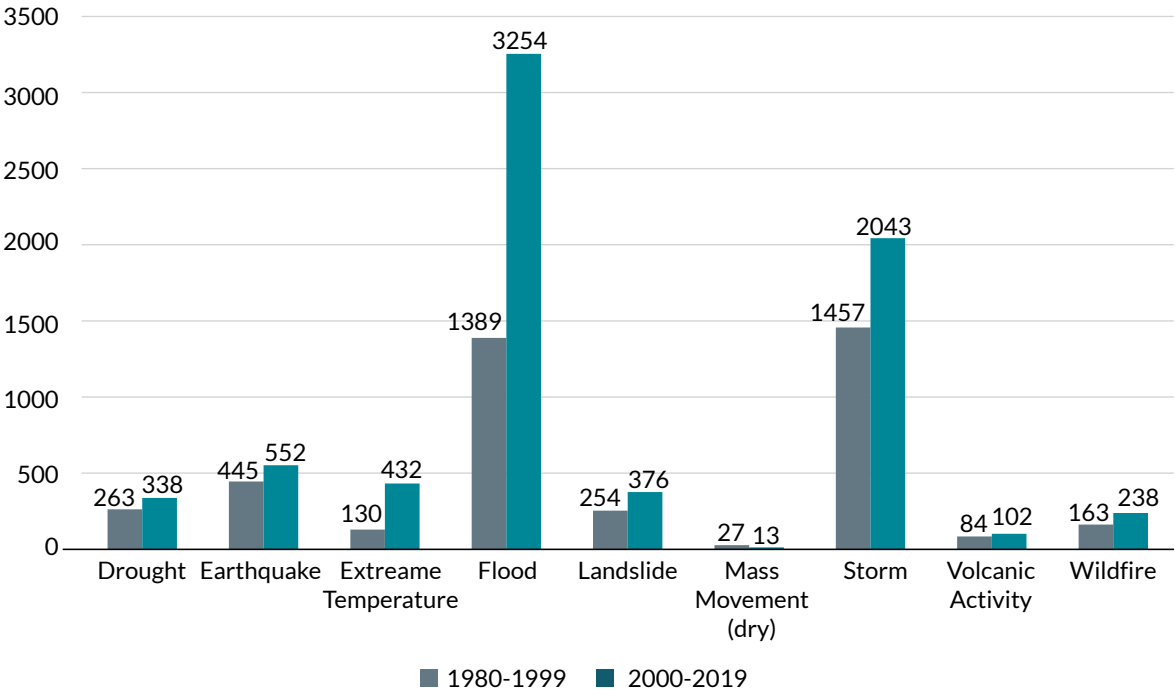


Figure 7: Global economic losses due to natural disasters, Data Source: UNDRR¹⁴

(UNDRR, 2022)¹⁴. This disparity highlights the vulnerability of less affluent nations to natural calamities and underscores the critical need for improved disaster resilience strategies.

2.2 Disaster vulnerability in Indian Context

India is highly vulnerable to a diverse range of natural disasters, including floods, cyclones, earthquakes, droughts, and landslides, which significantly impact the nation's populace and economy. According to the National Disaster Management Authority (NDMA), approximately 58.6% of India's landmass is prone to earthquakes, while 12% faces flood risks, and 68% of cultivable land is susceptible to drought¹⁵. The country's extensive 7,516-kilometer coastline heightens its vulnerability to cyclones and tsunamis. In 2019, India experienced 23 major natural disasters, leading to over 1,600 fatalities and affecting millions. The World Bank estimates annual economic losses due to these disasters at around \$9.8 billion.

The factors contributing to this vulnerability are multifaceted, including a growing population, rapid urbanization, development in high-risk areas, environmental degradation, deforestation, and the overarching impacts of climate change. Vulnerable groups, such as children, the elderly, women, and individuals with disabilities, suffer disproportionately during such events. The World Risk Report 2023¹⁶ highlights India's precarious position, placing it among the top third of countries facing high disaster risk, with 27 of its 29 states and seven union territories

regularly exposed to natural hazards.¹⁷

Despite the implementation of various policies, such as the Disaster Management Act of 2005 and the National Policy on Disaster Management established in 2009, which advocate for a comprehensive approach to disaster risk reduction (DRR), challenges remain. The advisory nature of existing frameworks often leads to inconsistent integration of DRR measures into master and development plans at the state and district levels. This inconsistency underscores the need for making DRR a mandatory component of spatial planning processes.

In the first nine months of 2024, India experienced extreme weather events on 255 out of 274 days, surpassing the 235 days in 2023 and the 241 days in 2022 for the same period. This increase in frequency has led to devastating human and economic losses, with 3,238 lives lost in 2024 compared to 2,755 in 2022—a rise of 18 per cent in just three years.¹⁹

The current risk profile of Indian cities reveals that 12% of the total land area is susceptible to flooding, with major metropolitan areas experiencing recurring urban flood events of increasing severity. The country's extensive 7,516 km coastline exposes numerous major coastal cities to cyclonic events and rising sea levels, while urban heat stress has emerged as a critical concern across inland cities²⁰. Almost all points in the continental India received the rainfall more than 100 mm/day during the 72-year period²¹.

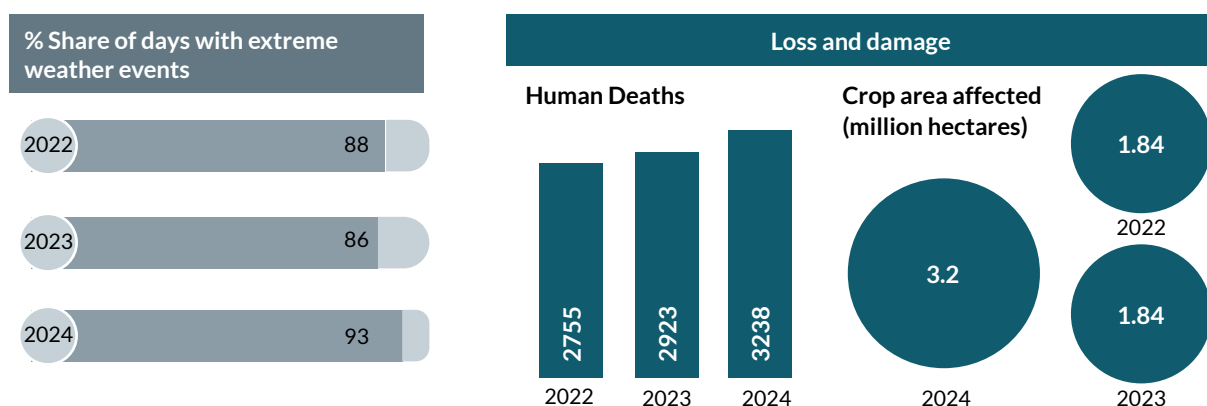


Figure 8: 2024 saw the highest number of days with extreme weather and resultant loss and damage in the past three years²²

India's diverse geography exposes its states to different types of natural disasters, ranging from floods and cyclones to droughts, earthquakes, and landslides. The table below provides an overview

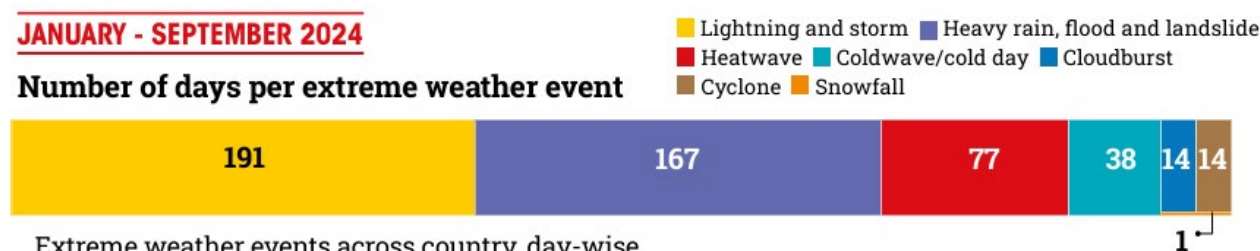
of the major hazards affecting various states, highlighting the regional patterns of disaster vulnerability across the country.

Table 1: Climate hazards in various states and UTs, India, Data Source: IMD¹⁸

States/UTs	Drought	Thunderstorm	Cold Wave	Flood & Extreme Rainfall	Dust Storm	Cyclones	Heat wave	Hail Storm	Fog	Lighting	Snowfall	Wind Hazards
Andaman and Nicobar Islands	✓			✓		✓						✓
Andhra Pradesh	✓			✓		✓						✓
Arunachal Pradesh	✓	✓					✓					✓
Assam	✓	✓		✓	✓							✓
Bihar	✓		✓	✓								
Chandigarh												
Chhattisgarh	✓											✓
DNH & DD												
Delhi	✓				✓				✓			✓
Goa	✓											✓
Gujarat	✓											✓
Haryana	✓								✓			
Himachal Pradesh	✓	✓		✓				✓			✓	✓
Jammu and Kashmir	✓	✓		✓				✓			✓	✓
Jharkhand	✓		✓									✓
Karnataka	✓	✓		✓								✓
Kerala	✓	✓		✓								
Lakshadweep												
Madhya Pradesh	✓											✓
Maharashtra	✓			✓								✓
Manipur	✓	✓		✓					✓			✓
Meghalaya				✓								✓
Mizoram												✓
Nagaland		✓										✓
Odisha	✓			✓		✓				✓		✓
Puducherry						✓						
Punjab	✓		✓									✓
Rajasthan	✓		✓				✓					✓
Sikkim				✓								
Tamil Nadu	✓					✓						✓
Telangana	✓			✓								✓
Tripura	✓	✓							✓			✓
Uttarakhand	✓	✓		✓	✓			✓				✓
Uttar Pradesh	✓	✓	✓		✓				✓			✓
West Bengal	✓	✓		✓		✓			✓			✓
Ladakh											✓	

JANUARY - SEPTEMBER 2024

Number of days per extreme weather event



Extreme weather events across country, day-wise

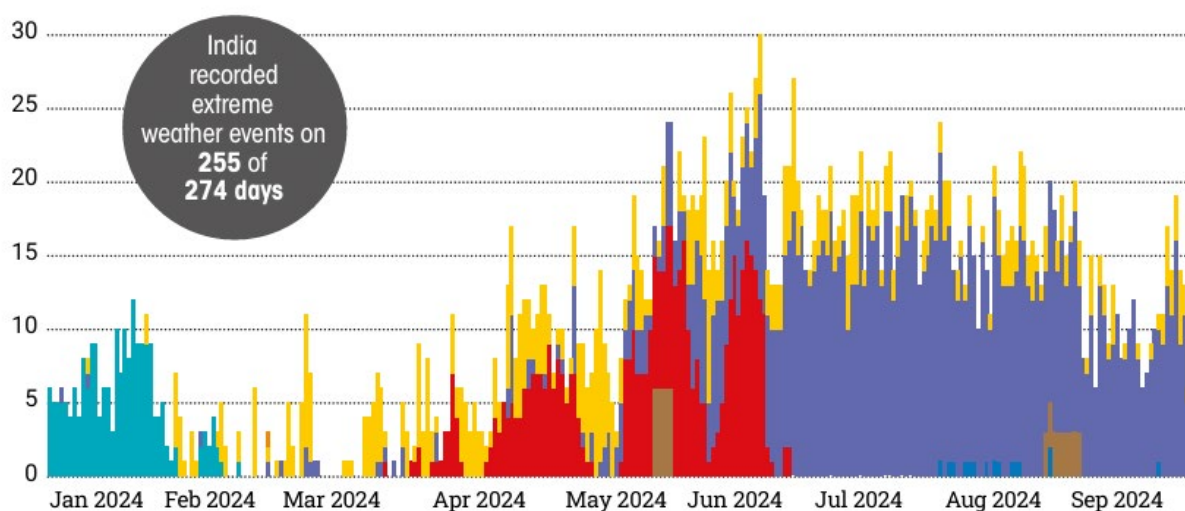


Figure 9: No. of days per extreme weather event in India from January- September 2024²³

According to previous studies^{22,23}, India's surface temperature has significantly increased during the past two decades and India could experience a temperature rise of 1.1-5.1°C by 2100²⁴. These changes are particularly significant in the context of urban infrastructure and development, as they compound existing vulnerabilities and create new risk scenarios.

2.3 Major Vulnerabilities in India

The country's vulnerability to natural disasters is multifaceted, encompassing various geographic challenges:

2.3.1 Geographic Vulnerability²⁵

- Drought Risk:** A significant portion, specifically 68% of the cultivable land, faces the threat of drought, which can severely impact agricultural productivity and food security.
- Landslide Prone Areas:** Approximately 15% of the landmass is susceptible to landslides, particularly in hilly and mountainous regions, where heavy rainfall can trigger sudden and destructive soil movements.
- Earthquake Hazards:** A staggering 58.6% of the

total landmass is located in seismically active zones, making it highly vulnerable to earthquakes that can lead to massive destruction and loss of life.

- Flood Exposure:** About 12% of the land faces the threat of flooding, which can result from heavy rainfall or the overflow of rivers, endangering both rural and urban communities.
- Coastal Vulnerability:** Out of the country's extensive coastline measuring 7,516 km, an alarming 5,700 km is at risk from cyclones and tsunamis. These events can cause catastrophic damage to coastal ecosystems and human settlements, highlighting the need for robust disaster preparedness and response strategies.

2.3.2 Demographic Vulnerability²⁶

- Poverty :** Approximately 30% of the Indian population (around 363 million individuals) live in poverty. Over 1.77 million people are homeless.
- Climate Change Hotspots:** Many homeless individuals are concentrated in areas highly vulnerable to climate change impacts.
- Migration Due to Climate Change:** In 2020-2021, India ranked fourth globally for climate change-

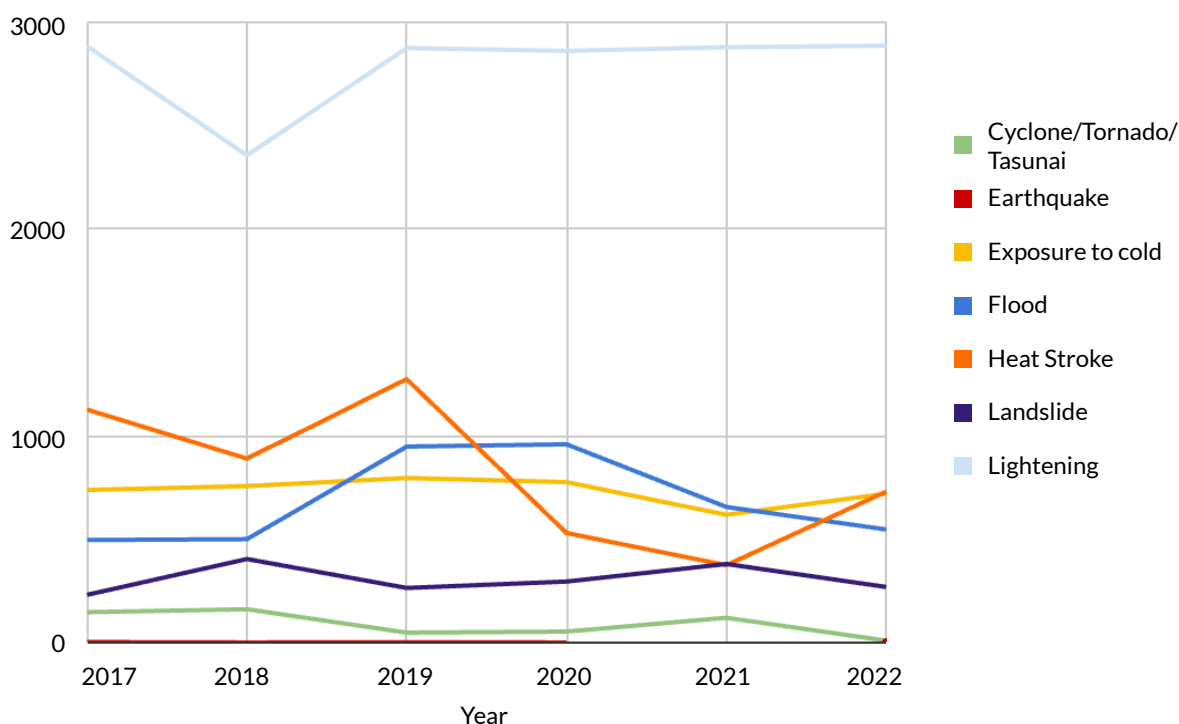


Figure 10: Number of Deaths due to natural disasters in India

Data Source: National Crime Record Bureau, Ministry of Home Affairs (The detailed table is attached at Annexure-1)

induced migration. Over 3 million people were displaced due to climate-related factors.

- d. **Increased Vulnerability:** The combination of a large vulnerable population and socio-economic challenges (like limited access to education and job opportunities) exacerbates the vulnerability of young individuals to the consequences of climate change.
- e. **Gender Vulnerability:** In reaction to environmental and climate-related challenges, families may be driven to migrate within the country, looking for improved opportunities and safety in different regions. This internal migration, especially from rural to urban areas, can place considerable strain on the social systems and economic resources of both the areas people are leaving and those they are moving to. Such movement can disrupt family units and social networks, with young people particularly impacted as they encounter interruptions in their education, social integration, and access to healthcare. Moreover, this internal migration to safer locations disproportionately affects young girls with limited financial means, creating social environments that may foster child marriages.

2.4 Economic Impact of Disasters: Global context

Natural disasters can result in significant economic losses, not only by directly affecting populations and their resources but also by indirectly disrupting production capacity and influencing economic decisions. Between 1998 and 2017, disaster-affected countries reported direct economic losses totalling USD 2,908 billion, with climate-related disasters accounting for USD 2,245 billion, or 77% of the total. This represents an increase from 68% (USD 895 billion) of losses reported between 1978 and 1997, out of a total of USD 1,313 billion. Overall, the losses from extreme weather events surged by 251% over these two 20-year periods²⁷.

The year 2022 has been recorded as the fifth costliest year on record for insurers, with approximately \$50-55 billion of the global insured loss total resulting from Hurricane Ian in the United States - the second-costliest natural catastrophe in history from an insurance perspective, surpassed only by Hurricane Katrina in 2005, which resulted in nearly USD 100 billion in insured losses on a price-inflated basis.

Approximately 31,300 people lost their lives due to

global natural catastrophe events in 2022. The total number of fatalities remains below average for now 12 years in a row; however, more than 19,000 of the fatalities were heat-related deaths in Europe alone, primarily as a result of heatwaves²⁸.

Further findings of the 2023 Weather, Climate and Catastrophe Insight report include:

- A total of 421 significant natural disaster events were recorded globally in 2022, exceeding the 21st century average of 396.
- The United States accounted for 75 percent of global insured losses, significantly higher than the typical average of 60 percent.
- Windstorm Eunice was the costliest individual European windstorm since 2010, with \$3.4 billion in insured losses. Widespread hailstorms in France contributed to the second-highest natural disaster payouts for the country on record of €6.9 billion (USD 7.4 billion).
- Droughts and heatwaves severely impacted Europe, the United States, China and other regions and global insurance payouts for the drought peril were the second highest on record, at \$12.6 billion globally.
- Flood losses in Australia broke the historical record as La Niña conditions persisted for a third year and Sydney recorded the highest annual rainfall.
- Monsoonal floods in Pakistan had a far-reaching humanitarian impact on the country.

Over the past 20 years, the United States recorded the highest absolute economic losses from disasters, totalling USD 945 billion, driven by both high asset values and frequent disaster events. In comparison, China experienced a significantly greater number of disasters (577 events) compared to the U.S. (482 events), but the total losses were much lower, at USD 492 billion.

However, these reported losses represent only a fraction of the total economic impact, as the majority of disaster reports in the EM-DAT database (63%) lack economic data. The World Bank estimates the true global cost of disasters to be a staggering USD 520 billion annually, with disasters pushing approximately 26 million people into poverty each year.

When examining the economic burden of disasters as a percentage of Gross Domestic Product (GDP), it becomes clear that the impacts are disproportionately felt by poorer nations. Only one high-income territory, Puerto Rico, ranked among the top 10 countries in terms of GDP losses over the past two decades. The most severely affected countries were predominantly lower-income, with Haiti topping the list, followed by Cuba, an upper-middle-income country, in terms of economic losses relative to GDP.

Floods were the most widespread disaster, impacting over two billion people, followed by drought, which affected an additional 1.5 billion people between 1998 and 2017²⁸. Climate-related events, which

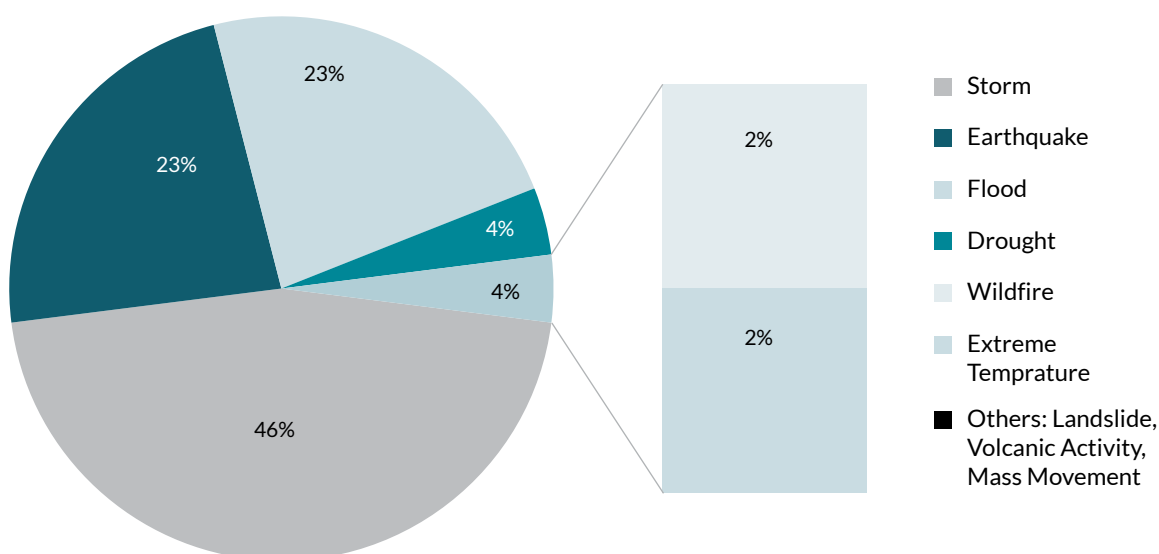


Figure 11: Breakdown of recorded economic losses (US\$) per disaster type 1998-2017, Data Source: UNDRR²⁹

began to increase in frequency in the late 1990s, have continued at a high level, pushing the average number of disasters per year to 329 during the most recent 20-year period. This represents a twofold increase from the 165 events per year recorded between 1978 and 1997. However, it's important to note that improved reporting and data collection in recent decades likely contributes to the apparent rise in the number of recorded disasters.

Storms were by far the most expensive type of disaster, with reported losses reaching USD 1,300 billion over the past 20 years. This figure is twice the reported losses from either flooding or earthquakes.

2.5 Economic Impact of Disasters: Indian context

Government Expenditure Analysis (2018-2024): The financial response to natural calamities shows a steady increase in government allocation

and expenditure. Maharashtra stands out with consistently high expenditure, allocating INR 75.38 billion in budget estimates for 2023-24. States like Bihar (INR 50.85 billion), Tamil Nadu (data partially available), and Uttar Pradesh (INR 42.84 billion) also show substantial budget allocations for disaster management. The temporal trend indicates a significant increase in disaster-related expenditure across most states. For instance, Assam's budget estimates increased from INR 5.25 billion in 2018-19 to INR 14.28 billion in 2023-24, representing a nearly threefold increase. This escalation in expenditure reflects both the increasing frequency and intensity of disasters and the growing recognition of the need for robust disaster management infrastructure.

In India, floods have been the leading cause of disasters. Globally, floods represent nearly half of all natural disasters. Since 1950, India has experienced over 300 flood events, resulting in the loss of at least 75,000 lives and affecting more than 900

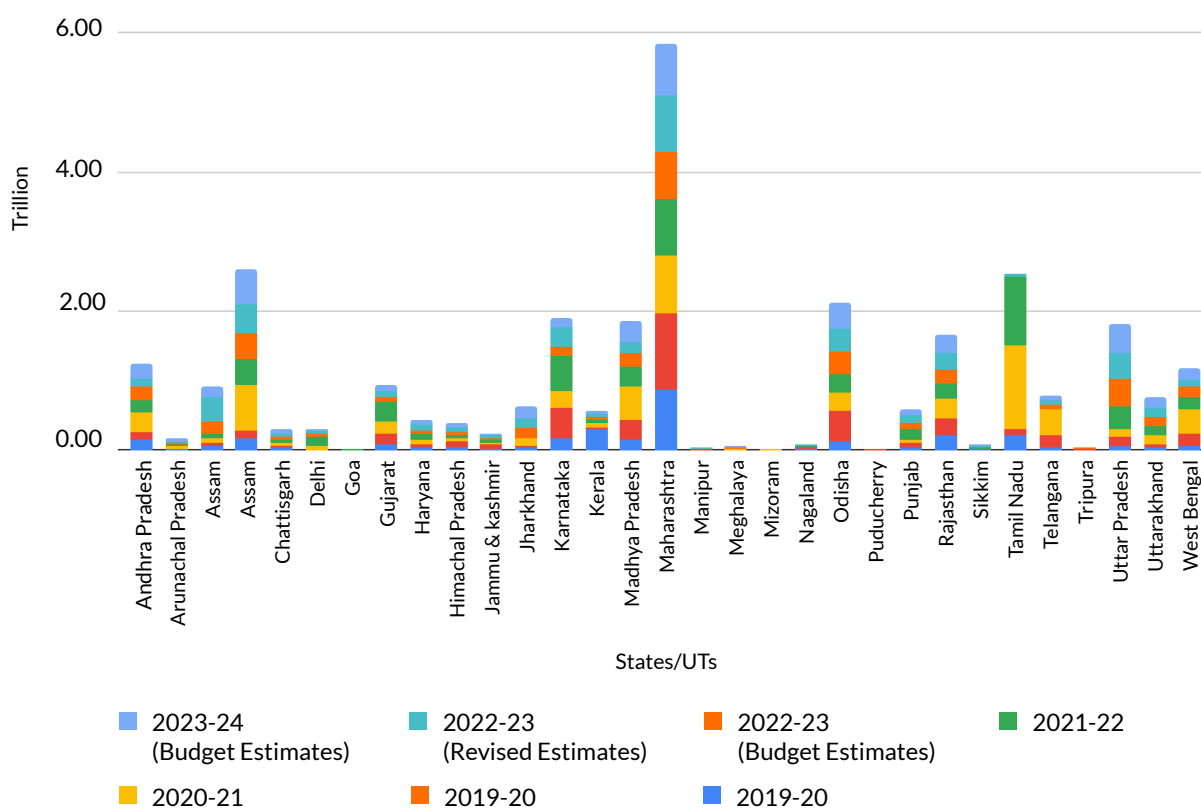


Figure 12: Government Expenditure on account of Natural Calamities (Trillion)(as on 11.12.2023)

Data Source: State Finances: A Study of Budgets, Reserve Bank of India (RBI), (Detailed table attached at Annexure-4)

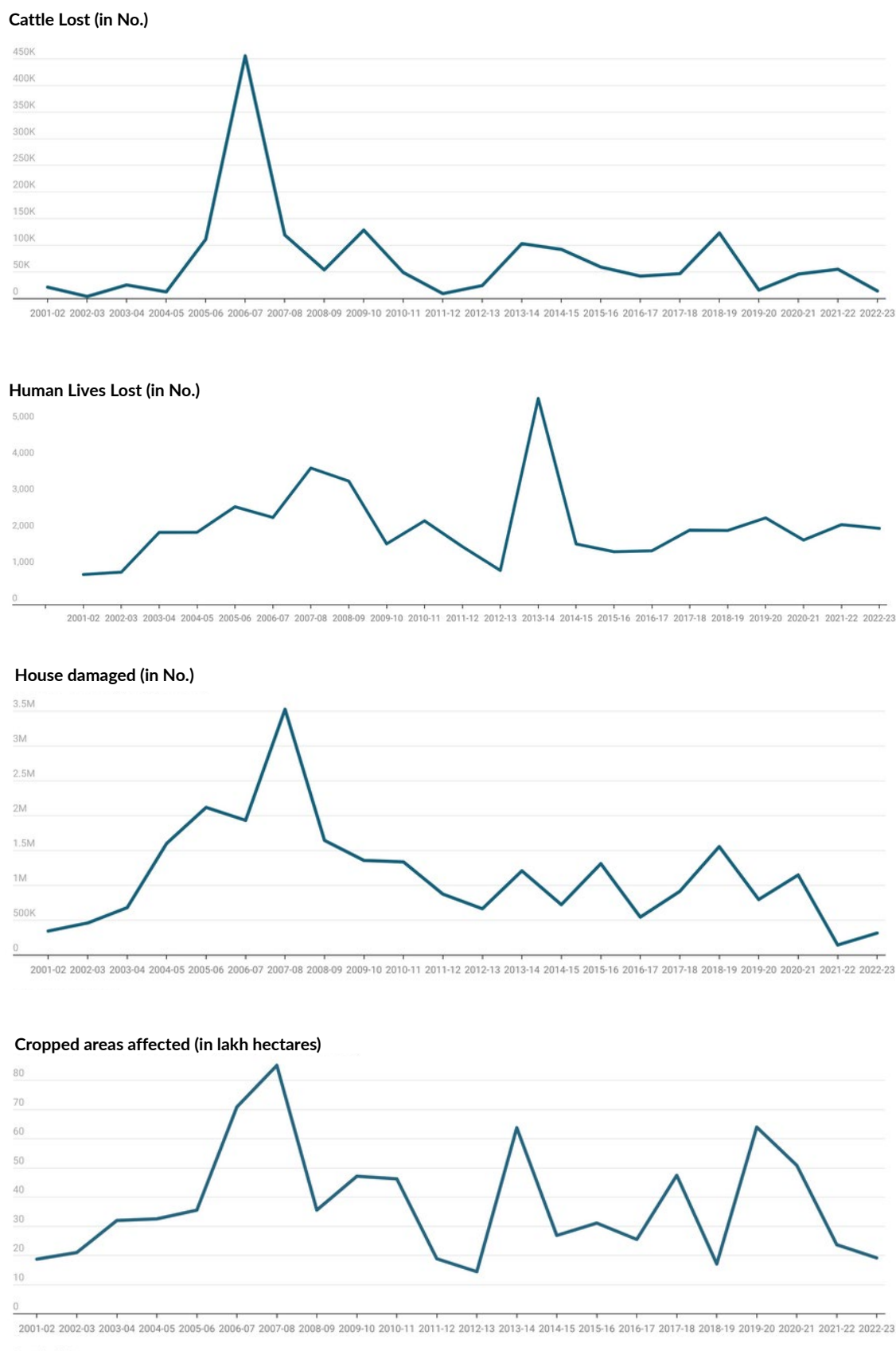


Figure 13:Year-wise damage due to natural extreme events in India

Data Source: Disaster Management Division, Ministry of Home Affairs (Detailed table attached at Annexure-2)

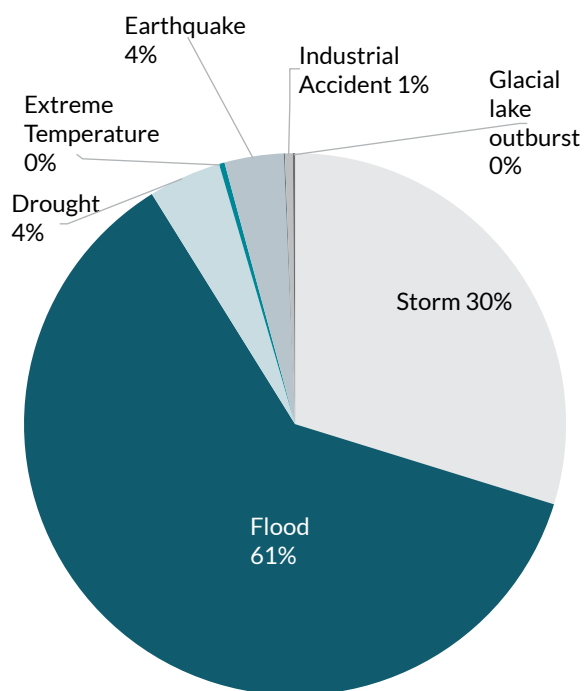


Figure 14: Economic Loss due to Natural Disasters in India since 1900 to 2022 (billion USD),

Data Source: EM-DAT

million people, either through injury, homelessness, or other forms of impact. In addition to the human toll, natural disasters in India result in substantial economic losses. Since 1900 to 2022, India has faced economic damages totalling \$150 billion (where data is available), with floods accounting for the largest share at \$92.1 billion, followed by storms with \$44 billion³⁰.

The cyclone Biparjoy (2023) was projected to cause economic losses of approximately INR 830 crore (around USD 100 million), primarily due to wind damage, storm surge, and flooding. The recent floods in North India have caused widespread devastation in Himachal Pradesh, Uttarakhand, Punjab, Uttar Pradesh, Rajasthan, Jammu & Kashmir, and Delhi. These floods, believed to be triggered by a combination of monsoon rains and a western disturbance, have also led to significant landslides. Although the precise economic losses from these floods are yet to be determined, initial estimates suggest they could range between INR 100 billion and INR 150 billion crore³⁴.

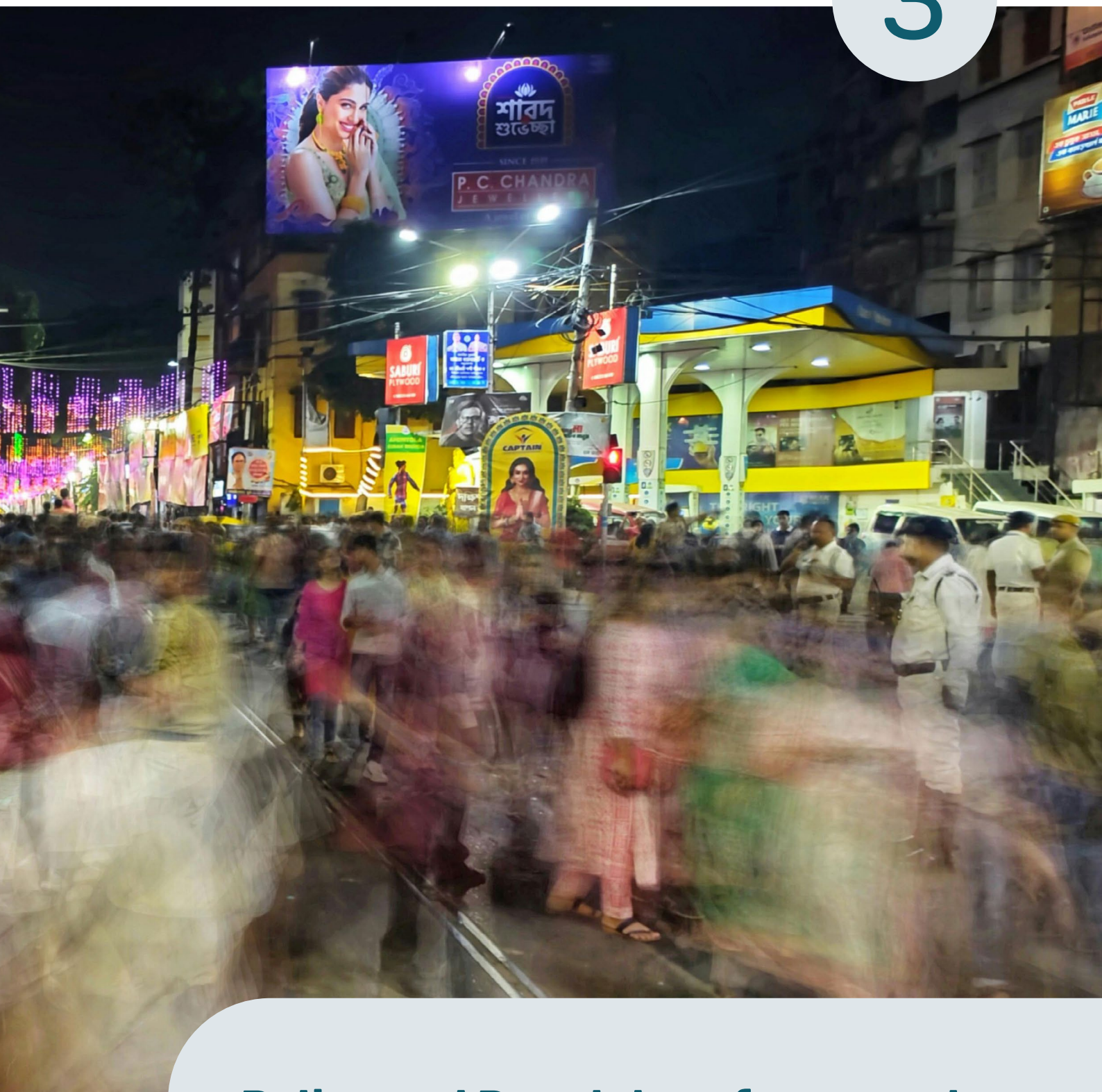
Analysing Damage Patterns (2001-2023) : Data from 2022-23 reveals the severe toll of natural disasters, with 2,104 human fatalities and the loss of 14,166 livestock. Housing damage also presents a mixed pattern, with 318,000 houses affected in that year compared to a peak loss of 3.527 million houses in 2007-08. Additionally, 1.9 million hectares of crops were impacted during the same period. These statistics emphasize the urgent necessity for comprehensive disaster preparedness and mitigation strategies to protect communities and their livelihoods, ensuring resilience in the face of escalating disaster risks (Envistats India, 2024)³¹.

2.6 Conclusion

This chapter highlights the critical vulnerabilities faced by India and the global community in the context of natural disasters. With a significant increase in disaster events driven by climate change, the economic and human toll has become increasingly severe. In India, the multifaceted nature of vulnerability—including geographic, demographic, and economic factors—underscores the urgent need for comprehensive disaster risk reduction strategies. Vulnerable populations, particularly women, children, the elderly, and those living in poverty, are disproportionately affected by these events.

Despite existing policies like the Disaster Management Act of 2005, inconsistencies in implementation and integration of disaster preparedness into urban planning remain significant barriers. The data reflects a pressing need for enhanced resilience strategies, improved infrastructure, and targeted support for marginalized communities to mitigate the escalating impacts of natural disasters. Addressing these vulnerabilities holistically will be crucial for safeguarding lives and livelihoods as climate-related risks continue to rise.





Policy and Regulatory frameworks

3. Policy and Regulatory frameworks

The relevance of promoting disaster risk reduction efforts on the international, regional as well as national and local levels has been recognized in recent years in several key multilateral frameworks and declarations as explained below:

3.1 Global frameworks

3.1.1 The Hyogo Framework for Action 2005-2015³²

The United Nations promoted a 10-year plan (2005-2015) to make the world safer from natural hazards. It has since guided national policy and international organisations in their efforts to substantially reduce losses stemming from natural hazards. The Hyogo Framework for Action addresses the roles of states, regional and international organisations, calling on civil society, academia, volunteer organisations and the private sector to join efforts. It promotes

the decentralization of authority and resources to promote local-level disaster risk reduction. The expected outcome of the Hyogo Framework is to substantially reduce disaster losses in terms of lives and the social, economic and environmental assets of communities and countries. The five HFA priorities for action are (United Nations Office for Disaster Risk Reduction, 2005):

- a. **Build institutional capacity:** Ensure that disaster risk reduction is a national and local priority with a strong institutional basis for implementation;
- b. **Know your risks:** Identify, assess and monitor disaster risks and enhance early warning;
- c. **Build understanding and awareness:** Use knowledge, innovation and education to build a culture of safety and resilience at all levels;
- d. **Reduce risk:** Reduce the underlying risk factors through land-use planning, environmental, social



Figure 15: Hyogo Framework for action priorities, Data

Source: Hyogo Framework³³

and economic measures;

- e. **Be prepared and ready to act:** Strengthen disaster preparedness for effective response at all levels;

3.1.2 Sendai Framework for Disaster Risk Reduction 2015-2030³⁴

The Sendai Framework is developed as the successor instrument to the Hyogo Framework for Action (HFA). It is a non-binding agreement, which the signatory nations, including India, will attempt to comply voluntarily. The HFA was conceived to give a further push to the global work under the International Framework for Action to the International Decade for Natural Disaster Reduction of 1989, and the Yokohama Strategy for a Safer World: Guidelines for Natural Disaster Prevention, Preparedness and Mitigation and its Plan of Action, adopted in 1994 and the International Strategy for Disaster Reduction of 1999. The Sendai Framework is developed on elements that ensure continuity with the work done by states and other stakeholders under the HFA and introduce several innovations. To support the assessment of global progress in achieving the outcome and goal of the present framework, seven global targets have been created (United Nations Office for Disaster Risk Reduction, 2015).

These seven targets are:

- a. Substantially reduce global disaster mortality by 2030, aiming to lower the average per 100,000 global mortality rates in the decade 2020–2030

compared to the period 2005–2015;

- b. Substantially reduce the number of affected people globally by 2030, aiming to lower the average global figure per 100,000 in the decade 2020–2030 compared to the period 2005–2015;
- c. Reduce direct disaster economic loss in relation to the global gross domestic product (GDP) by 2030;
- d. Substantially reduce disaster damage to critical infrastructure and disruption of basic services, among them health and educational facilities, including through developing their resilience by 2030;
- e. Substantially increase the number of countries with national and local disaster risk reduction strategies by 2020;
- f. Substantially enhance international cooperation to developing countries through adequate and sustainable support to complement their national actions for implementation of the present framework by 2030;
- g. Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to people by 2030;

3.2 Synergy between SFDRR and SDG

The SFDRR (Sendia Framework for Disaster Risk Reduction) has seven targets and four action priorities to achieve a substantial reduction of disaster risk and losses in the global population, gross domestic product (GDP), and infrastructure. Since the SFDRR is a product of interconnected natural, social, and

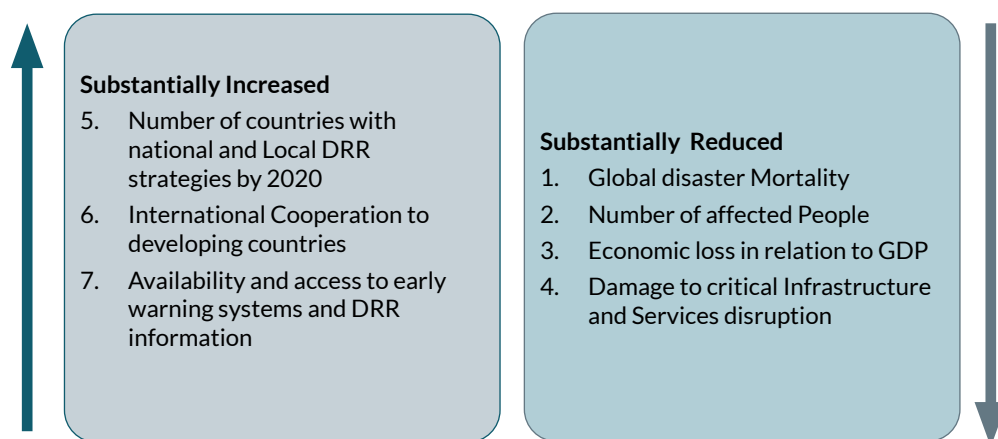


Figure 16: The Sendai Framework outlines seven global targets to be achieved between 2015 and 2030

Data source: Sendai Framework³⁵

economic processes, it is also closely associated with the Sustainable Development Goals (SDGs). Three goals of SDGs involving 11 indicators are monitored and measured by the SFDRR, facilitating considerable synergy between the two policy instruments³⁶. Therefore, the SDGs and the SFDRR constitute an overarching global milestone for creating a better and more sustainable future worldwide.

3.3 National frameworks

3.3.1 National Disaster Management Act (2005)

The Disaster Management Act of 2005 is a comprehensive legislative framework established by the Government of India to manage and respond to disasters more effectively. It was prompted by the devastating tsunami that occurred in 2004 that highlighted the urgency to incorporate disaster preparedness, response, and recovery efforts throughout the country. Before the DM Act 2005, India followed a relief-centric approach to disasters which focused primarily on the immediate response and recovery post-disaster. The act created a paradigm shift from an erstwhile relief-centric response to a proactive prevention, mitigation, and preparedness-driven approach for conserving developmental gains while minimizing loss of life, livelihood, and property.

The DM Act of 2005 lays down institutional and coordinated mechanisms for effective DM at the national, state, district, and local levels. As mandated by this Act, the Indian government created a multi-tiered system consisting of NDMA, SDMA, and DDMA with provisions stating the roles, responsibilities, and fund allocations for the same. The act also formulates a National Disaster Management Plan with supporting bodies like the National Institute of Disaster Management (NIDM), National Executive Committee (NEC), State Executive Committee (SEC), National Disaster Response Force (NDRF), State Disaster Response Force (SDRF), Cabinet Committee Security (CCS), etc. Figure 19 shows the detailed Organisation structure of Disaster Management, India.

3.3.2 The salient features of the national disaster management act

a. Policy and Planning:

- The Disaster Management Act (DM Act), 2005 mandates the creation of Disaster Management Plans at the national, state, and district levels, covering mitigation, preparedness, response, and recovery;
- The Act emphasizes preventive measures, including the establishment of early warning systems, disaster-resistant building codes, and public awareness programs;

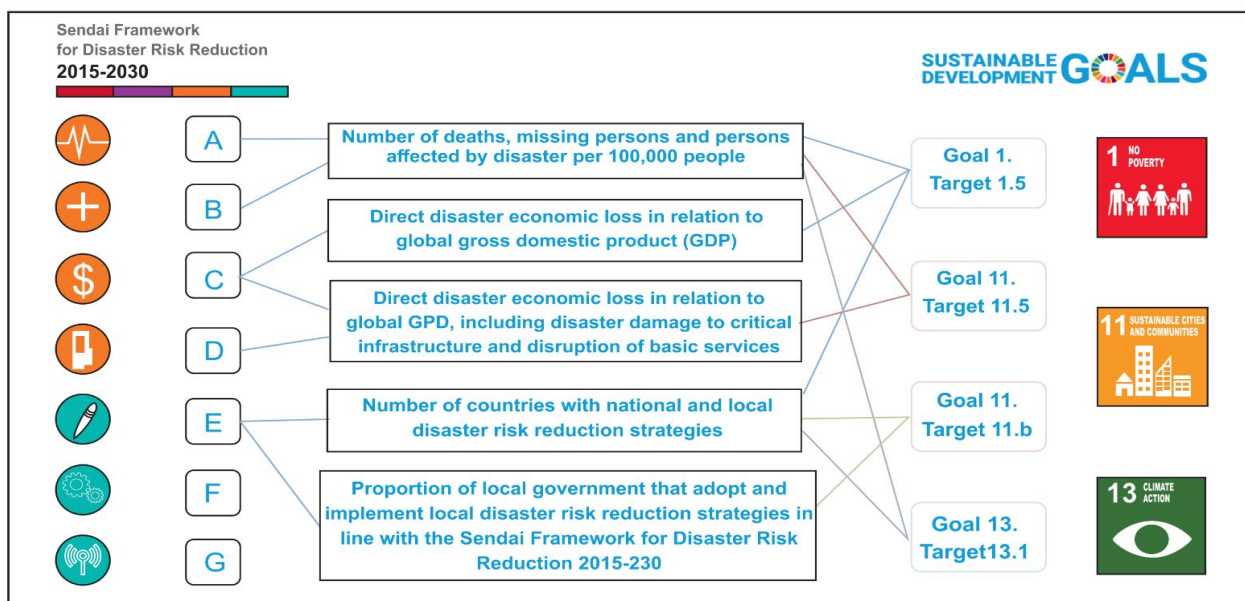


Figure 17: Coherence and mutual reinforcement of SDGs and SFDRR

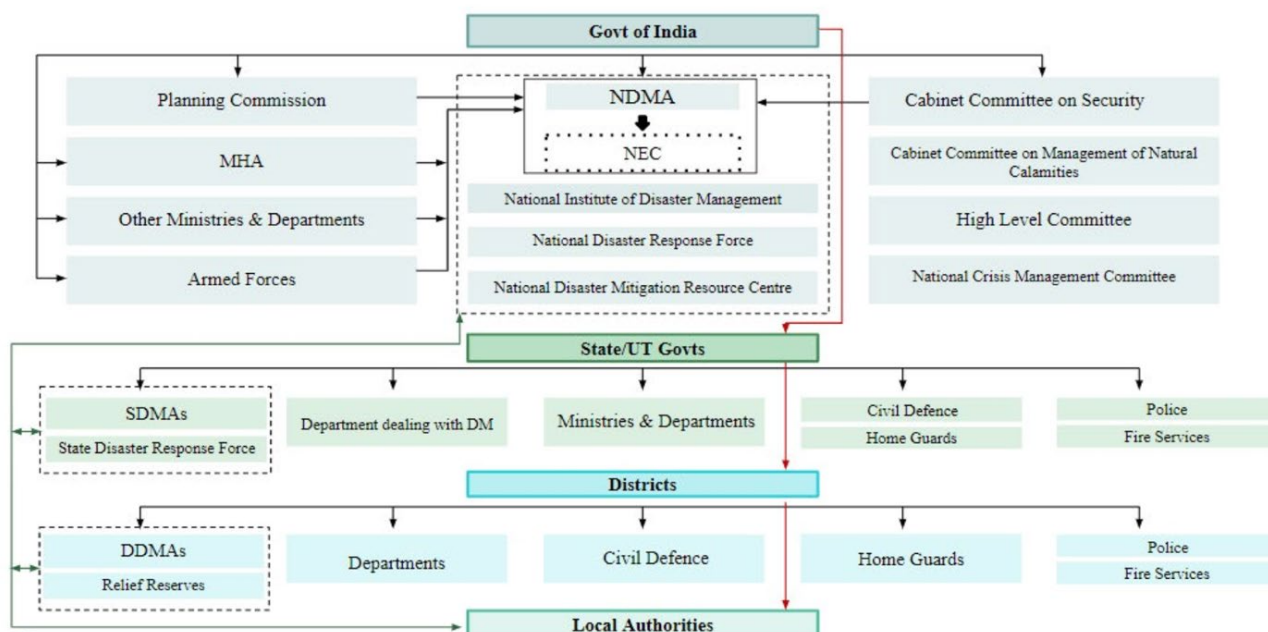


Figure 18: Organisation structure of Disaster Management, India³⁷

- h. It promotes risk assessment and vulnerability mapping to identify and mitigate potential hazards;
- The National Disaster Response Force (NDRF) and State Disaster Response Forces (SDRFs) are established to ensure an effective response to disasters, including rescue operations, medical assistance, and relief distribution;
 - The National and State Executive Committees assist the National and State Authorities in implementing policies and ensuring compliance with disaster management guidelines set by the Central Government;
 - The Act promotes collaboration among stakeholders, including government agencies, NGOs, and community groups, to develop a unified approach to disaster management;

b. Institutional Framework:

- The Act establishes the National Disaster Management Authority (NDMA), State Disaster Management Authorities (SDMAs), and District Disaster Management Authorities (DDMAs), responsible for coordinating disaster management efforts at different levels;
- NDMA, chaired by the Prime Minister, formulates national policies, plans, and guidelines for disaster management and coordinates efforts at the national level;

- SDMAs, headed by the Chief Minister or Lieutenant Governor of Union Territories, develop state-specific disaster management plans aligned with the National Disaster Management Plan (NDMP) and other guidelines;
- DDMAs, led by District Collectors, manage disaster response and recovery activities at the local level in accordance with the State Disaster Management Plan (SDMP) and the NDMP;

c. Funding Mechanisms:

The National Disaster Response Fund (NDRF) and State Disaster Response Funds (SDRFs) are created under the Act to provide financial resources for disaster response and recovery.

There are two primary funds established for disaster management: the National Disaster Risk Management Fund (NDRMF) at the national level and the State Disaster Risk Management Fund (SDRMF) at the state level. The NDRMF is divided into the National Disaster Response Fund (NDRF) and the National Disaster Mitigation Fund (NDMF). Similarly, the SDRMF includes the State Disaster Response Fund (SDRF) and the State Disaster Mitigation Fund (SDMF). Out of the total allocated grants for disaster management for both the national and state levels, 20% is designated for mitigation efforts, while the remaining 80% is allocated for response activities.

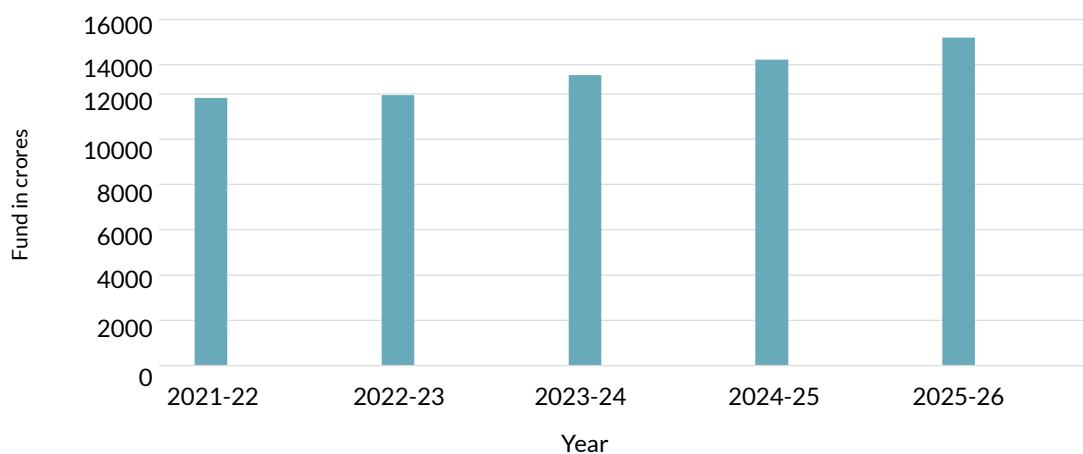


Figure 19: Year wise allocation of NDRMF⁴⁰

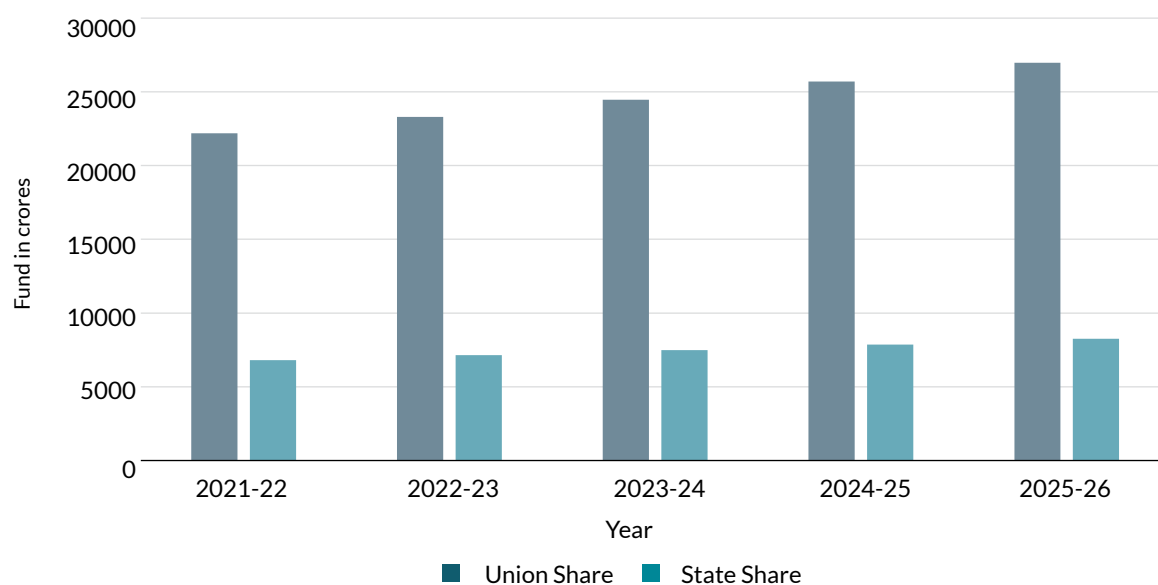


Figure 20: Year wise allocation of SDRMF³⁸

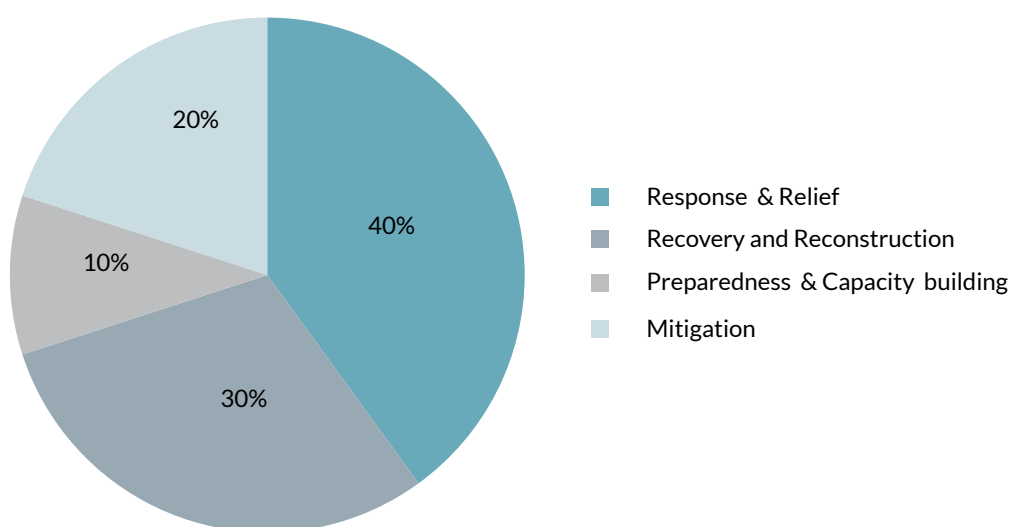


Figure 21: The budget distribution of SDRMF⁴¹

The response fund is further divided into three specific categories:

- a. Response & Relief (40%): 40% of NDRMF/SDRMF is allocated for response & relief from disasters;
- b. Recovery & Reconstruction (30%): 30% of NDRMF/SDRMF
 - To focus on recovery after the disaster;
 - To re-build assets and livelihoods;
- c. Preparedness & Capacity building (10%): 10% of NDRMF/SDRMF
 - Needed for states to be essentially prepared for disasters to respond effectively;
 - Allocation to support SDMAs, SIDM, training & capacity building activities;
 - Response facilities;

3.3.3 National Policy on Disaster Management (NPDM, 2009)³⁹

The NPDM 2009 in India aims to build a disaster-resilient nation by promoting a culture of prevention, preparedness, and resilience. It emphasizes integrating disaster risk reduction (DRR) into development plans, establishing strong institutional frameworks, enhancing capacity building, and ensuring

effective response and recovery mechanisms.

These objectives aim to minimize the impact of disasters on lives, property, and the environment, fostering a safer, more resilient society. By enhancing institutional frameworks, the policy establishes accountability and coordination among stakeholders for a unified emergency response and management.

Promoting a culture of risk reduction encourages community involvement in preparedness, while integrating disaster management into development plans embeds risk considerations in infrastructure and urban planning. Improving preparedness and response mechanisms enhances emergency services' capacity to act effectively, saving lives and reducing damage. By leveraging technology and innovation, the policy seeks to use data for better decision-making and proactive measures.

Ultimately, the National Policy on Disaster Management strives to build a society that withstands disasters and recovers swiftly, emerging stronger in their aftermath.

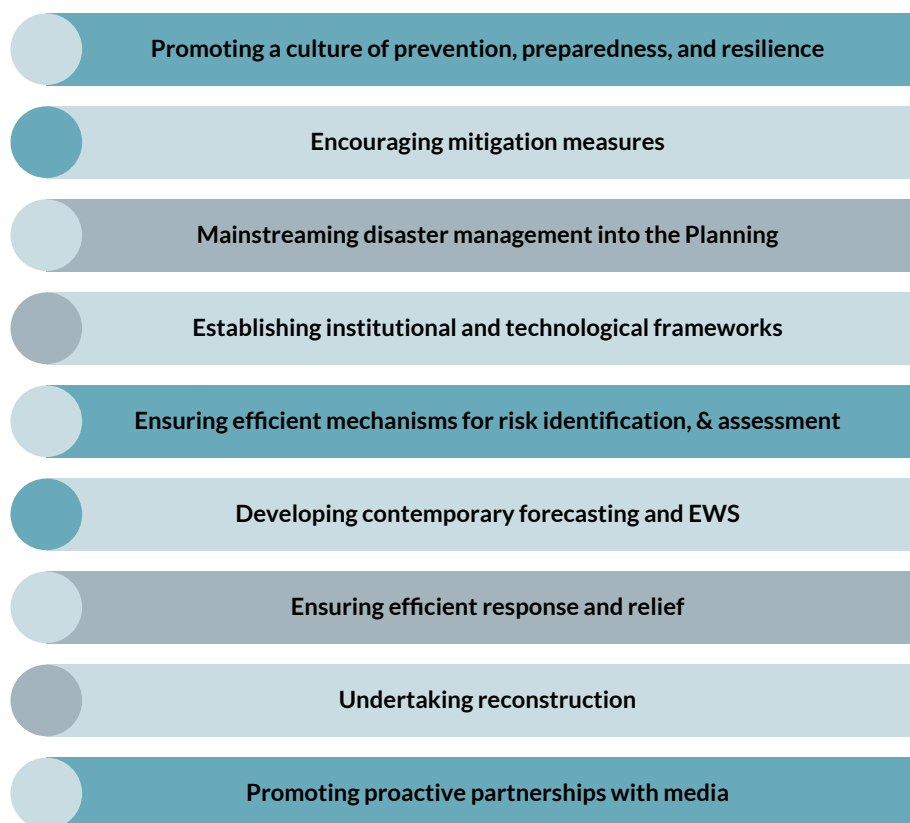


Figure 22: Objectives of NDMP

Table 2: National Policy on Disaster Management: Clause-wise Strategies for DRR integration in Spatial Planning

Sl. No	Chapter	Section	Strategies for DRR integration in spatial planning	Page No.
1	Techno-legal Regime	6.2.1 Revision of Municipal Regulations	- Revisit and review development control regulations, building bye-laws and structural safety features periodically to identify gaps from various types of disasters and suitable modifications will be made to align them to the revised building codes of the Bureau of Indian Standards (BIS); - Undesirable practices compromising safety during disasters – unsuitable areas used for construction without necessary safeguards;	23
		6.3.1 Land Use Planning	- To analyse environmental and hazard data to formulate alternative land use plans for different geographical and administrative areas with a holistic approach; - Land use planning based on an inventory database of various uses; - Future land use to be assessed based on anticipated intensity of development;	
		6.4.1 Safe Construction Practices	- Ensure safe construction of new buildings and retrofitting of old buildings, as given in the Earthquake Guidelines for earthquake mitigation; - Building codes will be updated every five years as a mandatory requirement and put in the public domain; - Observance of the National Building Code should be made mandatory in all the State/ Municipal building bye-laws;	
		6.4.2 Safe Construction Practices	Safe schools and hospitals (with large capacity) and National monuments besides other critical lifeline buildings regarded as a national priority. Enabling provisions shall be made in all the Centrally Sponsored Schemes to design school buildings/ hostels with disaster-resilient features and to equip them with appropriate fire safety measures;	24
		6.5.1 Compliance Regime	- Revision of municipal regulations and safe construction practices for disaster-resilient structures; - Self-certification, a social audit by professional agencies, etc;	
2	Reconstruction and Recovery	9.1.1 Approach	Build back better principles– incorporating disaster-resilient features;	31
		9.2.1 Owner Driven Reconstruction	- Reconstruction plans and designing of houses need to be participatory (involving NGOs, govt, communities, etc); - Reconstruction should be confined to qualitative specifications laid down by the Government;	
		9.3.2 Speedy Reconstruction	Plans for reconstruction in highly disaster-prone areas need to be drawn out during the period of normalcy, which may include architectural and structural designs in consultation with various stakeholders;	

Table 2 elaborates on these mandates, offering detailed strategies for embedding DRR into spatial planning. Key strategies include revising municipal regulations and building codes, ensuring safe construction practices, incorporating hazard zoning and land use planning, and enhancing infrastructure resilience. Environmental considerations, such as protecting natural buffers, play a significant role in mitigating disaster impacts. Community involvement and capacity building are also emphasized to ensure that DRR measures are practical, effective, and widely accepted.

3.3.4 National Disaster Management Plan 2016 (Revised in 2019)

The National Disaster Management Plan (NDMP)⁴⁰ is a dynamic document that provides a framework and direction to all government agencies for all phases of the DM cycle. The NDMP emphasizes a multi-hazard approach to disaster management, recognizing the diverse disasters faced across the country. It outlines the roles and responsibilities of various stakeholders in DM, emphasizing capacity building on all levels, enhancing early warning systems, improving infrastructure resilience, and promoting community

participation in disaster preparedness and response.

3.3.5 Main Pillars of NDMP

- a. Conforming to the national legal mandates - the DM Act 2005 and the NPDM 2009;
- b. Participating proactively in realizing the global goals as per agreements to which India is a signatory-Sendai Framework for DRR, Sustainable Development Goals (SDGs), and Conference of Parties (COP21) Paris Agreement on Climate Change;
- c. Prime Minister's Ten Point Agenda for DRR articulating contemporary national priorities;
- d. Social inclusion as a ubiquitous and cross-cutting principle;
- e. Mainstreaming DRR as an integral feature;

3.4 PM's 10-point Agenda

The Prime Minister's 10-Point Agenda for Disaster Risk Reduction outlines a comprehensive framework to enhance India's resilience to natural disasters. This agenda emphasizes proactive measures and strategic planning to minimize the impact of disasters on communities and the economy.

The 10-Point Agenda is crucial for enhancing disaster resilience in India, fostering a culture of preparedness among communities and significantly reducing vulnerability. By promoting an integrated approach, it weaves disaster risk reduction into all aspects of governance and development, ensuring that these considerations are prioritized. The agenda emphasizes the importance of early warning systems

and emergency response mechanisms, aiming to minimize loss of life and property during disasters. Additionally, by mitigating the economic impact of disasters, it supports sustainable development and safeguards livelihoods. Furthermore, involving communities in disaster management not only builds local capacities but also strengthens social cohesion. In summary, the 10-Point Agenda serves as a vital framework that promotes a proactive and integrated approach to disaster risk management, ultimately enhancing the overall resilience of society.

3.5 Conclusion

The integration of Disaster Risk Reduction (DRR) into spatial planning is critical for building resilient communities that can effectively withstand a range of natural and human-made hazards. While the Disaster Management Act (DM Act) of 2005 lays the foundational framework for DRR, its direct implications for spatial planning are not explicitly defined. Nevertheless, it sets out essential mandates that can help guide the incorporation of DRR principles into urban and regional master plans.

The National Policy on Disaster Management (NPDM) builds on the DM Act by offering more detailed strategies for embedding DRR into spatial planning processes. Key approaches outlined in the NPDM include revising municipal regulations and building codes to ensure safe construction practices, incorporating hazard zoning and land-use planning, and enhancing infrastructure resilience. The protection of natural buffers, such as wetlands

Prime Minister's 10-Point Agenda for Disaster Risk Reduction

- a. All development sectors must imbibe the principles of disaster risk management;
- b. Risk coverage must include all, starting from poor households to SMEs to multi-national corporations to nation-states;
- c. Women's leadership and greater involvement should be central to disaster risk management;
- d. Invest in risk mapping globally to improve global understanding of Nature and disaster risks;
- e. Leverage technology to enhance the efficiency of disaster risk management efforts;
- f. Develop a network of universities to work on disaster-related issues;
- g. Utilise the opportunities provided by social media and mobile technologies for disaster risk reduction;
- h. Build on local capacity and initiative to enhance disaster risk reduction;
- i. Make use of every opportunity to learn from disasters and, to achieve that, there must be studies on the lessons in every disaster;
- j. Bring about greater cohesion in the international response to disasters;

and forests, is also emphasized as an important strategy to mitigate disaster risks. Furthermore, the NPDM underscores the importance of community involvement and capacity building to ensure that DRR measures are not only practical and effective but also widely accepted by local populations.

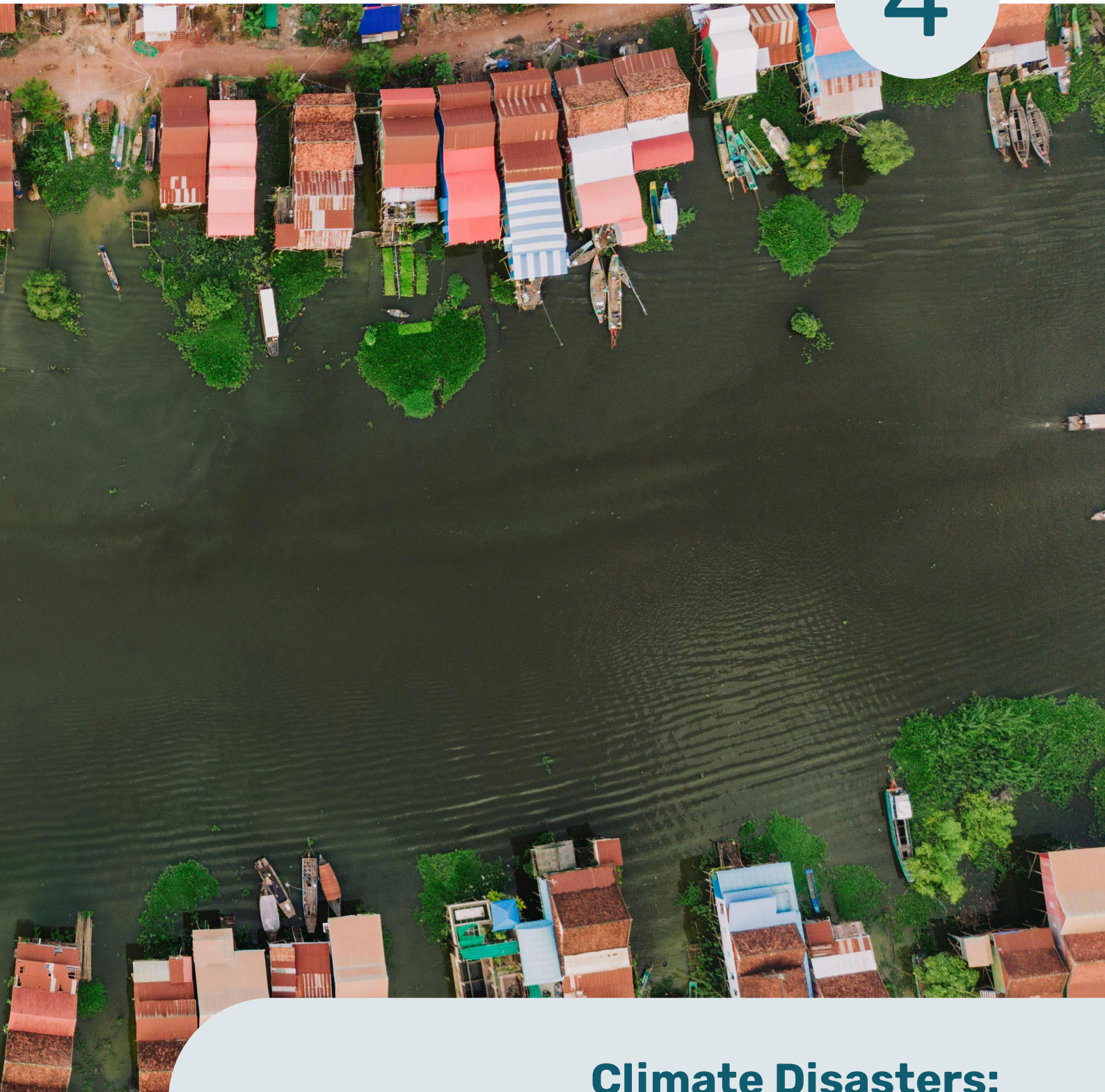
To effectively plan urban and regional development, it is essential to incorporate hazard mapping, updated building codes, and resilient infrastructure into master plans. These elements, when aligned with environmental protection and restoration efforts, create a comprehensive framework that strengthens a city's resilience against disasters. In addition, engaging communities in the planning process ensures that DRR measures are locally relevant and widely supported. Regular reviews and updates of master plans—incorporating the latest data, technological advancements, and lessons learned from past events—are essential for ensuring that urban areas remain adaptable to emerging risks and future uncertainties.

Furthermore, a clear, structured approach to incorporating DRR into spatial planning can help cities easily implement these strategies. Urban planners and local authorities can follow a step-by-step methodology, which includes integrating DRR considerations at all stages of the planning process, from hazard assessment and land-use mapping to policy development and community engagement. By making DRR a fundamental part of spatial planning, cities can ensure that these principles are embedded in their long-term development plans, making disaster resilience a key aspect of urban growth.

In conclusion, while the DM Act of 2005 provides a crucial starting point for disaster risk management, the NPDM offers a more comprehensive, detailed approach to integrating DRR into spatial planning. By adhering to the guidelines set out in these documents, urban planners, local authorities, and communities can collaborate to develop master plans that not only address current vulnerabilities but also anticipate and mitigate future risks. This holistic approach fosters sustainable, disaster-resilient cities and regions, contributing to the creation of communities that can withstand the challenges of tomorrow.







Climate Disasters: Urban Flood & Urban Heat

4. Climate Disasters: Urban Flood & Urban Heat

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4.1 Rationale for focusing on these two disasters

Indian cities face multiple climate-related disasters, but urban flooding and urban heat emerge as critical priorities demanding immediate attention. This strategic focus stems from their widespread impact, increasing frequency, and deep connection to urban infrastructure decisions. In India, floods have been the leading cause of disasters, with over 300 flood events recorded since 1950, resulting in the loss of at least 75,000 lives and affecting more than 900 million people through injury, homelessness, or other impacts. Globally, floods represent nearly half of all natural disasters, underscoring their significance. The economic toll is equally alarming; from 1900 to 2022, India has faced economic damages totalling approximately \$150 billion, with floods accounting for the largest share at \$92.1 billion, followed by storms at \$44 billion.

Additionally, the increasing incidence of urban heat islands, driven by factors such as deforestation, extensive concrete surfaces, and climate change, threatens residents' quality of life and energy consumption. The first nine months of 2024 alone saw extreme weather events occurring on 255 out of 274 days, highlighting the urgent need for effective interventions.

By concentrating on these two critical challenges, researchers can gain a holistic understanding of the interconnected nature of urban environmental issues. This focused approach not only facilitates the identification of underlying causes and contributing factors but also promotes the development of integrated solutions that can enhance the resilience of urban centers. Such solutions may include improved water management systems, innovative urban planning strategies, and the implementation of green infrastructure, all aimed at mitigating the adverse impacts of both flooding and heat. Ultimately, addressing urban flooding and heat is essential for

fostering sustainable and resilient cities that can adapt to the evolving challenges posed by climate change and urbanization.

4.1.1 Compound Effects and Interconnected Nature

Urban heat and flooding create mutually reinforcing cycles that amplify their impacts. When intense heat waves strike cities, they can dry out soil and reduce its water absorption capacity, making subsequent flooding more severe. Conversely, flood damage to green infrastructure reduces natural cooling capacity, exacerbating the urban heat island effect. Researchers have identified a correlation between more severe heat waves and the occurrence of extreme coastal sea level events occurring simultaneously. Globally, heat waves are intensifying, and the study reveals that these compound events are typically associated with specific atmospheric conditions. These conditions include elevated temperatures and the presence of swirling low-pressure systems, which frequently give rise to coastal storms⁴¹. Understanding these interconnections allows cities to develop integrated solutions that address both challenges simultaneously.

4.1.1.1 Infrastructure and Development Nexus

Both disasters are intimately linked to urban development patterns and infrastructure decisions. The proliferation of impervious surfaces, reduction in green spaces, and inadequate drainage systems contribute to both flooding and heat island effects. This connection means that well-designed interventions can deliver dual benefits. For example, increasing urban green spaces serves both as flood control infrastructure and natural cooling mechanism.

4.1.1.2 Climate Change Amplification

Climate projections indicate that both urban heat and flooding will intensify in coming decades. In India, Heat Wave (HW) days are projected to increase by 7-8 days in the near future (2025-2050) and by 10-

17 days in the far future (2076-2100)⁴², while in the far future, the extreme threshold of precipitation would increase by 6% and 21% under the SSP245 and SSP585 scenarios, respectively⁴³. This climate change amplification makes these disasters particularly urgent priorities for risk reduction efforts.

The pervasive nature of urban flooding and heat events sets them apart from other natural disasters in Indian cities. While disasters like earthquakes or cyclones may occur sporadically and affect specific regions, urban flooding and heat impacts manifest consistently across India's urban landscape, creating a persistent challenge for city administrators and residents alike. Rise in temperatures would increase flood events in frequency during end of century (2071-2100), according to Climate change and India: A 4 X4 assessment a sectoral and regional analysis for 2030s report. Temperatures in the Himalayan region are projected to rise by as much as 2.6 degrees Celsius by the 2030s, with an increase in intensity of 2-12 percent. This rise in temperature is expected to lead to more frequent flash floods, resulting in widespread landslides and a loss of agricultural land, which will ultimately impact food security.⁴⁴

In recent years, India has experienced a rise in urban flood disasters, significantly affecting the country's largest cities. Notable instances include floods in Hyderabad in 2000 and 2020, Ahmedabad in 2001 and 2020, Delhi in 2002, 2003, 2009, and 2010, Chennai in 2004 and 2015, Mumbai in 2005, Surat in 2006, Kolkata in 2007, and Srinagar in 2014.

Urban heat presents an even more consistent challenge. Unlike flooding events that may last days or weeks, heat stress affects cities for months at a time. A heat wave in 2015 across the Indian subcontinent in South Asia killed 2200 individuals in India. After these events in 2015, Indian National Disaster Management Authority (NDMA) declared heat waves as a disaster at the National level as the heat wave impacted nine Indian state⁴⁵. The urban heat island effect consistently maintains temperature differentials of 2-5°C between urban centres and their surrounding rural areas throughout the year, affecting millions of urban residents daily.

4.1.1.3 Housing Vulnerability

Informal settlements, home to approximately 33-47% of India's urban population⁴⁶, typically lack basic infrastructure to combat these disasters. For instance, in Mumbai's informal settlements, The city's slum settlements are five-six degrees warmer than their neighbouring housing societies, while 37% of Mumbai's households with metal roof structures are exposed to a risk of high rise in temperatures or heat risk post monsoon, a study by the geo-analytics team of environment group World Resource Institute (WRI) India across the city during October over the past three years has revealed. During flooding events, these areas often experience water logging for 2-3 times longer than formal settlements due to inadequate drainage infrastructure.

4.1.1.4 Health Implications

The health burden falls heavily on vulnerable populations. In India, roughly 65 million people inhabit slums, including areas like More. As climate change intensifies and leads to extreme temperatures, these informal settlements face serious risks. The combination of inadequate access to water, poor sanitation, and overcrowding amplifies the residents' vulnerability to the adverse health effects associated with extreme heat⁴⁷. Urban poor populations often experience increased rates of infectious disease after flood events. Increases in cholera, cryptosporidiosis and typhoid fever have been reported in low - and middle-income countries. Floods have led to increases in diarrhoeal disease have been reported in India⁴⁸.

4.1.1.5 Economic Vulnerability

Record-breaking heat waves in the last two years have put 90% of people in India at increased risk of income loss, poor crop yields, and vector-borne disease, according to a study⁴⁹. In the past two decades between 2003 and 2022, the country suffered INR 4.23 lakh crore worth of losses due to floods and heavy rains and these years made up for 83 per cent of rain-related losses during the past seven decades⁵⁰. India lost \$141 billion worth of income due to heat in 2023. The potential labour hours lost due to heat exposure in 2023 stands at 181 billion, an increase of 50% from the 1990-1999 average⁵¹.

The combination of socioeconomic impact, substantial economic significance, and the availability of measurable interventions makes urban flooding and heat priority areas for disaster risk reduction in Indian cities. Addressing these challenges effectively can create more resilient and equitable urban environments while providing a framework for tackling other urban disasters.

4.2 Urban Flood

Urban flooding has become a pressing challenge for Indian cities, increasingly threatening the safety, infrastructure, and economy of rapidly growing urban populations. Over the past few decades, Indian cities have experienced rapid urbanization, which, combined with inadequate infrastructure, climate change, and poor urban planning, has significantly increased their vulnerability to flooding. The government's data on urban flooding paints a worrying picture of the growing scale of the problem.

According to the National Disaster Management Authority (NDMA), floods are among the most frequent and destructive natural disasters in India. In recent years, urban flooding has been a major issue in cities like Mumbai, Chennai, Kolkata, Bengaluru, and Delhi. A report from the Ministry of Home Affairs reveals that, over the past two decades, floods have affected more than 30 million people annually in India, with urban centers being increasingly vulnerable due to their poor drainage systems and high population densities. On average, India experiences the tragic loss of approximately 1,671 lives each year due to floods. Over the span of nearly seven decades, specifically from 1953 to 2021, around 115,000 individuals have succumbed to flood-related incidents in the country. The year that stands out for the highest number of flood fatalities was 1977, which recorded an alarming 11,316 deaths. Analysing the patterns of flood-related deaths over the decades reveals some concerning trends. The decadal average

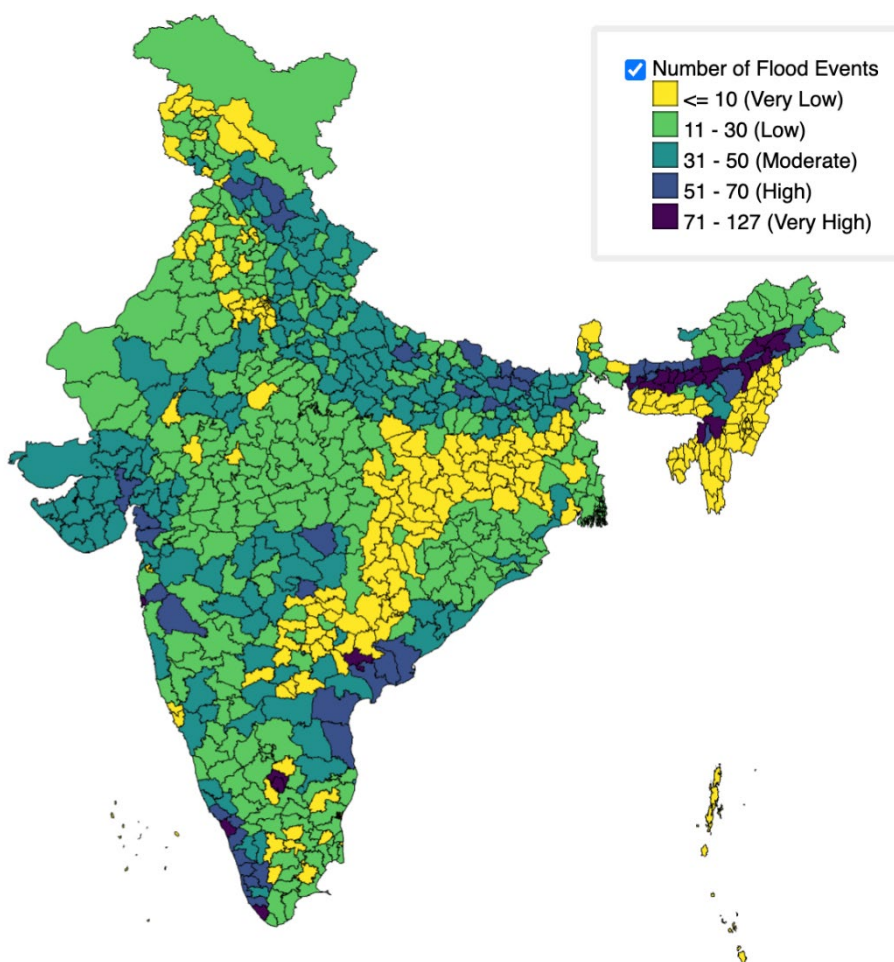


Figure 23: Total number of flood events in India (1969-2019)⁵⁴

Source: IMD

of fatalities increased sharply, climbing from 440 deaths per year during the period from 1953 to 1960 to a staggering 2,560 in the decade from 1971 to 1980. This surge underscores the vulnerability of the population during that time, likely exacerbated by a combination of environmental and infrastructural factors. However, following this peak, there has been a noticeable decline in flood-related fatalities in the subsequent decades. The years from 1981 to 1990 saw an average of 1,965 deaths annually, followed by averages of 1,892 during 1991-2000, 1,867 between 2001-2010, and then 1,775 in the decade from 2011 to 2021. This gradual decrease suggests improvements in disaster management, awareness programs, and possibly better infrastructure to handle floods. Nonetheless, the figures remain a stark reminder of the ongoing challenges faced in flood-prone regions of India.^{52,53}

The Ministry of Housing and Urban Affairs highlights that approximately 13.7% of India's total population lives in urban areas, a number expected to increase to 600 million by 2031⁵⁵. This rapid urban expansion, combined with the encroachment on natural water bodies and floodplains, has significantly reduced cities' natural ability to manage water during heavy rainfall. In Delhi, inadequate drainage systems and poor storm water management have led to severe flooding incidents, particularly in the capital's informal settlements. The Delhi Disaster Management Authority (DDMA) has reported that over 1,500 areas in Delhi experience flooding every year, particularly during the monsoon months, impacting thousands of residents.

Moreover, the Indian Ministry of Environment, Forest and Climate Change (MoEFCC) has noted that the frequency and intensity of heavy rainfall events have

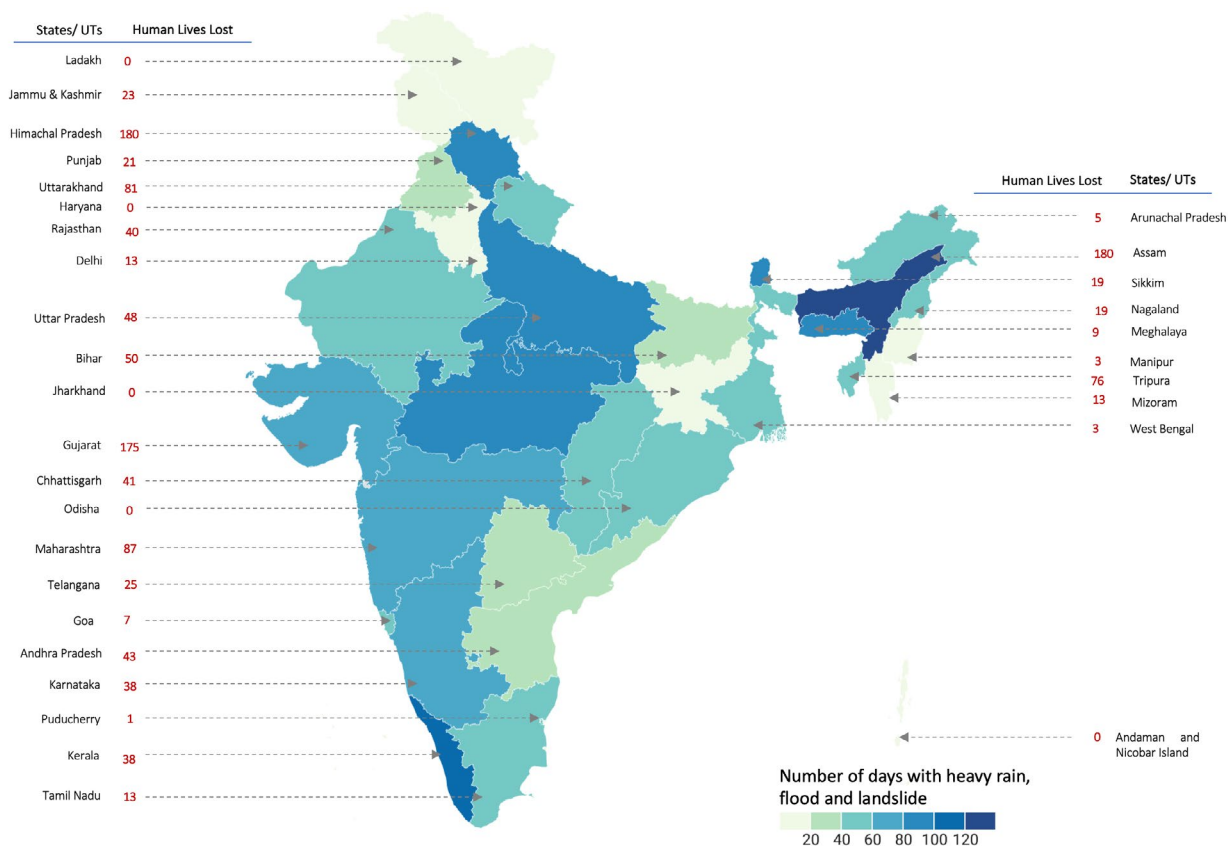


Figure 24: Number of Heavy rainfall flood and landslide days and human lives lost in Indian states in 2024

Data compilation :NIUA

IMD Definition/Criteria: Heavy rainfall happens when a region receives 64.5-115.5 mm rain in 24 hours. In the case of very heavy rainfall, the threshold increases to 115.6-204.4 mm and in extremely heavy rainfall it is 204.5 mm or more. The report has considered all very heavy and extremely heavy rainfall events, and heavy rainfall events only when they have caused damages.

increased in many parts of the country, contributing to more severe flooding. The Climate Resilient Cities (CRC) Programme, initiated by the government, identifies Mumbai, Chennai, Kolkata, and Bengaluru as cities most at risk of urban flooding due to a combination of climate change, sea-level rise, and inadequate drainage infrastructure.

Both small and large-scale temporary flooding can have serious detrimental effects on soil health. Flooding on slopes, which includes processes like overland flow, sheet flow, return flow, and groundwater ridging, is closely associated with soil erosion and landslides. The combination of floodwater and saturated soil conditions can harm soil macropores and the organisms that help maintain soil structure. Consequently, this can make the soil more vulnerable to problems such as compaction, crusting, and elevated bulk density.⁵⁷

In 2024, the Frequency Tracker⁶⁰ for extreme weather events in India highlighted the nation's growing vulnerability to heavy rains, floods, and landslides throughout the year. In January, India experienced 2 days of such events, while February had 3 days. This frequency sharply increased in March, with 9 days of extreme weather. April saw 6 days of heavy rain, floods, or landslides, setting the stage for the intense monsoon months. From May to September, nearly every day was marked by extreme weather, with 25 days in May, 30 days in June, and the entirety of July and August experiencing continuous heavy rains, floods, or landslides. September also saw 30 days of extreme weather.

These statistics reflect the alarming reality of urban flooding in India. With increasingly erratic weather patterns, rising sea levels, and continued urban sprawl, the impacts of urban flooding are expected to worsen. Addressing this growing problem will require a concerted effort from government agencies, city planners, and local communities to build climate-resilient infrastructure, implement efficient flood management systems, and restore natural water bodies to mitigate the effects of urban flooding in Indian cities.

4.2.1 Vulnerability of Specific Populations to Urban flood

a. Women

Women face disproportionate risks during floods due to sociocultural and economic factors. Their vulnerability stems from traditional gender roles, limited mobility, and restricted access to resources⁵⁸. During floods, women often prioritize saving family members and household items over their own safety. Additionally, they face unique challenges:

- Pregnant and nursing mothers face increased health risks due to limited access to healthcare services during floods;
- Women's responsibility as primary caregivers becomes more challenging during evacuations and in relief camps;
- Limited swimming abilities due to sociocultural restrictions increase drowning risks;
- Privacy and security concerns in evacuation centers and temporary shelters make women more vulnerable to harassment and abuse;
- Menstrual hygiene management becomes particularly challenging in flood situations;

b. Elderly⁶³

The elderly population faces severe challenges during flood events due to several factors:

- Limited mobility makes quick evacuation difficult;
- Higher prevalence of chronic conditions requires continuous medical attention;
- Difficulty in accessing relief centers and healthcare facilities;
- Social isolation can lead to delayed rescue efforts;
- Cognitive impairments may affect their ability to understand and respond to warning systems;
- Recovery from flood-related trauma and displacement takes longer for elderly populations;

c. Rural Agricultural Workers

Agricultural workers, who constitute a significant portion of India's rural workforce, are particularly vulnerable:

- Direct economic losses from crop damage and livestock deaths;
- Loss of livelihood during and after flood events;
- Extended exposure to waterborne diseases while

salvaging crops;

- Limited alternative employment options during flood recovery;
- Increased debt burden due to agricultural losses;
- Mental health impacts from loss of livelihood and property;

d. **Slum Dwellers**

Urban slum residents face acute vulnerabilities due to their living conditions:

- Settlements in flood-prone areas and low-lying regions;
- Poor drainage infrastructure leading to prolonged waterlogging;
- Weak housing structures that are easily damaged;
- Limited access to early warning systems;
- High population density increasing disease transmission risks;
- Loss of daily wages during flood events;
- Limited insurance coverage and savings for recovery;

e. **Children**

Children are particularly vulnerable during floods⁶³

- Higher risk of drowning due to limited swimming abilities;
- Increased exposure to waterborne diseases;
- Disruption of education due to school closures and damage;
- Psychological trauma from displacement and loss;
- Nutritional challenges during and after floods;
- Heightened risk of separation from families during evacuations;
- Vulnerability to post-flood diseases due to weaker immune systems;

f. **Individuals with Disabilities**

People with disabilities face unique challenges during flood events:

- Difficulty in rapid evacuation without assistance;
- Limited access to early warning information, especially for those with hearing or visual impairments;
- Challenges in accessing relief centers and emergency services;
- Risk of losing essential assistive devices during

floods;

- Higher vulnerability to post-flood health complications;
- Limited participation in disaster preparedness planning;

g. **Daily Wage Workers**

Daily wage earners face severe economic and social vulnerabilities:

- Immediate loss of income during flood events;
- Limited savings to sustain during recovery periods;
- Often living in flood-prone areas due to affordability;
- Lack of social security and insurance coverage;
- Forced to continue working in hazardous conditions;
- Limited access to formal financial support systems;

h. **Fisher Communities**

Coastal and riverine fishing communities face specific vulnerabilities:

- Direct impact on livelihood due to damaged fishing equipment;
- Loss of storage facilities and catch during floods;
- Limited alternative income sources;
- Exposure to extreme weather conditions during rescue operations;
- Traditional knowledge systems may become less reliable due to changing flood patterns;
- Higher risk due to proximity to water bodies;

These vulnerabilities are often interconnected and compound each other, creating complex challenges for disaster management and relief efforts. The intersection of multiple vulnerability factors – such as being an elderly woman with disabilities in a flood-prone rural area – creates particularly high-risk situations that require specialized intervention strategies. Understanding these specific vulnerabilities and their intersections is crucial for developing targeted intervention strategies and inclusive disaster management policies that address the needs of all affected populations.

Regional variations in vulnerability patterns across India's diverse geographical and social landscape further complicate the situation. States like Bihar,

Assam, and West Bengal, which face recurring floods, show distinct patterns of vulnerability that require locally adapted solutions. The data underscores the need for comprehensive, inclusive, and targeted approaches to flood risk management that consider the specific needs and challenges of each vulnerable group while acknowledging the complex interplay of social, economic, and environmental factors that contribute to their vulnerability.

4.2.2 Challenges and concerns

Urban flooding is a multifaceted problem that threatens the sustainability, liveability, and resilience of cities. While localized flooding events may seem like isolated incidents, they are often symptomatic of larger systemic issues such as inadequate drainage infrastructure, urban sprawl, poor land-use planning, and climate change. The increasing frequency and intensity of rainfall due to climate change have compounded these challenges, pushing many cities to the brink of their capacity to cope. Furthermore, the socio-economic impact of urban flooding disproportionately affects vulnerable populations, often leading to displacement, loss of property, and public health risks. Despite the growing awareness of the issue, many urban areas continue to face persistent gaps in flood risk management, requiring urgent action and innovative solutions to prevent further damage and protect urban populations.

Several key challenges and concerns are associated with addressing urban flooding:

- a. **Inadequate Infrastructure:** Many urban areas have outdated or undersized drainage systems that are unable to handle the increased volume of water during heavy rainfall. Aging infrastructure, combined with the limited capacity for expansion in densely populated areas, makes flood prevention difficult.
- a. **Climate Change:** The increasing frequency and intensity of extreme weather events, such as heavy rainfall, storms, and rising sea levels, exacerbate urban flooding. Cities that were not initially designed to withstand such changes are particularly vulnerable.
- a. **Rapid Urbanization:** As cities expand, natural floodplains and green spaces are often converted into built environments, reducing the natural

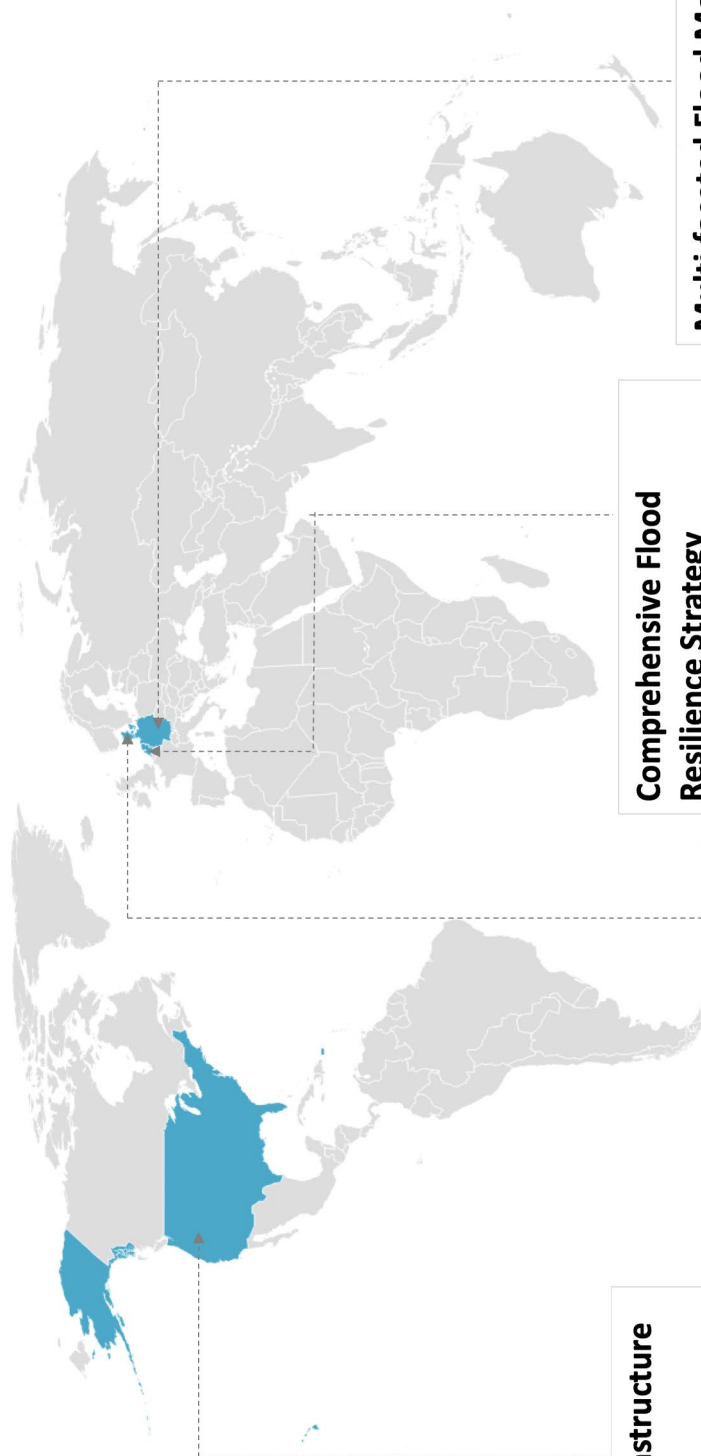
ability of the landscape to absorb rainwater and mitigate flooding. This urban sprawl increases surface runoff and puts more pressure on existing drainage systems.

- b. **Poor Land-Use Planning:** Inefficient zoning laws and poor planning can lead to construction in flood-prone areas, further increasing flood risks. In many cases, the lack of comprehensive land-use strategies leaves cities ill-prepared for flood events.
- c. **Socioeconomic Vulnerability:** Vulnerable populations, including low-income communities, often live in areas more prone to flooding and may have fewer resources to recover from flood-related damages. These groups are disproportionately impacted by the effects of urban flooding, including health risks, property loss, and displacement.
- d. **Lack of Data and Early Warning Systems:** Many cities lack the necessary data, technology, or early warning systems to predict and mitigate flooding risks effectively. Insufficient monitoring of rainfall, water levels, and flood-prone areas can hinder timely responses to flood events.
- e. **Funding:** Adequate funding for flood prevention infrastructure, research, and community resilience projects is often lacking. Additionally, political challenges and short-term priorities can delay the implementation of necessary long-term flood management strategies.

These challenges require a comprehensive approach that combines improved infrastructure, better urban planning, climate adaptation strategies, and community engagement to effectively address the growing problem of urban flooding

4.2.3 Learnings from case studies

To address the pressing issue of urban flood, several cities have implemented innovative initiatives and programs aimed at enhancing flood resilience and managing storm water more effectively. This report examines key strategies employed in four cities—Copenhagen, Hamburg, Rotterdam, and Portland—highlighting their approaches to flood management, the benefits derived from these initiatives, the challenges faced, and the lessons learned through implementation.



Green Infrastructure Solutions

Portland, USA

- Encouraged the installation of green roofs through incentives and regulations;
- Restored and created urban wetlands to capture and treat storm water runoff;
- Used permeable pavements in various urban areas to allow rainwater infiltration.

Cloudburst Management plan

Copenhagen, Denmark

- Infrastructure improvements to redirect excess rainwater;
- Designated areas to temporarily hold water;
- Green infrastructure to absorb water and reduce runoff.

Comprehensive Flood Resilience Strategy

Rotterdam, Netherlands

- Protective infrastructure such as dams, sluices, dikes, and storm surge barriers
- Innovative architecture like floating structures that adapt to changing water levels;
- Advanced water management systems;
- Green infrastructure for water absorption;
- Participatory planning.

Multi-faceted Flood Management Approach

Hamburg, Germany

- Advanced storm water management systems with retention basins and underground tanks;
- Integrated Flood Management Plan;
- Enforced building codes and land-use regulations;
- Public awareness campaigns;
- Community involvement through flood watch groups and consultations.

Figure 25: Urban flood mitigation strategies on global level

Data compilation: NIUA

However, these initiatives demonstrate the importance of integrating community engagement, sustainable practices, and innovative financing to build resilient urban environments capable of withstanding the impacts of urban flood.

4.3 Urban Heat

Urban heat, specifically the Urban Heat Island (UHI) effect, has emerged as a growing environmental and public health challenge in rapidly urbanizing cities across India. The UHI effect occurs when urban areas experience significantly higher temperatures than their surrounding rural areas due to human activities, the density of built-up infrastructure, and the lack of natural vegetation. As urban populations continue to swell and cities expand both horizontally and vertically, the need to understand and mitigate urban heat becomes increasingly critical. The Sixth Assessment Report by the IPCC, published in 2021, revealed that human activities have already caused the climate to warm by nearly 2 degrees Fahrenheit (1.1 degrees Celsius) since the years 1850-1900. Within the next few decades, the global average temperature is projected to reach or surpass 1.5 degrees Celsius (approximately 3 degrees Fahrenheit). These changes will influence every region on Earth⁵⁹. As confirmed by WMO, 2023 was the hottest year on record, with particularly startling extremes in ocean temperatures. Extreme weather

events and wildfires ceased to be just part of future projections.

According to the **Global Climate, Risk Index 2020**⁶¹, countries in South Asia are among the most vulnerable globally to the impacts of climate change. The duration of heat waves is also expected to increase 92- to 200-fold⁶². Heat waves impact not only human health but have significant economic impacts also. These impacts are unevenly distributed with poor countries being impacted more. Callahan and Mankin (2022) have reported that increases in heat waves have depressed economic output most in the poor tropical regions. Cumulative 1992–2013 losses from anthropogenic extreme heat were estimated between \$5 trillion and \$29.3 trillion globally. Losses amount to 6.7% of Gross Domestic Product per capita per year for regions in the bottom income decile, but only 1.5% for regions in the top income decile.⁶³ Heatwaves caused 10,104 deaths between 2010 and 2022 in India (GCA, 2023)⁶⁴. The average temperatures in South Asia's thermal hotspots are projected to increase between 1.5 and 3°C by 2050 relative to 1981-2010 (World Bank, 2018)⁶⁵. Heat stress-induced deaths in 2100 are estimated to be about 85 per 100,000 globally⁶⁶ and above 100 per 100,000 in lower-income groups. According to Debnath et al. (2023), climate change-driven heatwaves threatened India's progress toward Sustainable Development Goals (SDGs) in 2022,

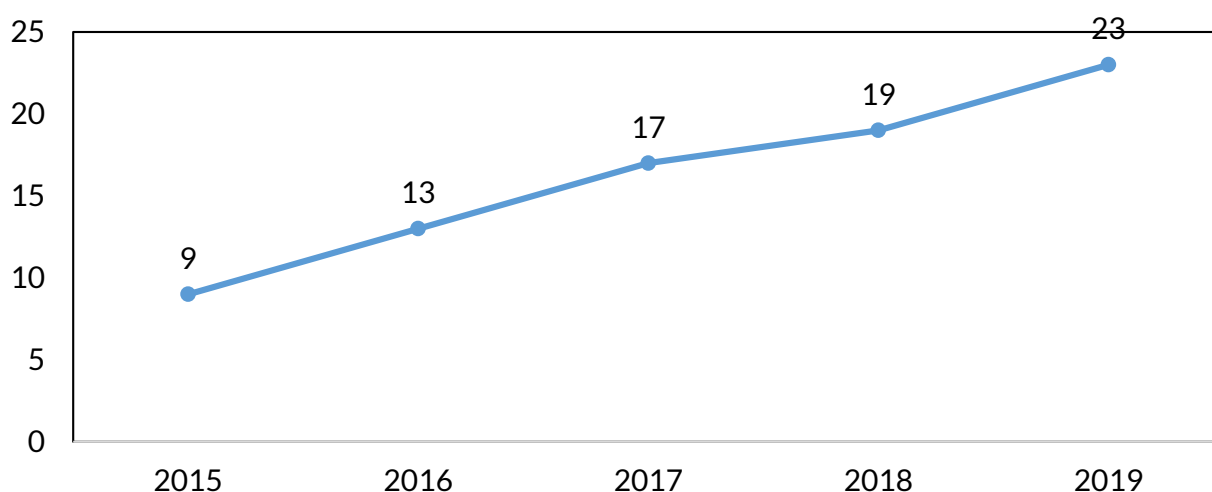


Figure 26: Heat Wave Vulnerability in Indian states,

Source: IMD, 2019

making almost 90% of Indians more vulnerable to public health issues, food shortages, and increased mortality risks. India's United Nations Sustainable Development Group global ranking has declined over the past 20 years, failing to meet 11 of the 17 SDGs, all of which were crucial for SDG 13 (Climate Action). While studies show India's recurring heatwaves increasingly burden its economy and public health resources, long-term projections indicate heatwaves will affect more than 300 million people by 2050 and reduce quality of life for nearly 600 million Indians by 2100. The research emphasizes that the absence of physical risk assessments for heatwaves impedes progress in multiple SDGs: SDG 2 (Zero Hunger), SDG 3 (Good Health and Well-Being), SDG 5 (Gender Equality), SDG 8 (Decent Work and

Economic Growth), SDG 9 (Industry, Innovation and Infrastructure), SDG 10 (Reduced Inequalities), and SDG 15 (Life on Land).⁶⁷

The records indicate that the number of states affected by Heat waves has been increasing over the years (2015-2019) (Integrated Disease Surveillance Programme (IDSP), National Centre for Disease Control (NCDC), Ministry of Health and Family Welfare (MoH&FW).

In 2024, India experienced significant heatwave activity, with heatwaves occurring on 77 out of 274 days. This resulted in the loss of 210 human lives across various states and union territories. Odisha and Bihar were particularly affected, experiencing

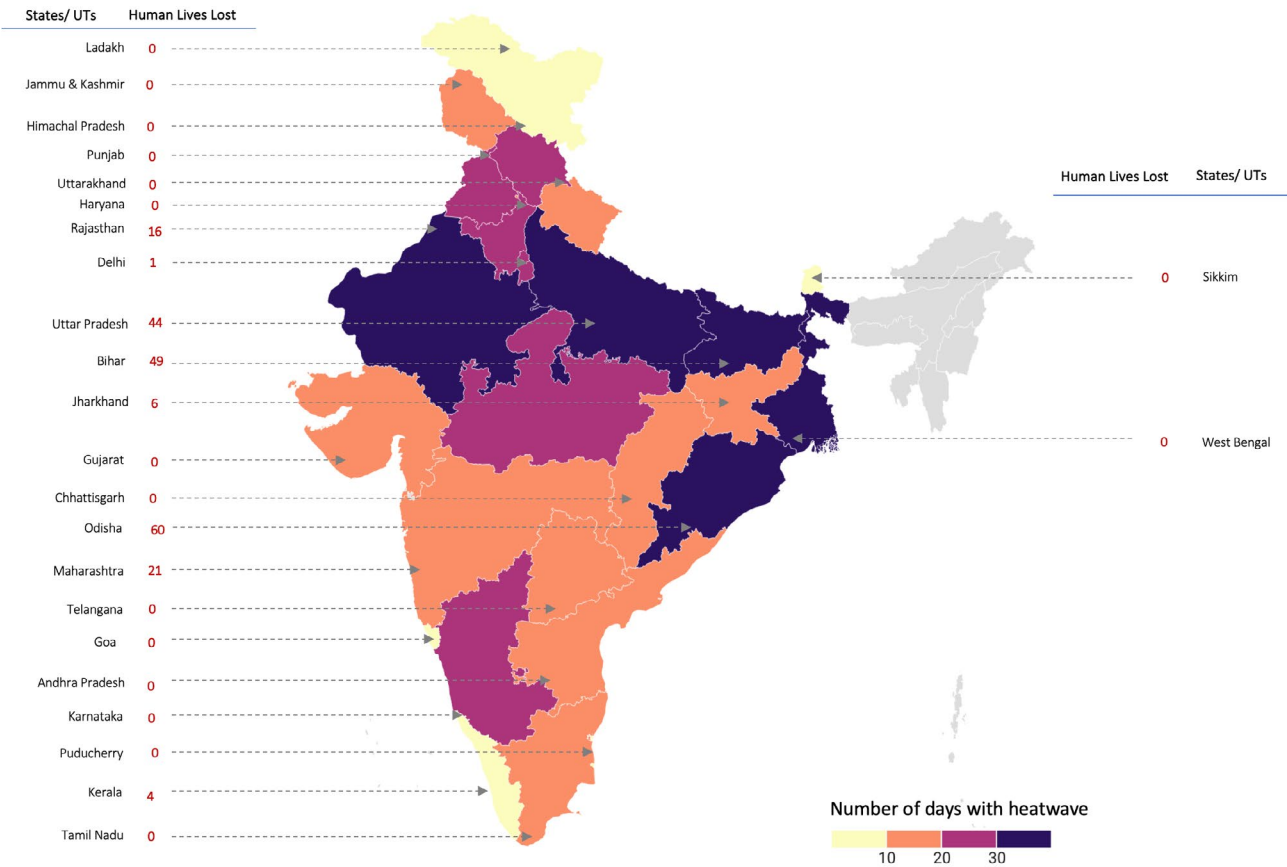


Figure 27: Number of heatwave days and human lives lost in Indian states in 2024⁶⁸

Data compilation :NIUA

IMD Definition/Criteria: Heatwave conditions signify a certain amount of rise in temperature at a given place with respect to normal climatological value. The report has considered heatwaves (4.5oC to 6.4oC departure of the maximum temperature from normal), and severe heatwaves (departure of more than 6.4oC).

the highest number of casualties with 60 and 49 lives lost, respectively. Other regions also faced numerous heatwave days, including Rajasthan, Uttar Pradesh, and West Bengal, among others.

The combination of increasing temperatures, poor urban planning, and climate change has made cities more vulnerable to extreme heat events, leading to substantial impacts on human health, energy demand, and overall urban sustainability. From April to June, nearly every day was marked by extreme heatwaves, with 25 days in April and May and 23 days in June. March also recorded 4 days of extreme heat.

India's heatwave data from 2024 highlights the alarming frequency and impact of extreme weather events across the country. The data shows that heatwaves were recorded on 77 out of 274 days, leading to a tragic loss of 210 human lives. Heatwaves were particularly prevalent in the summer months, with April, May, and June seeing the highest number of days with extreme temperatures.

Cities like Delhi, Mumbai, Bengaluru, and Chennai have witnessed a rise in average temperatures due to the UHI effect, exacerbating the impacts of heatwaves and increasing energy consumption. As

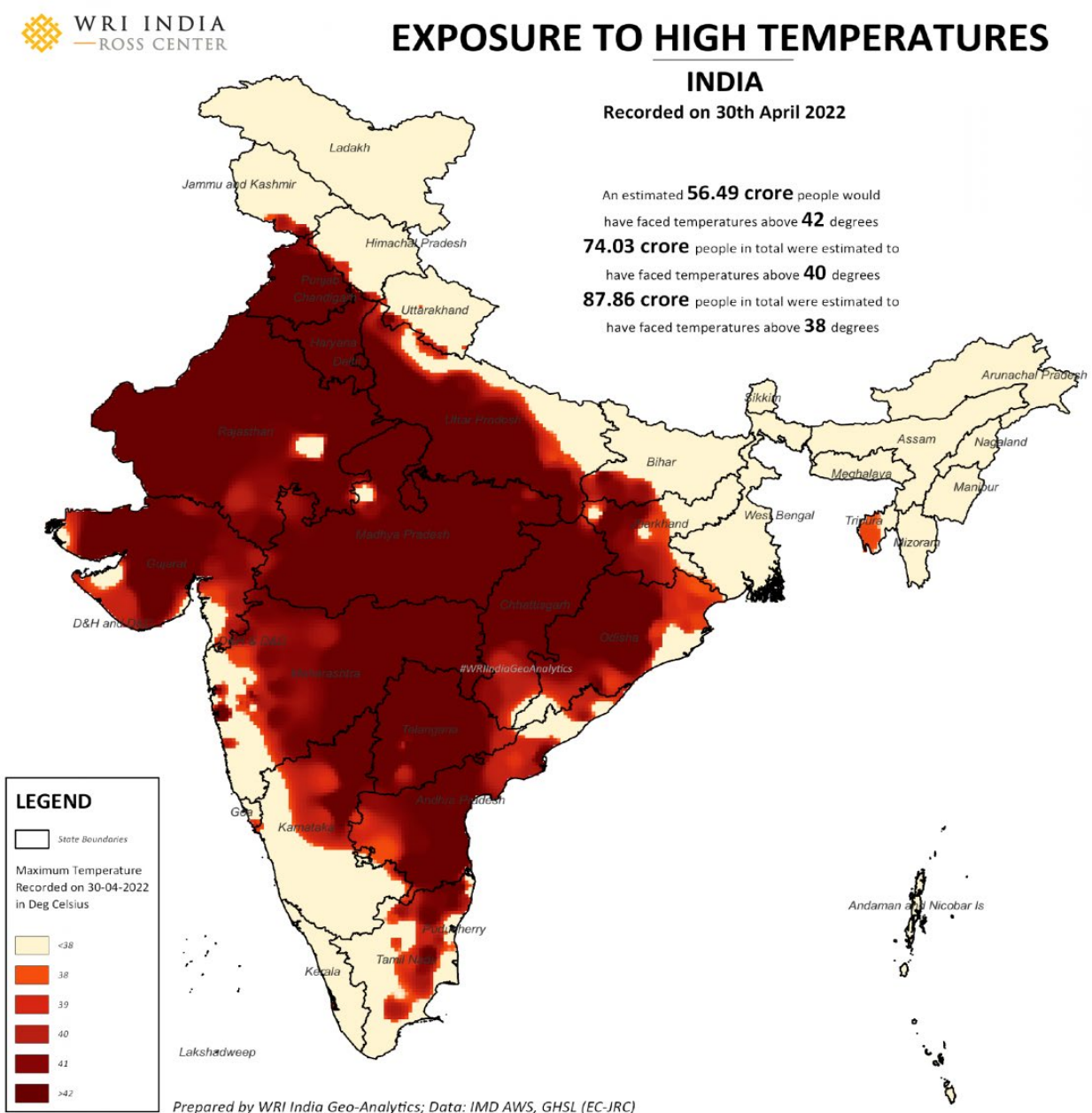


Figure 28: Exposure to high temperature, Source: WRI⁶⁹

per the National Action Plan on Climate Change (NAPCC), India's cities are experiencing temperature rises of 1–2°C per decade, with some urban centers like Delhi recording temperature increases of up to 4°C in recent decades.

The Indian Institute of Remote Sensing (IIRS) has found that Delhi and Mumbai exhibit a significant UHI effect, with temperatures rising 3–4°C higher than their rural surroundings. The Ministry of Earth Sciences (MoES) highlights that heatwaves in India are becoming more frequent, with the number of heatwave days in cities like Delhi, Ahmedabad, and Jaipur steadily increasing, leading to heightened health risks. In Delhi, the India Meteorological Department (IMD) recorded severe heatwave conditions in May 2022, with temperatures soaring to 46.5°C in some parts of the city, well above the historical average.

On April 30, 2022, approximately 820 million people in India experienced temperatures reaching 40 degrees Celsius, while around 990 million faced temperatures of 38 degrees Celsius⁷⁶, highlighting the extreme heat conditions affecting the country. The effects of urban heat extend beyond the discomfort of hot temperatures; they pose serious risks to human health, productivity, and urban resilience. According to the National Disaster Management Authority (NDMA), extreme heat events have been responsible for more than 3,000 deaths annually in India over the past decade, with cities being particularly vulnerable due to dense populations, inadequate infrastructure, and lack of access to cooling systems. As the UHI effect intensifies, addressing these issues requires a comprehensive understanding of urban heat dynamics and the development of policies that prioritize climate-resilient urban planning.

As urbanization accelerates, the proportion of cities, susceptible to UHI effects continues to grow. These UHIs are 2–5°C warmer than surrounding rural areas during heat events.⁷⁰ This phenomenon arises from the concentration of pavement, buildings, and other heat-retaining structures. The combination of limited green spaces, pollution, and concrete surfaces exacerbates the health risks associated with heat exposure, especially for economically disadvantaged segments of the population with no access to air

conditioning or other means of escaping extreme heat.

4.3.1 Vulnerability of Specific Populations to Urban heat

a. Women

Women in India face heightened vulnerability to extreme heat due to intersecting social inequalities and responsibilities. On average, 27,000 women die each year from heat-related causes, a number projected to rise to 73,500 by 2050, and potentially to 131,000 in extremely hot years⁷¹. Women often juggle multiple roles, including household chores, caregiving for children and the elderly, and physically demanding jobs like construction and street vending. These responsibilities leave them particularly susceptible to heat stress during extreme temperatures, impacting their health and well-being. Recognizing the complexities of women's roles is essential for advocating for their rights and supporting their health in both personal and professional spheres. In addition,

- Working in extreme heat can double the risk of stillbirth and miscarriage for pregnant women, according to new research from India.⁷²
- There is evidence of heat stress as a risk for pregnant women due to (i) increased body weight, and body-fat-triggered increased core body temperature and heat production; (ii) decreased ratio of surface area to body mass associated with pregnancy, reducing the heat-loss capacity of sweating, and (iii) foetal metabolic rate increasing the maternal core body temperature.^{73, 73}

Female mortality due to heatstroke shows an increasing trend since 2011, in the age group of below 14 years whereas male mortality has been reducing continuously.⁷⁵ Low-income women are disproportionately vulnerable to the ill-effects of climate variability and change, in part because of gender inequalities (e.g., unequal political, social, economic and cultural rights; lower levels of access to resources, information and education; and lower levels of participation and influence in shaping policies and decision making processes at all levels, including the household).

b. Elderly

In 2023, people over 65 years of age experienced an

average of 9.3 more heatwave days compared to 1986-2005, resulting in 167 per cent more annual deaths of adults older than 65 years than in the 1990s (Lancet, 2023)⁷⁶. Rising temperatures put older adults at risk of heat illness. A global analysis shows the challenges countries face now and by 2050 as temperatures rise and populations age⁷⁷. Physiological factors, social isolation, and limited mobility contribute to their vulnerability.

c. Outdoor Workers

A recent report from the International Labor Organization (ILO) reveals that 2.41 billion workers are exposed to such excessive heat worldwide, of whom nearly 19,000 succumb annually.⁷⁸

In India, up to 75% of the workforce, or 380 million people, depend on heat-exposed labor.⁷⁹ The impact of high heat index levels extends beyond physical health. Prolonged exposure to extreme temperatures can create psychological stress, leading to anxiety and mood disorders.

Studies have shown correlations between extreme heat and increased rates of mental health emergencies and violence. The discomfort caused by excessive heat can exacerbate existing mental health issues, creating a vicious cycle that further deteriorates an individual's overall well-being.

Moreover, heat waves can affect sleep patterns, leading to irritability and cognitive impairments. Over time, these factors can contribute to a decline in quality of life, impacting daily activities, academic performance, and job productivity.

Worker productivity declines by as much as 4 percent for every 1 degree increase in temperature on a hot day. As temperatures rise above 27° Celsius (80.6°F), productivity declines in settings where manual labour is important. For those in the milder climate of South and Central India, productivity declines by about 2 percent per degree Celsius. For the hotter regions of Delhi and Gujarat, productivity declines by as much as 4 percent per degree. Importantly, productivity in the highly automated steel industry does not drop on hot days.⁸⁰ A 2018 study estimated that India lost 75 billion work hours due to heat in 2017 alone.⁸¹

d. Urban Poor

The urban poor are most susceptible to extreme heat due to poor infrastructure and living conditions. 49 percent of India's urban population living in slums in 2020, often lack access to cooling, clean water, and healthcare during heat waves.⁸² The urban heat-island effect can raise temperatures by 5-10°C, exacerbating heat waves.⁸³

e. Children

Those under 5 are particularly vulnerable due to their developing thermoregulatory systems. Over 210 million children lost crucial school days in just April and May of 2024 due to school closures from extreme heat.⁸⁴ UNICEF found that, by 2050, if the current trend continues, almost every child under 18 in the world – nearly 2.2 billion – will be exposed to high heatwave frequency, up from only 24% of children in 2020.

f. Individuals with Chronic Conditions

People with cardiovascular diseases, diabetes, and respiratory conditions face heightened risks during heat waves. Every 1 °C average temperature rise could increase mortality risks by 0.2%–5.5%⁸⁵

4.3.1.1 Various Limitations

India has made significant strides in recent years to address the threat of heat waves. At present heat action plans (HAPs) have been implemented in 23 states that are prone to high temperatures leading to heatwave conditions⁸⁶. The India Meteorological Department (IMD) issues heat wave warnings when temperatures are expected to exceed specific thresholds - typically 40°C in plains areas and 30°C in hilly regions.⁸⁷ However, several critical limitations persist:

Limited Geographical Coverage:

- Only half of the world (52 per cent) is covered by an early warning system.⁸⁸
- Many remote and Vulnerable areas lack access to timely heat warnings due to insufficient infrastructure and communication networks.

Insufficient Lead Time:

- Warnings are often issued with just 24-48 hours notice, providing little time for vulnerable groups

to take protective actions.

- The 2019 Global Commission on Adaptation's flagship report, *Adapt Now*, found that EWS provides more than a ten-fold return on investment – far higher than any other adaptation measures included in the report. The report also found that issuing a warning just 24 hours before a coming storm or heatwave can cut the ensuing damage by 30 per cent.

Lack of Localized Data:

India's diverse geography means heat impacts can vary significantly even within small areas. Most current systems rely on broad regional forecasts rather than hyper-local data, leading to imprecise warnings.

Communication Gaps:

Language barriers and limited access to technology significantly impede effective communication, particularly within marginalized communities. It is crucial to ensure equitable outreach in risk communication such as early warnings to the most vulnerable segments of society. This includes recognizing and addressing challenges such as illiteracy, the digital divide, and language differences while formulating dissemination plans. Additionally, studies that evaluate communities' perceptions of risk communication can offer valuable insights into improving the overall process.

Limited Integration with Health Systems:

There's insufficient coordination between meteorological services and health departments to track and respond to heat-related illnesses in real-time.

Urban heat is a growing environmental crisis that directly impacts the sustainability, health, and resilience of cities. The Urban Heat Island (UHI) effect, characterized by significantly higher temperatures in urban areas compared to rural surroundings, is a key driver of this challenge. As urban centers in India expand rapidly, there is an increasing concentration of built-up infrastructure, limited green spaces, and a rise in impervious surfaces such as asphalt and concrete. These urban characteristics contribute to heat retention and exacerbate the UHI effect, pushing city temperatures 2-4°C higher than those in surrounding rural regions, as observed in cities like

Delhi, Mumbai, and Chennai.

In Delhi, a report from the Ministry of Environment, Forest and Climate Change (MoEFCC) highlights a 1°C rise in average temperatures between 1991 and 2021, with summers becoming progressively hotter. Similarly, in Mumbai, the Indian Institute of Tropical Meteorology (IITM) reported a rise in the annual mean temperature of 1.2°C over the last few decades, with some parts of the city experiencing up to 4°C higher temperatures than rural areas. In Bengaluru, the Bangalore Development Authority (BDA) has found that urban areas have warmed by 1.5°C–2°C in the last two decades, significantly impacting the health and comfort of the city's residents.

The UHI effect is not just a localized issue; it has far-reaching implications for human health, energy consumption, and public infrastructure. According to the National Health Portal of India, heat-related illnesses, including heatstroke and dehydration, increase significantly during periods of extreme heat, with vulnerable populations (such as the elderly, children, and low-income groups) being disproportionately affected. In Delhi, the Delhi State Government's Climate Action Plan estimates that heat-related illnesses have risen by 30% in the last five years, with a notable increase in hospital admissions during heatwaves.

Urban heat also increases the demand for energy, particularly for air conditioning and cooling systems. According to the Ministry of Power, the demand for electricity in Indian cities is expected to rise by 10–15% annually, driven largely by the increasing need for cooling during hot months. This places significant pressure on already overstretched energy infrastructure, often leading to power outages and further exacerbating the heat effects. Furthermore, the increased use of cooling technologies contributes to higher emissions, perpetuating the cycle of heat and climate change.

4.3.1.2 Challenges and concerns

Several key challenges and concerns exacerbate the problem of urban heat in Indian cities:

- a. Rapid Urbanization and Land Use Change: As cities rapidly expand, large areas of natural land,

including forests, wetlands, and agricultural land, are converted into impervious surfaces like roads, buildings, and parking lots. This urban sprawl significantly reduces the natural cooling capacity of the environment. According to the National Remote Sensing Centre (NRSC), urbanization has increased the built-up area by 200% in cities like Delhi and Mumbai over the past two decades, leading to a marked increase in the UHI effect.

- b. **Insufficient Green Spaces and Vegetation:** Green spaces, such as parks and urban forests, play a vital role in mitigating urban heat through evapotranspiration and shading. However, government studies from the Ministry of Urban Development (MoUD) indicate that green spaces in urban areas have decreased by up to 30% in the last 20 years in major cities like Mumbai and Chennai, which has led to higher surface temperatures and increased vulnerability to heatwaves.
- c. **Social Inequality and Vulnerable Populations:** The impact of urban heat disproportionately affects low-income communities and informal settlements, which often lack access to air conditioning, cooling infrastructure, and green spaces. The National Institute of Public Finance and Policy (NIPFP) notes that vulnerable populations in informal settlements, especially in cities like Delhi and Kolkata, are particularly exposed to the adverse effects of urban heat, increasing health risks and mortality rates during heatwaves.
- d. **High Energy Demand and Strained Infrastructure:** The rising temperatures due to urban heat led to a surge in the use of cooling devices, contributing to peak energy demand. The Central Electricity Authority (CEA) reports that urban areas account for over 60% of India's electricity consumption, with a large portion of this demand arising from air conditioning during heatwaves, thereby placing further stress on power grids and increasing the risk of blackouts.
- e. **Climate Change Amplification:** Climate change is expected to amplify the UHI effect, with

temperature rises predicted to be 3–4°C higher by the end of the century in many Indian cities. According to the Indian Meteorological Department (IMD), India is expected to see more frequent and intense heatwaves as a result of global warming, which will exacerbate existing urban heat challenges, particularly in cities with limited climate adaptation strategies.

- f. **Lack of Comprehensive Urban Heat Mitigation Strategies:** While some cities have begun implementing heat action plans, comprehensive urban heat mitigation strategies are still lacking in many areas. The National Action Plan on Climate Change (NAPCC) emphasizes the need for green infrastructure and cool roofs but highlights that only 5-10% of Indian cities have adopted these strategies at a scale large enough to significantly mitigate the UHI effect.

4.3.1.3 Learnings from case studies

This comprehensive analysis of urban heat management strategies across various global cities highlights a diverse range of initiatives aimed at mitigating the Urban Heat Island (UHI) effect and enhancing urban liveability. Key strategies include Singapore's Urban Greenery Initiative, which emphasizes the development of parks and green spaces, and Los Angeles's Cool Roof Program, promoting reflective roofing materials. Melbourne's Urban Forest Strategy aims to increase tree canopy cover, while Toronto's Green Roof Bylaw mandates green roofs on new developments. Each city demonstrates unique benefits, such as improved air quality, energy savings, and enhanced biodiversity, though they also face challenges like high installation costs and maintenance issues. Valuable lessons learned include the importance of government support, community engagement, and long-term planning in effectively addressing urban heat. Integrating green infrastructure with innovative technologies, as seen in Tokyo's data-driven approaches and Copenhagen's water-sensitive urban design, further underscores the potential for sustainable urban planning to foster resilience against extreme climate change.

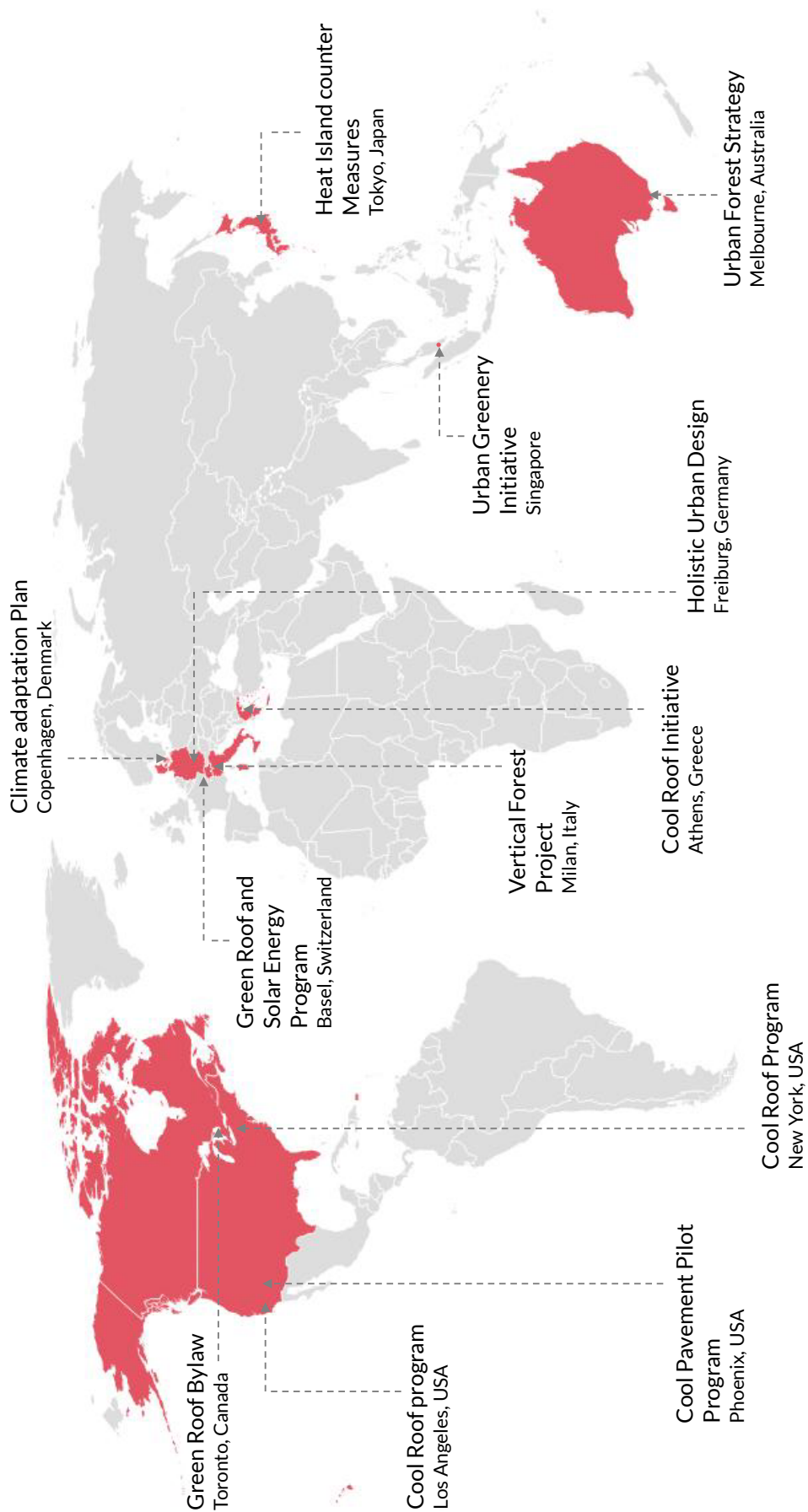


Figure29: Urban heat mitigation strategies on global level

Data compilation :NIUA

4.4 Conclusion

In conclusion, the selection of urban floods and urban heat for focused analysis is particularly significant due to their immediate and profound impacts on densely populated urban areas, where climate change is intensifying their frequency and severity. These disasters not only threaten infrastructure and livelihoods but also disproportionately affect vulnerable populations, including marginalized groups such as women, children, the elderly, and individuals with disabilities. Prioritizing these specific climate challenges allows for a deeper understanding of the unique vulnerabilities they present, particularly in terms of gender inclusion. Women often bear a disproportionate burden during disasters due to existing social and economic inequalities, underscoring the need for gender-sensitive approaches in disaster management and urban planning.

Additionally, addressing urban floods and heat is essential for fostering equitable and sustainable urban environments. As cities expand and climate change escalates, adaptive strategies must incorporate a holistic understanding of community needs, ensuring that interventions are inclusive and accessible to all demographics. This includes enhancing infrastructure resilience, promoting green spaces, and implementing effective water management systems that prioritize the well-being of vulnerable groups. Leveraging insights from case studies and fostering collaboration among diverse stakeholders can lead to the development of comprehensive strategies that mitigate the impacts of these disasters while empowering affected communities, thereby ensuring that the response to climate change is equitable and inclusive.







Recommendations

5. Recommendations

5.1 Introduction

Integrating risk into master planning is crucial for fostering resilient communities and infrastructure, ensuring that future developments are strategically designed to minimize vulnerabilities. This approach entails embedding risk considerations into the planning and design processes, which facilitates a more proactive stance toward anticipating potential threats and formulating effective mitigation strategies. The process of integrating risk typically unfolds in three major steps:

- **Data Integration:** The first step involves the comprehensive collection and synthesis of data from various sources, including historical disaster records, demographic information, and environmental assessments. This data serves as the foundation for understanding the specific risks faced by a community and provides critical insights into patterns and trends.
- **Analysis and Mapping:** Following data integration, a thorough analysis is conducted to identify and assess the various risks. This may include vulnerability assessments and hazard mapping, which visualize areas most at risk. Such analyses help stakeholders understand the spatial distribution of risks and the potential impact on different segments of the population.
- **Decision Making and Implementation:** The

final step involves using the insights gained from the data analysis and mapping to inform decision-making processes. This includes prioritizing interventions, developing policies, and implementing strategies that effectively address identified risks. Collaboration among stakeholders is vital in this stage to ensure that solutions are practical, inclusive, and tailored to the community's unique needs.

By systematically following these steps, master planning can effectively integrate risk management, resulting in more resilient urban environments capable of withstanding future challenges.

5.1.1 Legal framework

Section 30(2)(vi) of the Disaster Management Act 2005 recommends the District Disaster Management Authority to establish guidelines for prevention of disaster management plans developed by government departments at the district level and local authorities. Additionally, Section 39 of the Act mandates that every state government department must incorporate disaster prevention and mitigation measures into its development plans and projects.

5.2 Urban flood

A flood risk-informed master plan represents an effective approach to managing flood risk in urban

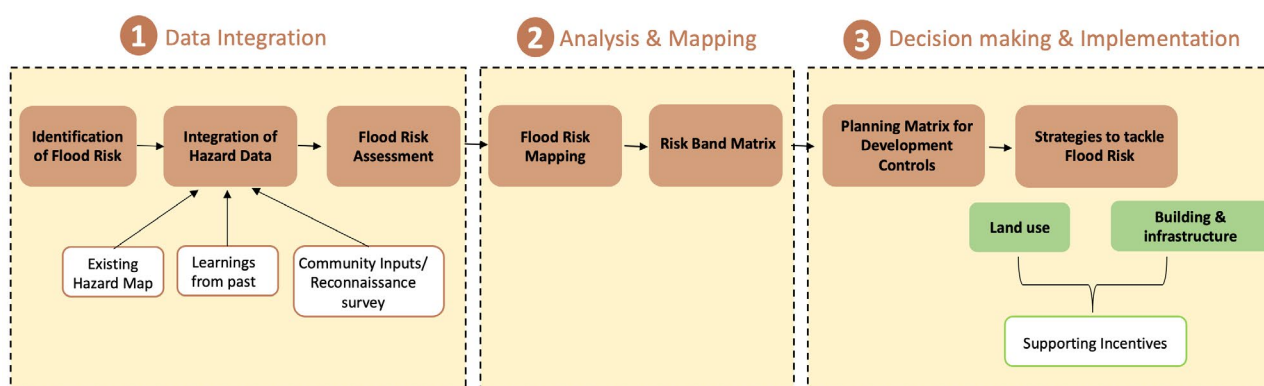


Figure 30: Milestones for flood risk informed Masterplan,

Data compilation: NIUA

areas. As outlined in the previous section, this process can be executed in three primary stages: data integration, mapping, and implementation.

Data integration involves the systematic collection and consolidation of diverse datasets into a cohesive framework. This consolidated data serves as the foundation for flood hazard and vulnerability mapping, enabling the identification of high-risk areas and facilitating informed decision-making. The final stage, implementation, concentrates on translating these insights into actionable policies, regulations, and design strategies that specifically address the identified risks.

Strategies for risk-informed planning are formulated through a comprehensive review of various pertinent documents, including disaster risk reduction frameworks, climate adaptation plans, and urban development guidelines, along with relevant national and international case studies. This thorough review ensures that the master plan is both comprehensive and tailored to the specific context of the area.

5.2.1 Data Integration

5.2.1.1 Identification of Flood Risk

Identifying potential hazards in a given area is a critical step in disaster management. Given the challenges posed by climate change and growing environmental degradation, tracking hazard events and accurately forecasting future risks has become increasingly difficult. This requires a multi-disciplinary approach to ensure reliable predictions.

The State Disaster Management Authority (SDMA) and District Disaster Management Authorities are the designated bodies under the Disaster Management Act, 2005 (DM Act). These authorities are responsible for providing technical support and guidance to local governments in the state on disaster management (Ref: DM Act, Section 22 (2)(k)).

The State Disaster Management Plan must detail the vulnerability of different regions of the state to various types of disasters, as well as the strategies for their prevention and mitigation (Ref: DM Act, Section 23 (4)(a) and (b)).

According to Section 31 (3) of the DM Act, the District

Disaster Management Plan prepared by the District Disaster Management Authority should include:

- a. Areas within the district that are vulnerable to different types of disasters.
- b. Measures to be taken by local authorities and government departments at the district level for disaster prevention and mitigation.

5.2.1.2 Integration of Hazard Data

A. Hazard Maps

It is expected to develop hazard maps for local areas, it can be extracted from district hazard map prepared by DDMA. For example, when it comes for flood, flood hazard probability map for different return periods prepared by SDMA can be used. From the raster file available, inundation depth should be reclassified as per requirement.

If an existing map is unavailable, one should be created at the same scale as the master plan to facilitate easy comparison and assessment. This map can be developed at various levels, including city, district, zone, or ward levels, to enhance understanding. For ward-level mapping, a scale of 1:4000 is recommended for greater clarity. Accurate delineation of hazard-prone areas is essential for effective land use planning, and technologies such as satellite imagery and LiDAR can be employed to achieve this.

The hazard data can be collected from various resources, such as;

- National Database on Emergency Management, NRSC
- Indian Meteorological Department
- Concerned SDMAs and DDMA's

The flood hazard mapping should include various geographical parameters, such as;

- **Slope:** It is advised to prepare using **Cartosat version 3 DEM** in ArcGIS. The slope map can be divided into multiple categories as per the location characteristics.
- **Elevation:** Altitude classes should be decided as per location characteristics
- **Drainage density:** Advised to compute from

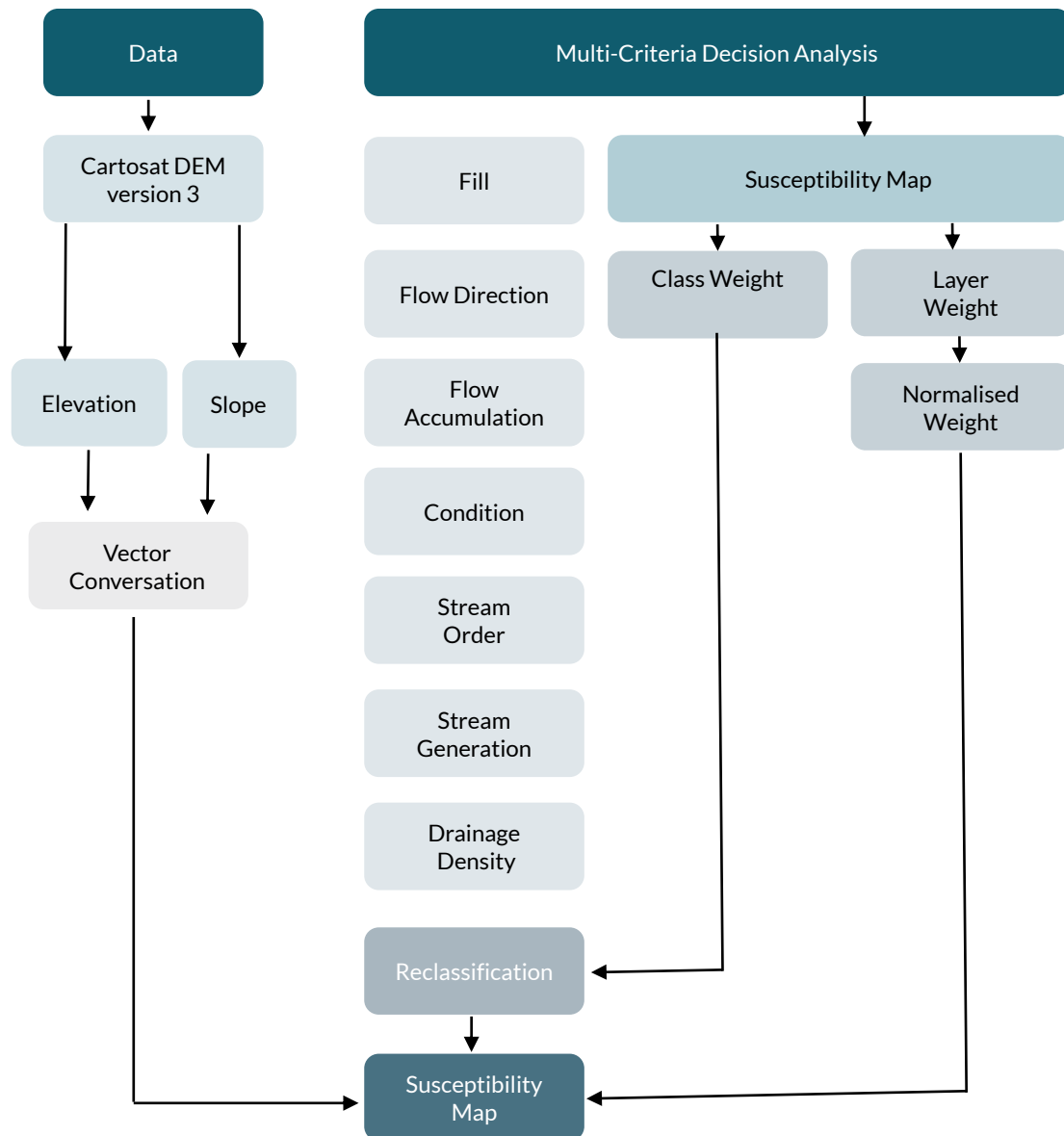


Figure 31: Hazard Susceptibility Mapping Methodology, NESAC

drainage network map using line density command in ArcGIS.

B. Learnings from past

Local knowledge about areas that have been affected in the past, the extent of the damages, the factors that contributed to those damages, and potential mitigation measures that could have lessened the impact, is essential for developing effective mitigation and preparedness strategies. The advised approach is;

- Review post-disaster damage assessment reports and studies.
- Gather and examine records from government agencies, educational institutions, research bodies, non-governmental organizations (NGOs), and social organizations. This may include reports, publications, manuscripts, and other relevant documents available in libraries, schools, community centers, and NGO offices.
- Conduct targeted group discussions with experts, local residents, student groups, and other

stakeholders.

- d. Consider significant disaster events that have occurred over the last two decades.
- e. Field data should be included wherever feasible.

C. Community Inputs

A participatory and multi-disciplinary methodology should be adopted for the systematic collection, compilation, and analysis of data. This process must involve a wide range of stakeholders including technical institutions, subject matter experts, senior citizens, government agencies, academic institutions, research bodies, non-governmental organizations (NGOs), social workers, self-help groups (SHGs), and other relevant entities.

At the community level, hazard identification mapping and reconnaissance surveys should be conducted at the ward level, led by Local Resource Groups. These surveys should aim to identify and record hazards through active community engagement. For determining approximate spatial locations of hazards and vulnerabilities, a cadastral base map may be employed to ensure accuracy and consistency.

It is essential that the survey process takes into account all significant disaster-related events that have occurred over at least the past two decades. The scope of the survey should include the collection and documentation of the following information:

- General details of the location
- Identification of the responsible Local Self-Government Institution (LSGI)
- Historical disaster occurrences and potential future risks (risk evaluation)
- Information on disaster preparedness, mitigation efforts, and social empowerment initiatives
- Details of available local resources and capacities
- Existing and proposed disaster risk reduction (DRR) and mitigation projects
- Infrastructure facilities relevant to disaster response
- Key contact information for emergency coordination
- Any other supplementary or relevant data

To facilitate standardized data collection, a sample template is available at the following link: [Local Government Disaster Management Plan Guidelines and Template](#)

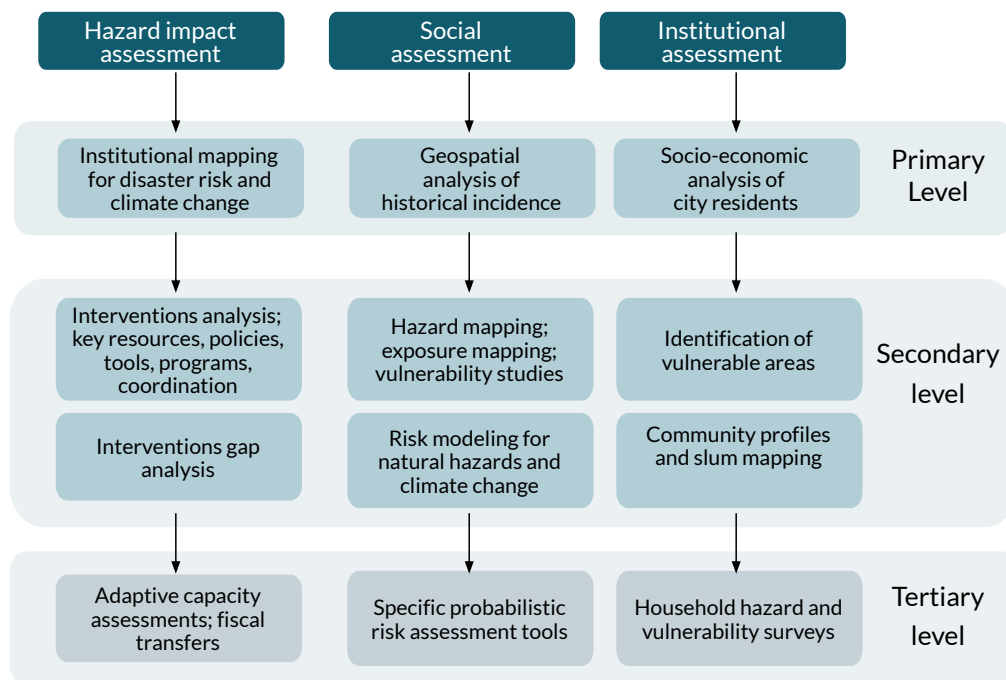


Figure 32: Urban Risk Assessment Report

Data Source: World Bank, Data compilation: NIUA

5.2.1.3 Flood Risk Assessment

Risk assessment is a critical element of disaster risk management. Its purpose is to define risks, understand the characteristics of potential hazards (such as frequency and severity), and identify community vulnerabilities. Effective risk evaluation helps prioritize risk management measures, considering the probability, impact, cost-effectiveness, and available resources. Risk assessments should be conducted at various scales, from local to global, and can target different areas, such as health, infrastructure, or expert judgment. These assessments must also account for multiple hazards, sectors, scales, and assets, as well as the diverse stakeholders influencing risk. Urban risk assessment (URA) are particularly complex due to the dynamic nature of cities, requiring regular updates to reflect changing population dynamics and growth patterns. URA uses a flexible, phased approach, integrating rapid-onset hazards (like floods) and slow-onset risks (like drought) to provide a comprehensive understanding of risk. The approach focuses on three pillars—institutional, hazard impact, and socioeconomic—across three levels of complexity (primary, secondary, tertiary), and incorporates institutional capacity and community vulnerability to enhance disaster preparedness and adaptive capacity.

a. **The Hazard Impact Assessment** focuses on understanding hazard trends and identifying populations and assets at risk from future hazards, especially in the context of increased climate variability. At the primary level, this assessment involves creating simple maps that show locations of past disasters in a city, along with current population and assets in those areas. At the secondary level, the assessment estimates impacts from selected hazard scenarios using simplified loss models. At the tertiary level, probabilistic risk modelling is used to assess the potential population and economic losses that could result from a range of hazards.

At this stage, an assessment of urban basic and critical infrastructure should be conducted. This includes evaluating **water supply, sanitation, land cover, solid waste management, stormwater drainage, roads, and energy/telecommunication** systems.

b. **The Socioeconomic Assessment** focuses on

identifying the geographic location and degree of vulnerability among urban residents. At the primary level, it looks at variables such as demographics, housing, welfare, human development, and poverty to understand how these factors influence disaster and climate change risk. The secondary level develops a comparative ranking of areas based on selected vulnerability variables across the city. At the tertiary level, a more detailed analysis is carried out at the community level through household surveys, focusing on specific hazards and vulnerabilities within those communities. In this stage **gender vulnerability** also have to take care and consider for the assessment.

c. **The Institutional Assessment** aims to develop effective policies and strategies for managing disaster and climate change risks. At the primary level, it involves mapping the institutions responsible for various phases of disaster risk management, including preparedness, response, reconstruction, and risk reduction. This also includes identifying institutions that contribute to the hazard impact assessment. At the secondary level, the assessment compiles an inventory of planning instruments, technical capabilities of staff, and policies, projects, and programs. At the tertiary level, the focus shifts to conducting a gap analysis to evaluate the effectiveness of current city services, management tools, and policies.

The Risk assessment can be done at the cadastral level for the entire flood prone area. It shall be overlaid with existing land use plan in Geographic Information System (GIS) for further analysis and for the preparation of Risk Reduction Plan, Sector level proposals, and the proposed Land Use Plan.

The collected data can be recorded and analysed through various methodologies, one of which is the Quick Risk Estimation (QRE) tool developed by the United Nations Office for Disaster Risk Reduction (UNDRR). The QRE tool is specifically designed to facilitate the identification and understanding of risks and exposure related to both human populations and physical assets. Rather than serving as a comprehensive assessment instrument, the QRE functions as a participatory, multi-stakeholder engagement process aimed at fostering a shared

understanding of disaster risk.

By considering existing measures and initiatives already in place, the QRE generates a dashboard-style risk overview. This output provides insights into the risks and hazards affecting human and physical assets, as well as the potential impacts of key risks and associated threats on a specific location or targeted asset. The tool supports informed decision-making by presenting a concise, visual representation of risk profiles that can guide planning and mitigation strategies.

5.2.2 Analysis and Mapping

5.2.2.1 Flood Risk Mapping Risk Band Matrix

A Risk Band Matrix for flood-prone areas is a tool used to assess and categorize flood risk levels based on two key factors: the likelihood of flooding and the potential impact or consequences of such events. It provides a clear framework for understanding flood risks and helps inform decision-making, planning, and mitigation strategies for communities and urban planners. It can be used as:

- a. **Identifying risk areas:** by mapping flood-prone areas onto the matrix, planners can determine which zones are at higher risk and prioritize mitigation efforts.
- b. **Guiding Policy and Zoning Decisions:** The matrix helps local governments set policies, such as zoning regulations, land-use planning, and building codes, to reduce flood risk, especially in high-risk zones.
- c. **Mitigation Planning:** The matrix aids in determining appropriate flood mitigation measures, such as levees, flood barriers, or wetland restoration, based on the level of risk.
- d. **Emergency Response and Preparedness:** By understanding risk levels, communities can better plan for flood-related disasters, including evacuation routes, shelters, and early warning systems.

Establishing a “Planning matrix” for flood risk involves determining the appropriate number of risk bands to effectively manage and reduce flood damage. Areas with greater flood depth variation, such as large floodplains, may require more risk bands to account for differences in risk across the region. The goal is to create a floodplain with a “Low Risk” or at least a

“Medium Risk” environment to limit flood damage. Local councils are responsible for deciding how to divide the floodplain into risk bands, using tools like a “**Risk Analysis Matrix**” to evaluate different configurations.

Overall, the Risk Band Matrix provides a structured approach to understanding flood risks, supporting effective urban planning, development of mitigation strategies. For example, Low-Risk Areas are flood-prone zones with rare flooding events and low impacts may require minimal mitigation, such as flood monitoring and public awareness campaigns. Same way, high-risk areas are Flood-prone areas with frequent flooding and high impacts (e.g., critical infrastructure or densely populated areas) would need extensive flood control measures and more robust emergency response plans.

5.2.3 Decision making and Implementation

Incorporating hazard mitigation and risk reduction into master plans is a crucial strategy, as it provides an overarching policy framework for other planning tools. Unlike many other planning documents, the master plan serves as a policy guide. When integrating hazards into these plans, key considerations to keep in mind include:

- a. Flood hazard mitigation measures go beyond just infrastructure; they can also involve community-level communication, preparedness planning, and other non-structural approaches;
- b. When feasible, mitigation strategies should aim to replicate natural processes instead of relying on engineered solutions. For example, reconnecting a creek to its floodplain for natural flood control is preferable to channelizing it;
- c. Special attention should be given to the safety of vulnerable communities in the master plan, focusing on both natural hazard risks and other social or environmental stressors;

5.2.3.1 Planning Matrix for Development controls

This matrix helps assess the potential damage from flooding, such as structural damage to typical homes, and guides councils in developing flood management plans. The final configuration of risk bands should be based on a careful balance between flood depth

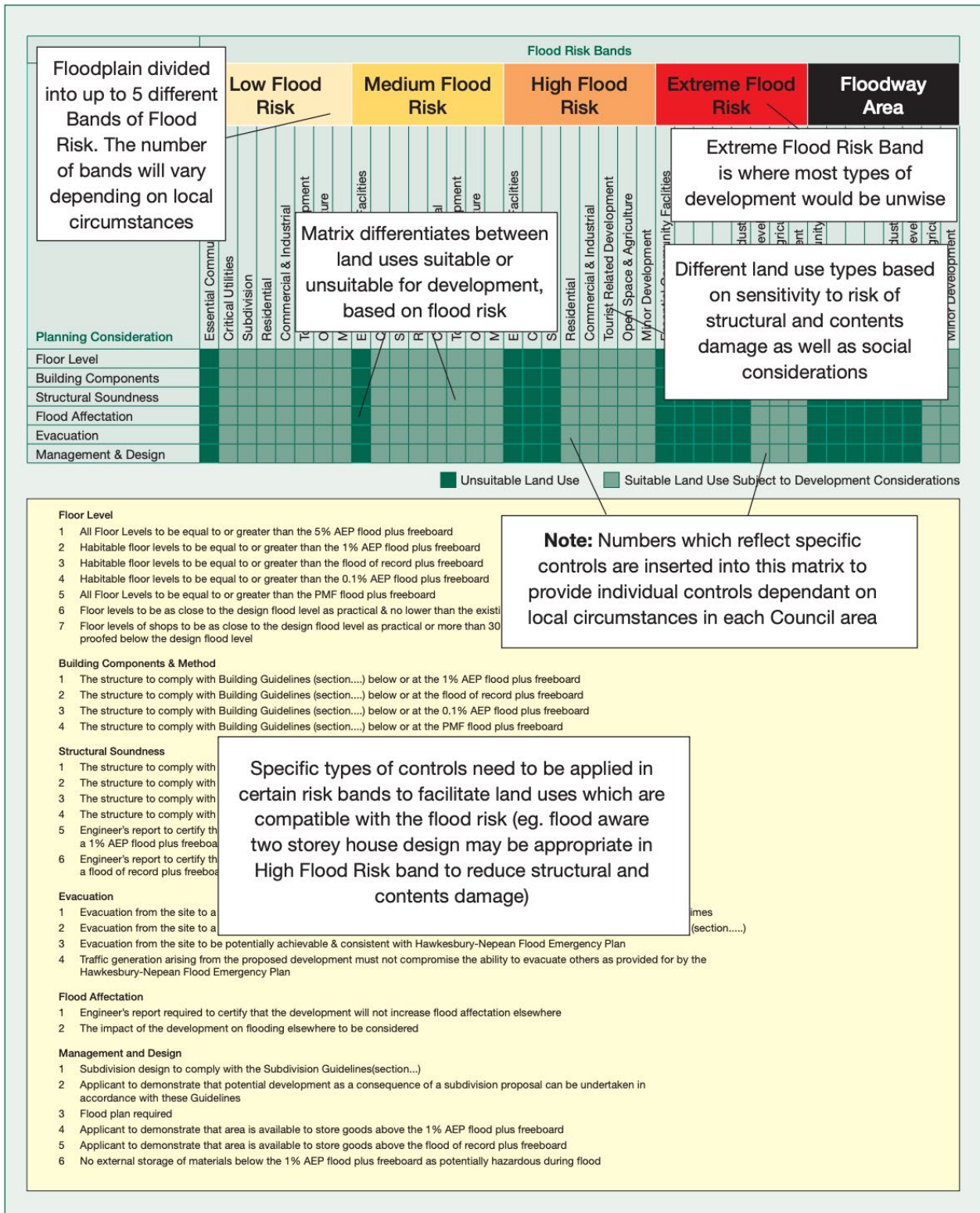


Figure 33: Risk Band Matrix for planning and development controls⁹⁰

Low Flood Risk	Medium Flood Risk	High Flood Risk	Extreme Flood Risk	Floodway
Damage risk low. Modifications to building structures not worthwhile.	Risk can cost effectively be reduced by minor building requirements to achieve a Low level of risk.	Damages beyond the financial capabilities of homeowners. Structural modifications to buildings can cost effectively lower risk to achieve a Medium level of risk	Major damage occurring too frequently for residential development.	Hydraulic hazard and destructive forces too high for safe occupation. Significant erosion risk.
PMF				
	1000-year flood			
		Flood of record		
			1 in 100 AEP	
No controls for most uses	Main areas where flood related development controls could be applied to modify risk by controlling likelihood and /or consequences of flooding			Most development restricted

Figure 34: Graduated development Controls⁹⁶; AEP⁹¹, PMF⁹²

and the associated damage, considering the specific characteristics of the area. The development controls can be decided as per the bands and associated risks.

5.2.3.2 Strategies to tackle Flood Risk

Land use

The matrix can specify planning controls, which can be applied across the floodplain for various land use and flood hazard categories. It also provides an opportunity to investigate options which maximise the use of the floodplain with the aim of achieving development expectations, while at the same time managing development and land use distribution in a manner which minimises vulnerability and ultimately, risks. It does this by avoiding the narrow traditional management approach which prohibited specified developments on lower parts of the floodplain.

i. Overlay zoning

Overlay zoning is a planning tool used in land-use regulation that allows communities to apply additional rules or conditions to specific areas, on top of the existing zoning regulations. A base zoning district (like residential or mixed-use) sets the basic rules for land use and building dimensions. The overlay zone adds extra requirements for areas within a defined boundary, regardless of the underlying zoning.

For example, a residential area zoned for single-family homes (R-1) might also be in a hillside overlay zone. While the R-1 zoning would allow single-family homes, the overlay could require additional steps, like submitting a geo-technical report, before construction can begin.

To implement an overlay zoning district for flood management, communities typically begin by conducting a detailed assessment that identifies flood-related risks and demonstrates how an overlay zone would support broader goals outlined in the comprehensive plan. This process usually involves technical studies, including hydrological analysis and floodplain mapping, to accurately define the geographic extent of flood-prone areas. Based on this information, a zoning ordinance is drafted, outlining specific standards, restrictions, and procedures tailored to flood mitigation within the designated overlay area. As with any zoning amendment, the ordinance must be reviewed and formally adopted by the appropriate local authority. Once established, the overlay district can be modified, expanded, or adjusted through the standard rezoning process to adapt to changing conditions or improved flood risk data.

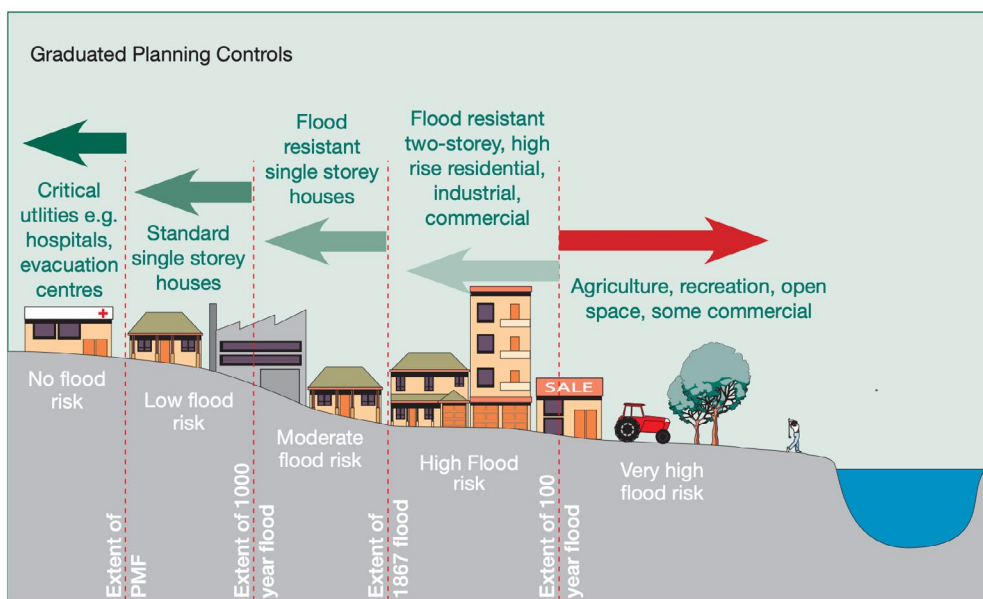


Figure 35: Distribution of land uses on the floodplain to reduce risk⁹³

National Disaster Management Guidelines: Management of floods (NDMA, Government of India, 2008) suggest the following:

- The area likely to be affected by floods up to a 10-year frequency should be kept reserved only for activities of play grounds, gardens, parks etc. Residential or public buildings, or any commercial buildings, industries, and public utilities should be prohibited in this zone.
- In area liable to flooding in a 25-year frequency flood, residential buildings could be permitted with certain stipulation of construction on stilts (columns), minimum plinth levels, prohibition for construction of basements and minimum levels of approach roads, etc. In urban areas there could be double storeyed buildings. Ground floors could be utilised for schools and other non-residential purposes.
- Public and Semi-Public institutions, Government offices, and residential areas should be located outside the 25 year flood or a 10 year rainfall contour, provided that the buildings if constructed between the 10 and 25 year contours should have either high plinth level above 25 year flood mark or constructed on columns or stilts, with ground area left for the unimportant uses;
- Installations and Buildings of critical infrastructure facilities should be located in such a fashion that the area is above the levels corresponding to a 100 year flood or the maximum observed flood levels whichever higher. Similarly they should also be above the levels corresponding to a 50 year rainfall flooding and the likely submersion due to drainage congestion.
- Certain areas on either side of the existing and proposed drains should be declared as green belts where no building or other activity should be allowed. These green belts, at suitable locations, can also be developed as parks and gardens. Unplanned growth needs to be restricted so that the construction of structures obstructing natural drainage or resulting in increased flood hazard is not allowed.
- Infrastructure such as playgrounds and parks can be located in areas vulnerable to frequent floods. Since every city needs some open areas and gardens, by restricting building activity in a vulnerable area, it will be possible to develop parks and play grounds, which would provide a proper environment for the growth of the city.
- Any vital infrastructure should be built on plinth or stilts. Vegetation should be promoted on the flood plain, if possible flood resistant in nature.
- Steep earth banks and slopes on riversides and the sides of gorges should be avoided.
- Build at least 500m away from the sea coast or at an elevation 3m above the High Tide Level.

The figure illustrates the overlay zoning of Chengannur, Kerala. The top-left image depicts the flooded area of Chengannur during the 2018 flood, superimposed with the existing land use. It highlights that a significant portion of the built-up area was affected by flooding. The proposed land use plan (right) categorizes the region based on three major risk levels, ensuring a more resilient and sustainable land use distribution.

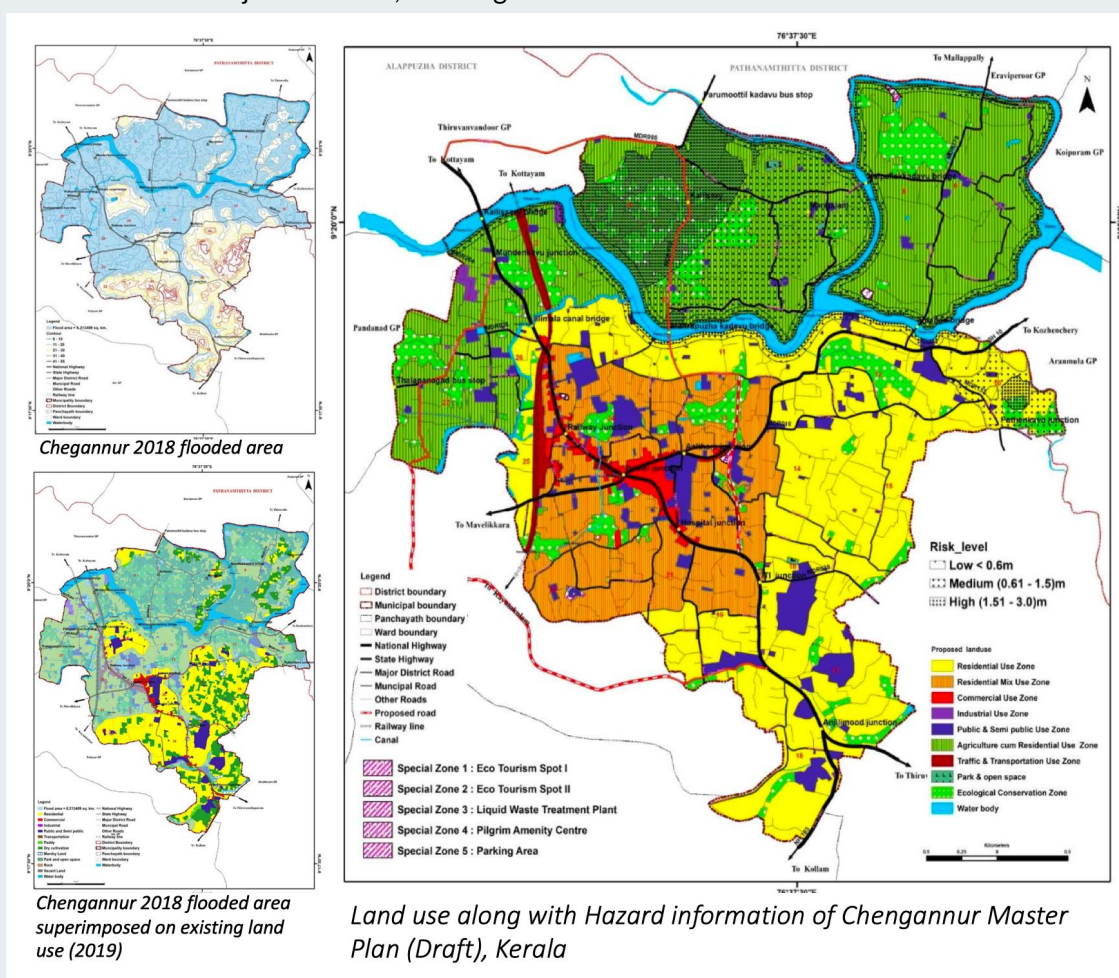


Figure 36: Example of overlay zoning

Source: Guidelines for RIMP⁹⁴

The city authority can adopt a tiered overlay approach to refine flood management further, segmenting the 100-year floodplain into zones based on site-specific risk and development priorities. For example, a Protection Zone may safeguard critical infrastructure through hardened flood defences, while an Accommodation Zone may promote adaptive strategies like elevated construction and setback requirements. In contrast, a Conservation Zone may encourage the retreat of development, favouring natural floodplain functions and open space preservation.

Overlay zoning supplements or supersedes existing regulations within an underlying base zoning district. When drafting an overlay zoning district ordinance, consider whether all overlay zoning districts shall supersede existing zoning regulations, or if certain overlay zones should be treated differently. Some overlay zones (e.g., infill and redevelopment) are drafted to permit exceptions or require a less-restrictive set of standards than otherwise provided in the zoning regulations. Properties within the overlay are often subject to additional standards concerning land uses, building elevation, stream buffers, outdoor storage, building materials, and

permitting procedures.

ii. Cluster Sub-Divisions

Cluster subdivisions are a way to design land developments that help protect open spaces and areas sensitive to environmental damage, including those that are prone to flood hazards. The idea behind clustering is to group buildings together in less sensitive parts of the land, while leaving the more vulnerable areas, such as natural open spaces, river-line, or floodplains, undisturbed. The main advantage for developers is that they can build on smaller lots than usual, in exchange for preserving these important natural areas.

Cluster subdivision layouts can be implemented by identifying suitable areas through flood risk assessments. The Urban Development Authorities/ ULBs can delineate high-risk flood-prone zones in the city master plan and designate areas for clustered development. This approach ensures that environmentally sensitive areas, such as wetlands and floodplains, remain protected while optimising land use for urban expansion. Additionally, local governments can incentivize developers through density bonuses or transferable development rights (TDRs) to encourage the adoption of this flood-resilient planning strategy.

Cluster subdivisions help protect flood-prone and sensitive areas while offering multiple benefits. They support environmental conservation by preserving wetlands and wildlife corridors, reduce infrastructure costs through compact development, and lower long-term maintenance expenses. This approach enhances property values by maintaining open spaces and allows for diverse and affordable housing options.

iii. Conservation easement

Conservation easements can serve as an effective legal tool to protect open spaces and ecologically sensitive areas, particularly in flood-prone regions. By restricting certain types of development, these easements help safeguard wetlands, floodplains, riparian zones, and other natural buffers that play a crucial role in flood mitigation. While they limit land use and development, property owners retain the right to live on, sell, or pass down their land, ensuring both environmental protection and property rights.

It can be established through a collaborative approach involving:

- State and local governments (municipal corporations, urban planning authorities)
- Land trusts and environmental NGOs
- Private landowners and community groups

Unlike broad public land-use regulations, conservation easements are voluntary agreements, making them a flexible and community-driven flood management strategy. Land trusts often have the expertise and resources to manage these easements, but with adequate institutional capacity, state or local governments can also establish their own programs. The steps involves;

a. Identifying High-Risk Areas

- Use GIS mapping and flood hazard zoning to identify areas at risk, such as riverbanks, low-lying urban zones, and coastal floodplains.
- Include these areas in the city/town's Master Plan or Development Plan under special environmental protection zones.

b. Partnering with Land Trusts and NGOs

- Organizations like Wetlands International, WWF India, and local environmental groups can assist in managing easements.
- Collaboration with academic institutions can provide research support for sustainable land use planning.

c. Engaging Landowners and Communities

- Conduct awareness programs to explain the economic and ecological benefits of conservation easements.
- Offer incentives such as tax benefits, grants, or transfer of development rights (TDRs) to encourage participation.

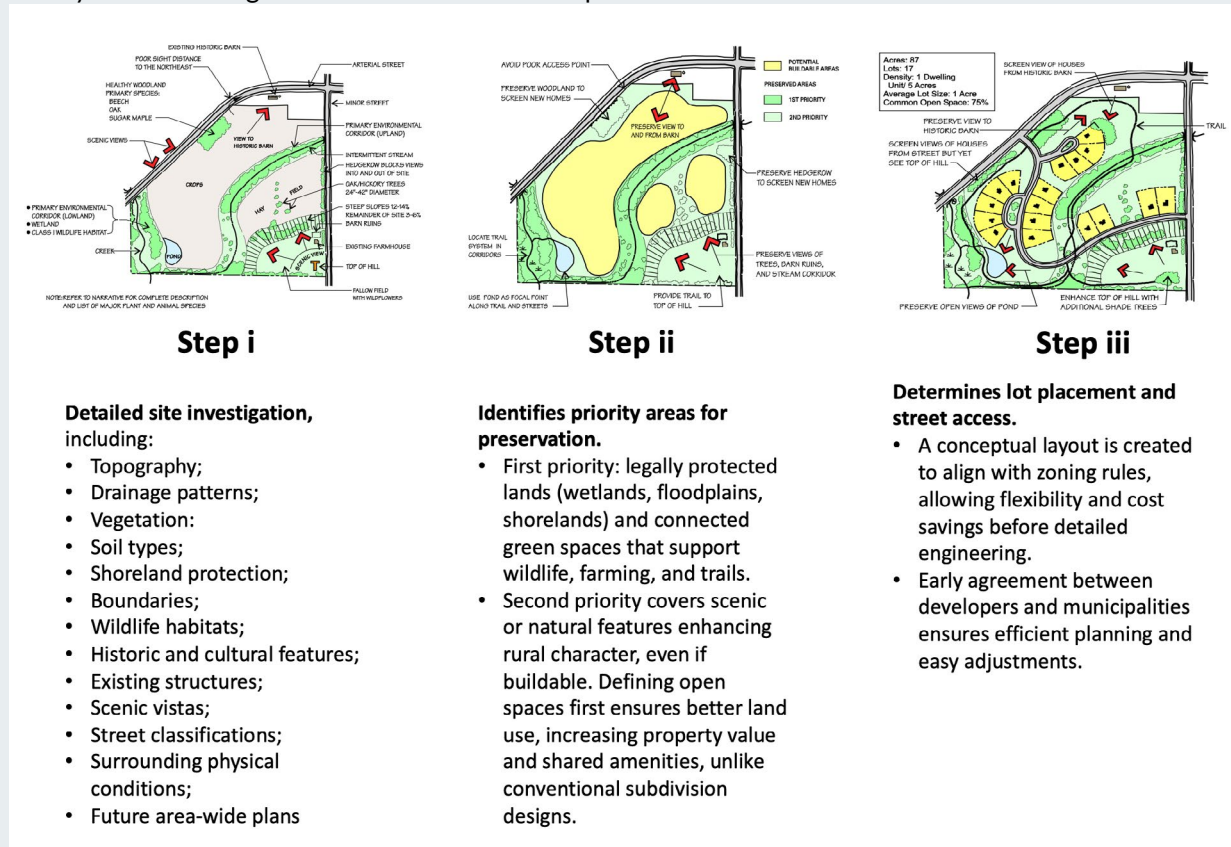
d. Legal Recording of the Easement

- Once an agreement is reached, the easement is legally recorded with the concerned revenue department or urban local body.
- Management and Enforcement Responsibilities

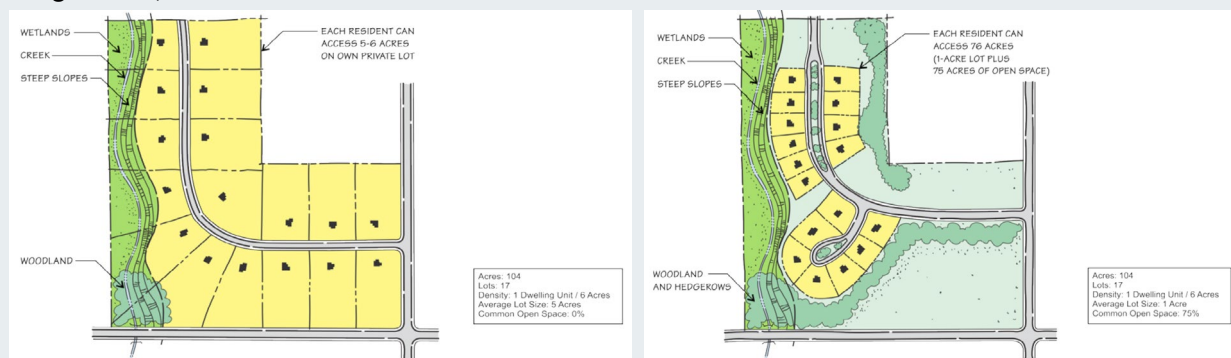
Whether managed by a government authority or a non-profit, the easement holder must:

The development of open space subdivisions should be guided by a structured three-step process that incorporates relevant local regulations—such as zoning requirements, official maps, and land division controls—as well as applicable planning recommendations related to future streets, parks, greenways, and recreational trails.

- Identification and analysis of existing conditions, or site analysis;
- Delineation of preservation areas; and
- Layout of dwelling locations and street and lot pattern.



A well-planned layout will allow streets and homes to fit naturally into the landscape, preserving the site's character—unlike conventional subdivisions, which often impose rigid lot patterns onto the land.(Refer the image below).



Source: SEWRPC⁹⁶

Town of Bayfield Farmland Protection Program

The Town of Bayfield is using conservation easements to help protect its orchards and berry farms from the pressures of housing and tourism development. Protecting remaining productive farms and related rural character are top priorities in the Town's comprehensive plan. The microclimate of the Lake Superior ridge lands and the special soils required for fruit production make these remaining farms especially unique and valuable. The farms and orchards contributes over \$1million to the local economy and are a major tourist magnet. The Town of Bayfield, in partnership with the Bayfield Regional Conservancy, purchases and administers the conservation easements. Suitable properties are selected based on a set of criteria defined by the Town Board of Supervisors. Funding for the program comes from grants (50%), town funds (30%), and donations from foundations and private donors (20%). Additional information is

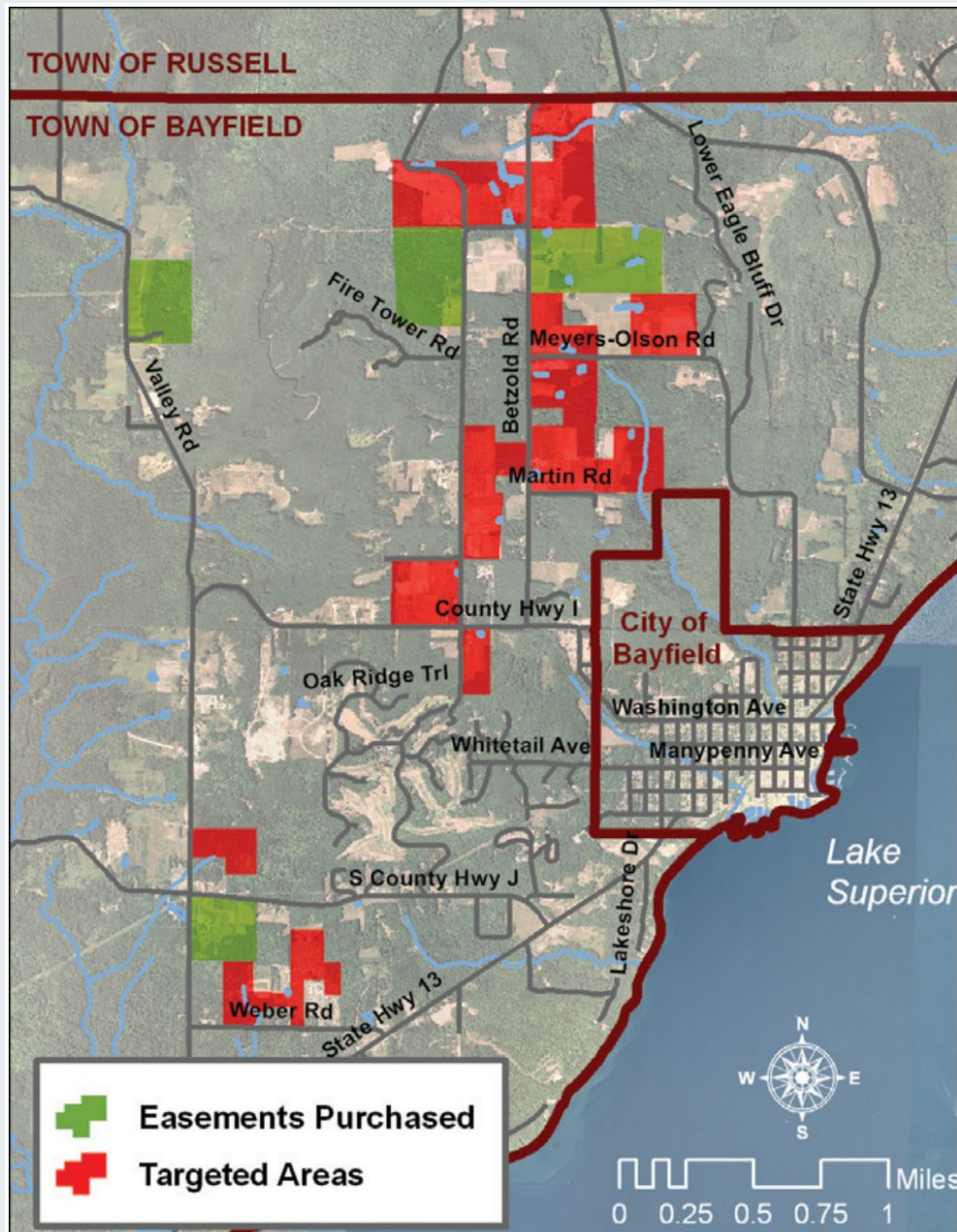


Figure 38: Map of Bayfield program to protect local orchards

Source: <https://www.uwsp.edu/wp-content/uploads/2024/04/ConservationEasement.pdf>

- Establish baseline documentation, mapping the ecological and hydrological characteristics of the land.
- Monitor land use compliance through regular site visits and remote sensing technologies.
- Provide information to new property owners about easement terms.
- Enforce the agreement legally if violations occur.
- Ensure financial sustainability through dedicated funds for enforcement and management.

Some of the benefits of implementing conservation easements include:

- Provides a beneficial way to preserve private lands with intrinsic public value or hazard risk without the need to acquire or further regulate.
- Provides income tax and estate tax benefits for landowners.
- Provides a relatively inexpensive way to meet community goals for open space, hazard mitigation, parks and recreation planning, etc.

By incorporating conservation easements into master plans and regional land-use policies, cities and towns can proactively address flood risks. This method promotes ecological resilience, cost-effective flood mitigation, and sustainable development, making it a viable strategy for climate-adaptive urban planning.

iv. Stream Buffers and setbacks

It is a designated area along a waterway that is kept free from development to protect the natural functions of riparian ecosystems and reduce the risks associated with hazards in these areas. A stream setback is the required minimum distance between a development and a riparian area to protect the surrounding buffer zone. Setback distances typically range from 50 to 100 feet from the water, but can vary depending on the specific riparian area. Generally, a larger setback provides better protection from water-related risks. Both stream buffers and setbacks are used to restrict or prevent certain types of development in these areas.

Stream buffers and setbacks can be implemented and enforced through local ordinance or codes. Generally, local requirements may be adopted either as part of a land use or zoning code, as stand-alone ordinances, or as part of other regulations (such as storm water management regulations). Local governments take many different approaches to implementing stream buffers and setbacks.

Benefits of implementing stream buffers and setbacks include:

- Helps to preserve natural and beneficial functions of the floodplain.

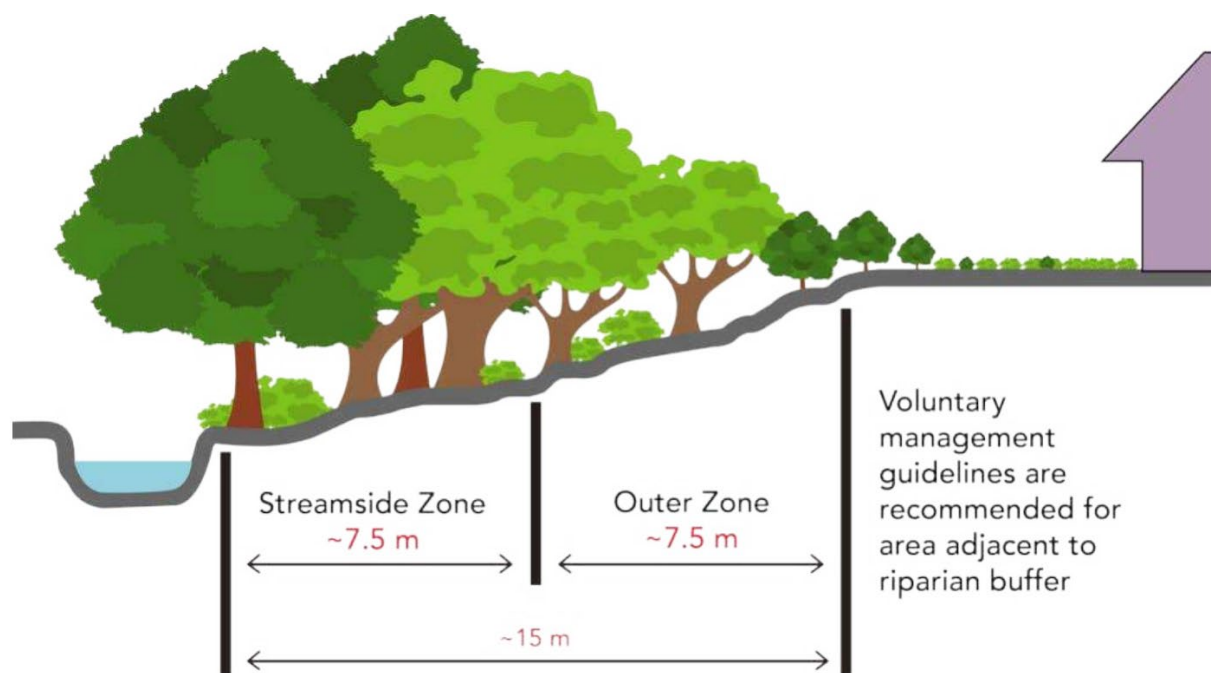


Figure 39: Typical riparian zonation used worldwide⁹⁵

Ministry of Environment, Forests and Climate Change (MOEF & CC) had come out with a draft notification for River Regulation Zones wherein it proposed to prohibit or regulate the developmental activities on riverfronts and floodplains

Prohibited activities zone:

The Prohibited Activities Zone extends from the riverbank to the outer edge of the floodplain and beyond, reaching up to **500 meters from the highest flood level in the past 50 years**. These areas are highly vulnerable to frequent flooding and human interference. If embankments are present, the zone extends from the riverbank to the **outermost embankment**, with an additional **100-meter buffer** beyond it. Furthermore, if the floodplain includes **ecologically sensitive areas, heritage sites, national parks, biosphere reserves, or habitats for endangered species**, the entire area is classified under this zone regardless of other criteria.

Restricted activities zones:

Restricted activities zone includes the floodplain areas which are less frequently affected by the floods and lie farther from the river. It will have limits extended from the outer limits of the prohibited zone and up to **1 KM**.

Regulated activities zone:

The Regulated Activities Zone extends up to **3 km** beyond the restricted zone, where certain activities such as traditional grazing, capture fishing, organic farming, and limited recreational activities are permitted. However, activities like bunding, solid waste dumping, new embankment construction, land reclamation, storage of hazardous materials, and commercial water withdrawal (except for hydro and irrigation projects) are strictly prohibited.

- b. Protects the water course from the impacts of neighbouring and upstream land uses.
- c. Helps reduce flood vulnerability both at the site as well as the surrounding area and downstream.
- d. Promotes habitat preservation of aquatic and adjacent riparian environments.
- e. Helps preserve water quality by limiting proximity of potential pollutants.
- f. Facilitates stream bank stability and reduces erosion potential.

v. Parks and Open Space plan

An Integrated Parks and Open Space Plan serves as a strategic approach to flood management while enhancing urban resilience. By designating parks, wetlands, and green corridors in flood-prone areas, cities can prevent encroachment, regulate land use, improve water absorption, and reduce runoff, ensuring long-term conservation of ecologically sensitive zones. These plans enable local governments to assess current and future land use needs, evaluate feasible flood mitigation options, and

develop a strategic action plan for sustainable urban growth. A comprehensive master plan provides a framework for incorporating flood-resilient parks and recreation facilities, ensuring they function as both public amenities and natural flood buffers. Regular monitoring mechanisms, including GIS-based tracking and community participation, help maintain these spaces effectively.

In addition, acquiring and either demolishing or relocating structures in flood-prone areas is a common strategy for communities aiming to reduce flood risks while aligning these efforts with other goals in the parks and open space plan. Moreover, utilizing parks and undeveloped lands for storm water detention or retention can not only help mitigate flooding but also contribute to water conservation, water quality improvement, biodiversity enhancement, and aesthetic value.

The key components of flood responsive parks and open space plan are;

Mumbai Metropolitan Region (MMR) developed an “Inventorisation of Open Spaces & Water Bodies in Greater Mumbai”. This is the first time ever that such a thorough study of all the Environmental Features has been undertaken in India by physically visiting each feature.

It begins with the creation of a base map that documents site conditions through site visits, categorization of key parameters, and the development of a statistical and qualitative ward-wise summary.

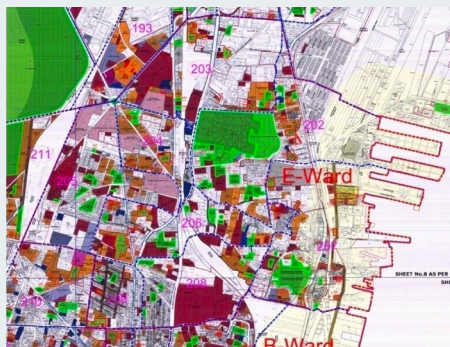


Figure 40: Typical ward map (part) with boundaries of each open space highlighted

In order to analyse the data and determine which sites are critical and require immediate attention, the sites had to be ‘graded’ i.e. assigned some values or ‘marks’. The process of grading of open spaces involved:

- a. Identification of parameters and Sub-parameters for grading purpose.
- b. Evolution of a grading system which in turn involved:
 - Assigning weights to various parameters
 - Assigning scores to various attributes
 - Calculating the total score or value of a site
- c. Application of grading criteria to all open spaces

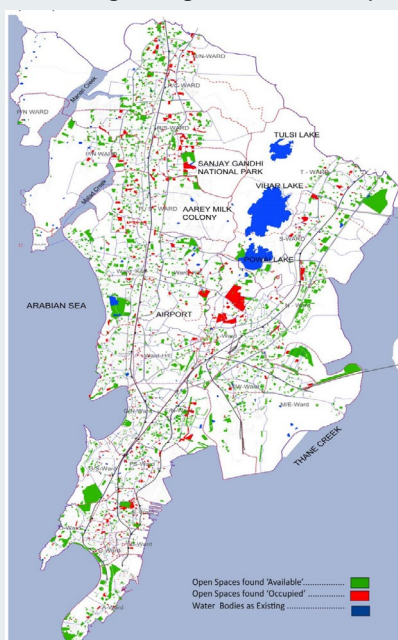


Figure 41: Open spaces and waterbodies in Greater Mumbai

The **grading process** aims to prioritize open spaces based on their need for intervention—**immediate attention, attention, or maintenance**. Each parameter is assigned a weight according to its impact: **high (50%), medium (30%), and low (20%)**. For example, a site’s **occupancy status** (open, semi-occupied, or occupied) is crucial and given high weight, while **predominant users** are less critical and assigned low weight. Parameters within each category hold equal weight. This structured approach ensures **effective planning and resource allocation** for open space management.

Source: <https://www.mmreis.org.in/images/research/Open-Spaces-Water-Bodies.pdf>

- I. Assess Existing Conditions
 - a. Conduct GIS mapping to identify flood-prone areas, wetlands, parks, and open spaces.
 - b. Analyse drainage patterns, soil conditions, ecological significance, and urban expansion trends.
 - c. Evaluate historical flood data to understand risk levels and past impacts.
- II. Define Goals and Objectives
 - a. Establish flood mitigation as a primary goal alongside recreation, conservation, and climate resilience.
 - b. Align the plan with local government policies, master plans, and environmental regulations.
 - c. Incorporate community needs and stakeholder input for sustainable land use.
- III. Identify, Grade, and Designate Open Spaces
 - a. Grade open spaces based on factors such as:
 - High-Risk Flood Zones (areas requiring full conservation, such as floodplains and wetlands).
 - Moderate-Risk Areas (suitable for multi-functional parks with flood mitigation features like bioswales and retention ponds).
 - Low-Risk Open Spaces (urban parks and recreational areas that can incorporate green infrastructure).
 - b. Design multi-functional open spaces that serve as both flood retention areas and public amenities.
 - c. Ensure connectivity between open spaces through greenways, riparian buffers, and permeable public spaces.
- IV. Develop Strategies for Implementation
 - a. Create land-use zoning policies to prevent development in high-risk areas.
 - b. Establish mechanisms for land acquisition, conservation easements, and incentives for private landowners.
 - c. Plan for storm water management infrastructure integrated into open spaces, such as wetlands and retention basins.
- V. Incorporate Monitoring and Management Systems
 - a. Implement GIS-based tracking and periodic field assessments to ensure compliance.

- b. Engage community participation in monitoring and maintaining green spaces.
- c. Develop a long-term funding plan for maintenance, adaptation, and expansion of open spaces.

Resilient Building and Infrastructure

Planning tools usually focus on the property line, but additional strategies like building codes are key to reducing hazard risks. These codes set safety standards to ensure structures in risky areas can withstand hazards. Adopting updated building codes strengthens hazard mitigation. Collaboration between land use planners, building officials, and emergency services is essential to align planning and building regulations for greater community resilience.

i. Building code to withstand flood risk

Building codes play a crucial role in reducing flood risk by ensuring that structures are designed to withstand extreme weather conditions and prevent water damage. In India, guidelines such as the National Building Code (NBC) 2016, the Model Building By-Laws (MBBL) 2016, and the Flood Protection and Risk Reduction Guidelines by the National Disaster Management Authority (NDMA) provide essential standards for flood-resilient construction. These include elevating structures above flood levels, using flood-resistant materials, ensuring proper drainage, and restricting construction in flood-prone zones. Compliance with these regulations helps minimize structural damage, protect lives, and enhance urban resilience against recurring floods. Strict enforcement of these codes, along with effective zoning laws and infrastructure planning, is essential for sustainable urban development in flood-prone areas.

Reducing ground coverage in construction is a vital strategy for flood risk reduction, as it allows better water percolation and minimizes surface runoff. High impervious surface areas, such as concrete pavements and fully covered plots, prevent natural infiltration, leading to waterlogging and urban flooding. Encouraging low-impact development, such as permeable surfaces, green roofs, and open spaces, helps recharge groundwater and improves overall drainage efficiency.

As per BMTPC, For the construction of buildings in the flood prone areas, the following basic requirements

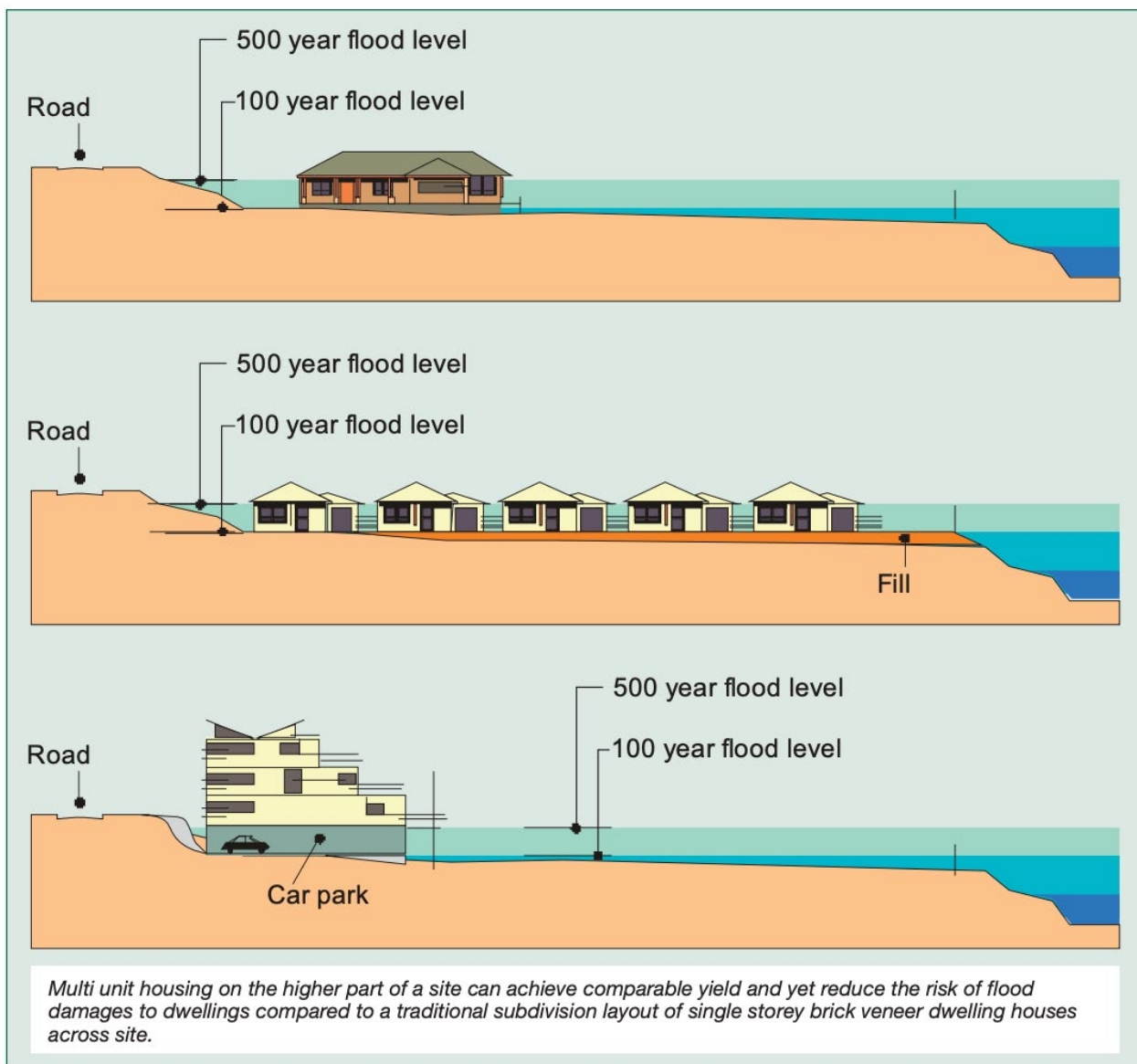


Figure 42: Alternative site layout can reduce risk⁹⁶

Guidelines for Flood Management by NDMA

- Plinth levels of all buildings should be 0.6m above the drainage /flood submersion levels under the mean annual flood;
- In the areas liable to floods, all the buildings should preferably be double and multiple storeys;
- Wherever there are single storey buildings, a stairway should be provided to the roofs so that temporary shelter can be taken there;
- The roof levels of the single storey buildings and the first-floor level in double-storey buildings should be above 100-year flood levels so that the human beings and movable property can be temporarily sheltered there during periods of danger on account of floods;

Layout Approvals: Required specifications and conditions

- Minimum open space set apart in the proposed layout for playground/park/educational institution or for any other public purpose shall be at the rate of 10% of the total site area;
- Construction of drain and channelization of nallahs/stormwater runoff. These may be channelized in such a way as to conserve or harvest the water in the nearest water body or public open space, etc;

Restriction of building activity in the vicinity of certain areas

- No building activity shall be allowed in the bed of water bodies like river, lake, pond or nallah/stormwater drain, etc, and
- No building activity shall be carried out within:
 - 50 m from the boundary of rivers and lakes of surface area for 10 Ha and above,
 - 30 m from the boundary of lakes of surface area for less than 10 Ha, and
 - 12 m from nallahs, canals, etc.

are to be taken care of:

- Preparation of large-scale maps (1:10,000 or 1:15,000) of the area vulnerable to floods with contours at an interval of 0.3 m or 0.5 m;
- Demarcation of areas liable to inundation by rains or floods of different frequencies, say once in two, five, ten or twenty years.
- Marking of likely submersion areas for different flood stages or accumulation of rainwater on these maps.

The National Disaster Management Guidelines for Flood Management recommend the introduction of specific building regulations for flood-prone areas. These guidelines suggest that state governments, SDMAs, and local authorities include certain provisions in building bye-laws for construction in flood-prone regions.

Detailed guideline with respect to General Protection of Habitat/Buildings from Flood Damage, Specific Protection of Houses against Inundation Effects, Recommendation for Construction of Flood Resistant Houses, Protection of Existing Houses from Rain and Flood Damage etc are available in the publication of Building Materials & Technology Promotion Council's Guidelines⁹⁷ for Improving Flood Resistance of Housing 2010 and the National Disaster Management Guidelines- management of floods (NDMA, Government of India, 2008).

Guidelines for the management of Urban Floods prepared by the National Disaster Management Authority - "Management of Urban Flooding" (NDMA, Government of India, 2010) is available at;

https://www.ndma.gov.in/sites/default/files/PDF/Guidelines/management_urban_flooding.pdf.

ii. Critical Infrastructure Protection Plan

Critical Infrastructure Protection Plan aims to enhance the resilience of key infrastructure, ensuring it remains functional during flood events. "Critical infrastructure" generally includes essential buildings (e.g., **hospitals, schools, government offices**) and physical systems such as **roads, storm drains, water pipes, and sewage systems**. These assets must be designed and protected to withstand flooding and remain operational during emergencies. Vulnerable infrastructure can severely hinder a community's ability to recover from floods.

To improve resilience, actions should focus on reducing flood risk to infrastructure. For buildings, this could involve relocation, elevating structures above the base flood elevation (BFE), or applying floodproofing methods (dry or wet). For critical systems, solutions include elevating flood-prone roadways, reinforcing water pipes, expanding culverts, and elevating vital equipment like HVAC systems and generators to prevent flood damage.

Each local authority should assess its critical infrastructure in the context of known flood risks and create a detailed strategy. This strategy should prioritize necessary improvements, outline associated costs, and identify potential funding sources. The plan should be integrated into the local hazard mitigation plan, the comprehensive plan, and the capital improvement program.

iii. Comprehensive Storm water Drainage Masterplan

Storm water drainage systems are frequently overwhelmed during heavy rainfall, often failing to function at their designed capacity due to inadequate maintenance. In many cities and towns, large-scale encroachments on natural drains and river floodplains further reduce the capacity of these systems, leading to flooding. Additionally, improper disposal of solid waste—such as domestic, commercial, and industrial waste, as well as construction debris—clogs drains and exacerbates the problem. Improved operations and maintenance of drainage systems are crucial to addressing these issues.

A well-planned Storm water Drainage (SWD)

system is essential for reducing flood risks in urban areas, particularly in vulnerable hotspots prone to waterlogging. A city-wide SWD network ensures efficient water flow, preventing excessive accumulation during heavy rainfall. Canal widening and deepening can help accommodate runoff based on the return period of rainfall, minimizing overflow and ensuring better flood control.

Additionally, solid waste and wastewater management play a critical role in maintaining the efficiency of the drainage network. Unregulated waste disposal often clogs drainage systems, reducing their capacity to handle storm water. Properly integrating wastewater treatment with SWD infrastructure enhances the system's performance during floods, preventing

Delhi faces annual flooding and waterlogging even during moderate monsoons due to blockages in drainage systems, inadequate storm water infrastructure, increased impervious surfaces, encroachments, and waste disposal in drains. Despite having three major drainage basins (Najafgarh, Barapullah, and Trans-Yamuna), reduced water-carrying capacity has worsened the situation.

To address this, the city government developed a Drainage Master Plan with IIT Delhi, conducting scientific analysis, flood modelling, and GIS-based assessments to identify gaps in the system. The findings helped authorities take timely action and implement Standard Operating Procedures (SOPs) for flood mitigation

Key recommendations implemented:

- Regular desilting of storm water drains and tackling encroachments, sanitation, and waste management.
- Correcting faulty drainage infrastructure and introducing low-cost flood mitigation measures like water body rejuvenation and rainwater harvesting.
- Strict enforcement of these measures with penalties to ensure an efficient stormwater management system.



Figure 43: Yamuna River basin with surrounding water bodies, parks & storm water drains

contamination and ensuring uninterrupted water flow.

A Comprehensive SWD system not only mitigates flooding but also improves urban resilience, public health, and environmental sustainability, making it a vital component of flood risk management in any city.

iv. Integrated green and blue infrastructure

Integrated green and blue infrastructure is a sustainable approach that combines natural landscapes (green infrastructure) such as parks, wetlands, and vegetated areas with water systems (blue infrastructure) like rivers, lakes, and drainage

networks to enhance flood resilience. By preserving and restoring these ecosystems, cities can improve water absorption, reduce surface runoff, and prevent waterlogging. Features like permeable surfaces, urban forests, bios wales, and rain gardens help in storm water management, while well-maintained canals, reservoirs, and retention ponds regulate excess water during heavy rainfall. Implementing this approach not only reduces flood risk but also enhances biodiversity, groundwater recharge, and urban liveability.

Supporting Incentives

Incentives are powerful tools for fostering positive relationships with the development community,

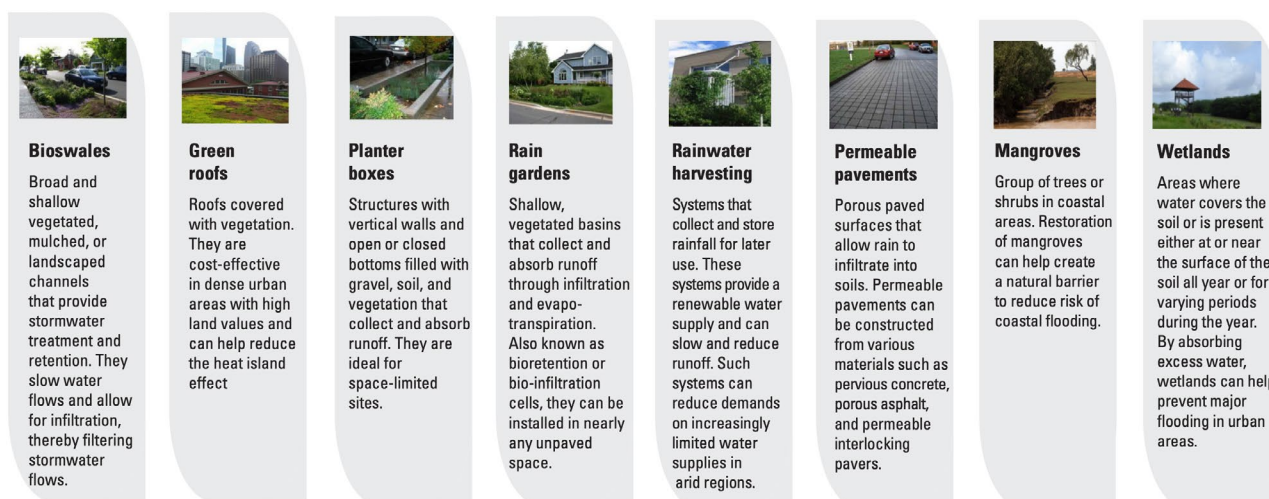


Figure 44: Examples of green infrastructure solutions⁹⁸

The **Sponge Park development in Chennai** is a nature-based solution to **enhance flood resilience** by absorbing, retaining, and gradually releasing rainwater. Designed to tackle **urban flooding**, these parks feature **permeable surfaces**, **wetlands**, and bios wales, reducing runoff and recharging groundwater. Inspired by **blue-green infrastructure**, they promote **sustainable water management** while providing **recreational spaces**, helping Chennai become more **climate-adaptive and flood-resilient**.

Sponge cities take this concept further, designing urban environments that “soak up” rainwater through green spaces and innovative water management systems. These approaches not only reduce the risk of flooding but also improve water quality, enhance biodiversity, and provide recreational spaces for communities. By promoting better water retention, GBI and sponge cities help cities adapt to climate change, improve resilience, and manage flood risks more effectively than traditional methods.

Sponge city require authorities and communities to realize four principles - **PROTECT, DELAY, STORE, and RELEASE**. While these principles complement each other in many ways, all four principles are mandatory to help close the water cycle in an urbanized context.

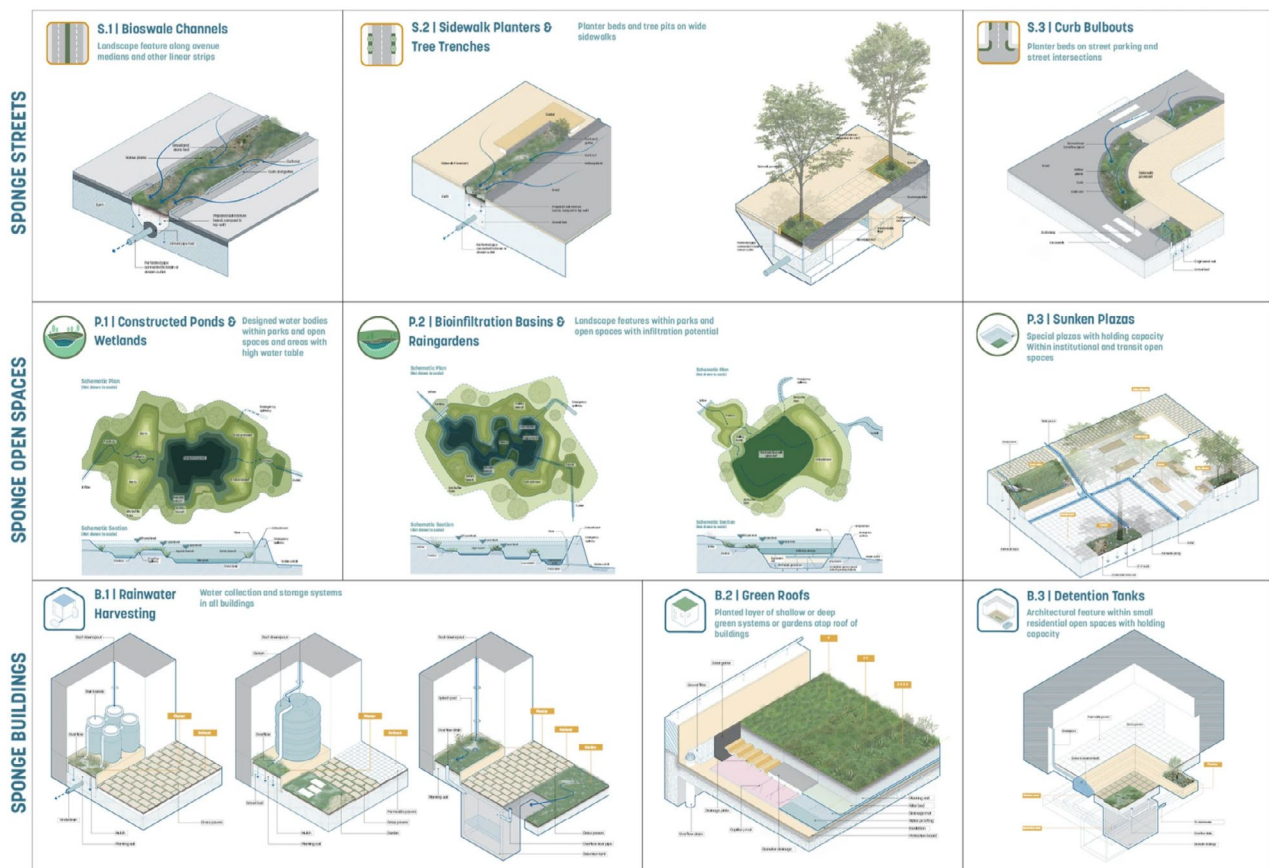


Figure 45: Sponge Responsive Infrastructure Toolkit

Source: *Sponge Collaboratives*⁹⁹

directing growth to preferred areas, and encouraging alignment with community goals without adding extra regulation. These incentives can take the form of financial savings, increased development density, eased regulations, faster review processes, or exemptions from fees or certain requirements. Such as;

- An incentive of 10% rebate in Property Tax can be given by the local authority for owners or their successors-in interest who undertake both recycling of waste water and rainwater harvesting structures.
- Introduce a targeted “Flood fee” on urban infrastructure/development projects to fund flood risk reduction initiatives.

Other than these incentives, the traditional tools also support the land management strategies and ensure their successful implementation. Among the most commonly employed mechanisms are;

- a. Density bonus;
- b. Development Agreement ;
- c. Transferable development rights;

The details of how these tools are implemented and the benefits they provide in managing flood risk are outlined below, highlighting their effectiveness in promoting resilient urban development. These strategies help ensure that growth is managed in a way that reduces flood vulnerabilities, enhances environmental sustainability, and supports social resilience in flood-prone areas.

Table 3: Supporting incentives

Tools	What	How	Advantages of the tool
Density Bonus	It is a zoning incentive that allows developers to build more units or greater floor area on a site than typically permitted under existing zoning regulations. In exchange for this increased density, developers are often required to provide additional benefits, such as preserving open space, improving building design, or including community amenities like affordable housing or green infrastructure. The amount of extra density granted is usually proportional to the benefit provided, with the goal of encouraging development that aligns with community objectives. Density bonuses may also come with design standards to ensure that the added density does not negatively impact the surrounding area, ensuring that the development meets high-quality standards and is well-integrated into the community.	Implementing a density bonus requires a clear process to ensure that both the developer and the community fulfil their commitments. If a density bonus is granted for conservation or other benefits, the local government should enforce protections, such as requiring a permanent conservation easement. Key steps to implement a density bonus include: • Define the program's purpose: Align the bonus with the community's goals and comprehensive plan. Determine where density bonuses apply—whether across all zoning districts, specific areas, or on a case-by-case basis; • Develop program details: Specify how much bonus density can be granted, whether it's automatic or requires a public hearing, and outline the conditions or agreements developers must meet, such as land conservation or design standards;	• Increased opportunity for developers to boost their bottom line. By purchasing development rights, a developer can increase the number of units and realize a higher profit; • Increased density where the community wants it. Densifying receiving areas can result in a more diverse housing stock, can help boost surrounding commercial areas, and could potentially result in development of affordable housing units not otherwise feasible without the added density bonus; • Density bonuses provide a direct incentive to a developer without requiring complex negotiations often associated with Transfer of Development Rights (TDRs); • Density bonuses can be calibrated to be either by-right or discretionary, depending on community values and political climate; • Density bonuses provide a community benefit without requiring public funding;
Development Agreement	It is a legally binding contract between a property owner or developer and a local government, outlining specific terms and conditions that go beyond standard zoning regulations. These agreements can cover various aspects of the development process, such as project phasing, infrastructure responsibilities, or financial arrangements like tax-sharing. For hazard mitigation, development agreements can require developers to implement additional measures, such as specific site development standards, conservation practices, or long-term maintenance plans, to reduce risk from hazards. In some cases, these agreements can also serve as incentives, offering benefits like reduced fees, expedited approvals, or density bonuses in exchange for developers agreeing to incorporate hazard mitigation strategies, such as defensible space in fire-prone areas.	To implement a development agreement, the developer and local government collaborate with legal counsel to create a binding contract. The planning staff should ensure the agreement aligns with the community's goals and comprehensive plan, clearly defining its purpose and the benefits to both the developer and the community. The agreement should establish consistent requirements for similar developments, such as incentivizing environmental practices or addressing hazard risks like wild-fire. Public input and stakeholder feedback are important to ensure community support. Additionally, the agreement should outline long-term maintenance responsibilities, monitoring procedures, and how the terms will be amended if necessary, throughout the development lifecycle.	• Creation of a separate contract from the zoning code and other ordinances allows all parties to negotiate any aspects of the development. However, this can be just as much of a challenge as a benefit; • Ability to tailor specific mitigation actions and tie them to conditions of approval, thereby securing the commitment; • The agreement can prescribe periodic reviews for compliance. This is especially helpful for site development standards such as landscaping or parking; • Allows developer to obtain "vested rights" protected from any changes to existing zoning or land use laws during the term of the agreement;

Tools	What	How	Advantages of the tool
Transferable Development Rights (TDR)	TDR program allows developers to increase density in designated growth areas ("receiving areas") by purchasing development rights from areas the community wants to preserve ("sending areas"). This helps protect sensitive or hazard-prone areas, such as floodplains, from future development. Developers in receiving areas can gain additional building potential, while landowners in sending areas receive financial compensation for selling their rights.	Adopting a TDR program involves designating sending and receiving areas, as well as establishing values and allocation rates for development rights. Developers need to see a clear profit from purchasing additional rights, while landowners must feel fairly compensated for limiting their development potential. To implement a TDR program, communities should: • Define the program's purpose: Align the TDR program with community goals and hazard risk reduction priorities. • Identify sending and receiving areas: Determine where TDRs are allowed and under what conditions, specifying the areas for preservation and development. • Set valuation and costs: Establish the value of development rights, either through research or consulting with experts and landowners. • Create administration procedures: Decide whether to use an existing financial institution or set up an internal system to manage transactions and development credits. • Outline program details: Clarify the level of incentives, whether they require public hearings, and any additional conditions. • Adopt the ordinance: Draft and pass an ordinance that formally establishes the program, ensuring it aligns with existing land use regulations.	• Increased opportunity for developers to boost their bottom line. By purchasing development rights, a developer can increase the number of units and realize a higher profit; • Increased density where the community wants it. Densifying receiving areas can result in a more diverse housing stock, can help boost surrounding commercial areas, and could potentially result in development of affordable housing units not otherwise feasible without the added density bonus;

5.3 Urban Heat

The relevance of an Urban Heat Risk informed Master Plan is significant for Indian cities facing rapid climate change and urbanization. These plans are crucial for understanding and addressing the increasing risks associated with urban heat, including heat waves and the Urban Heat Island (UHI) effects.

The process typically unfolds in three key steps: **data integration, Analysis and mapping, decision making and implementation**. Effective data integration employs tools like Geographic Information Systems (GIS) to compile and visualise spatial and

socioeconomic data, allowing planners to identify heat-prone areas and assess the effectiveness of proposed interventions.¹⁰⁰ Through advanced analysis techniques, including remote sensing, planners can evaluate heat distribution and devise evidence-based strategies tailored to local contexts, ensuring that interventions are both effective and equitable ¹⁰¹.

Notably, the implementation of these plans faces various challenges, including the incorporation of informal settlements, balancing environmental sustainability with urban development, and ensuring

effective stakeholder engagement. Issues such as a lack of statutory backing and limited resources often hinder the realisation of comprehensive master plans, complicating the decision-making process^{102,103}. Moreover, fostering community involvement is vital; when residents are actively engaged in planning discussions, the resultant strategies are more likely to reflect local needs and gain public support^{104,105}.

Prominent examples of urban heat-informed initiatives, such as Singapore's Garden City vision and Melbourne's Urban Forest Strategy, illustrate the successful application of these frameworks in enhancing urban resilience against heat-related challenges^{106,107}. As cities continue to grapple with the consequences of climate change, the relevance of urban heat-informed master plans in fostering sustainable, liveable environments is more crucial than ever.

The development of heat-informed master plans follows three key stages:

1. **Data Integration:** Employs Geographic Information Systems (GIS) to compile and visualize spatial and socioeconomic data, identifying heat-prone areas and assessing intervention effectiveness.

2. **Analysis and Mapping:** Utilizes remote sensing and other advanced techniques to evaluate heat distribution and develop evidence-based, context-specific strategies.
3. **Decision Making and Implementation:** Translates findings into actionable policies, balancing environmental sustainability with urban development needs.

Several obstacles can hinder effective implementation:

- Incorporation of informal settlements in to formal planning
- Balancing environmental sustainability with development pressures
- Securing effective stakeholder engagement
- Limited statutory backing and resources

Community involvement is crucial—when residents actively participate in planning discussions, strategies better reflect local needs and gain public support.

5.3.1 Data Integration

Data integration forms the foundation of urban heat-informed master plans, particularly for understanding and addressing the urban heat island (UHI) effect. It involves combining diverse datasets from multiple

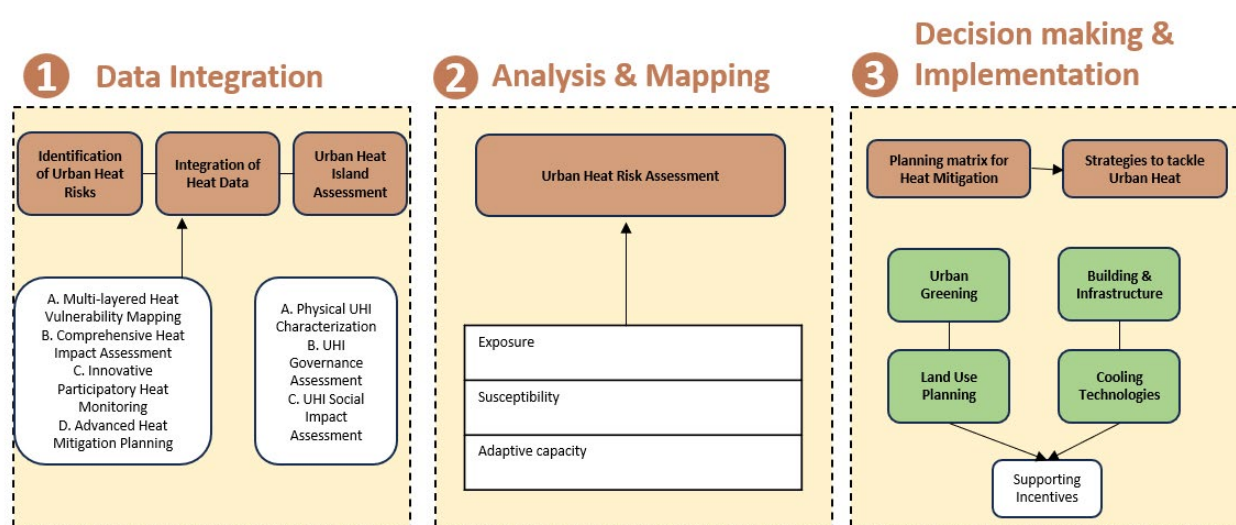


Figure 46: Milestones for heat wave informed Masterplan

Data compilation: NIUA

sources—satellite imagery, ground-based weather stations, and community inputs—to create a comprehensive view of urban climate dynamics.

Techniques such as data cleaning, transformation, and normalization are critical to ensure that the integrated data is accurate and consistent, allowing for effective analysis and visualization^{108,109}. Cities typically have preliminary data available that can be leveraged for master planning.

5.3.1.1 Identification of Urban Heat Risks

Identifying urban heat risks is crucial for effective planning and resilience-building in cities. Extreme heat, exacerbated by urban heat islands (UHIs), poses significant health and safety threats to communities, particularly vulnerable populations.^{110,111}

Urban heat islands are areas within urban environments that experience higher temperatures due to human activities and impervious surfaces. A comprehensive risk assessment should involve analysing both chronic and acute heat risks, which can inform policymakers about the most affected neighbourhoods and populations.^{112,113}

Data-driven approaches highlight disparities in heat exposure across different demographic groups and areas, ensuring resources are directed toward those in greatest need. One significant challenge is integrating informal settlements and slums into formal master

plans, as these areas often lack adequate housing, basic services, and infrastructure.

Institutional Framework

- State Disaster Management Authority (SDMA) and District Disaster Management Authorities are responsible for providing technical support and guidance to local governments on disaster management (DM Act, Section 22(2)(k))
- State Disaster Management Plans must detail regional vulnerability to various disasters and include prevention and mitigation strategies (DM Act, Section 23(4)(a) and (b))
- District Disaster Management Plans must identify vulnerable areas and outline measures for disaster prevention and mitigation (DM Act, Section 31(3))

The Indian government has established several policy frameworks addressing urban heat management:

- India Cooling Action Plan (2019)
- Energy Conservation Building Codes
- National Mission for Sustainable Habitat 2.0
- Addendums to Urban and Regional Development Plan Formulation and Implementation Guidelines (2014)
- Model Building Bye-Laws (2016)

Despite these initiatives, urban heat management lacks comprehensive implementation.

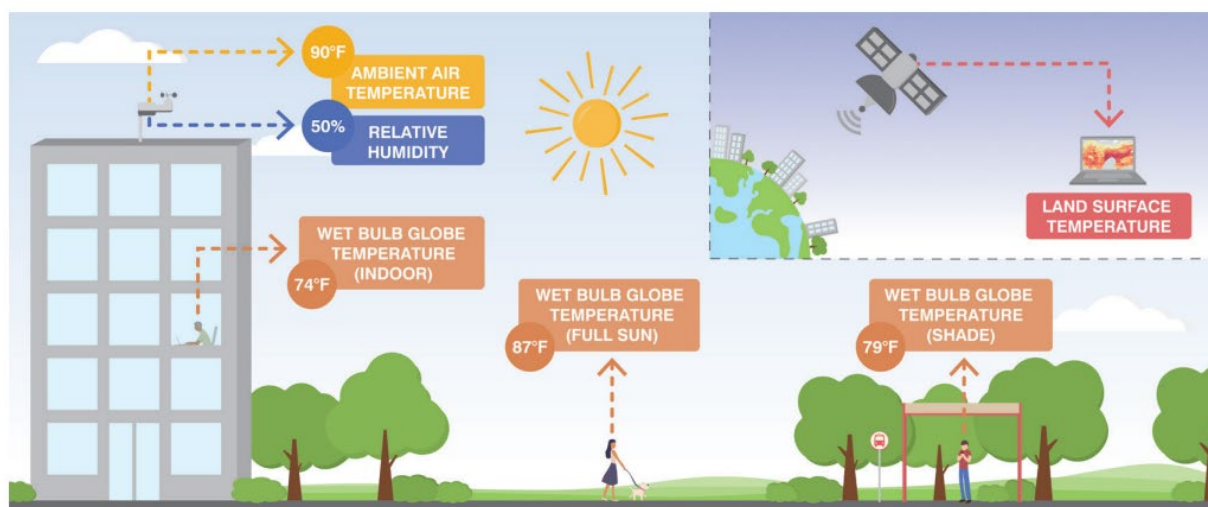


Figure 47: A multitude of measures exist for heat, including remote sensing of land surface temperatures, ambient air temperatures, and wet bulb globe temperature readings

5.3.1.2 Integration of Heat Data

Integrating heat data from multiple sources is essential for developing effective heat master plans. A coordinated effort that incorporates meteorological data, land-use information, and demographic statistics allows cities to understand the interactions between urban design, climate impacts, and community vulnerabilities

A. Multi-layered Heat Vulnerability Mapping

Urban heat vulnerability requires a sophisticated mapping approach beyond simple temperature data:

1. **Thermal Imagery Analysis:** High-resolution surface temperature maps from satellites (Landsat, MODIS, Sentinel) to identify persistent hot spots across seasons and years.
2. **Vertical Heat Profiling:** Three-dimensional heat mapping accounting for vertical distribution of heat within urban canyons using temperature sensors at various heights.
3. **Diurnal Heat Patterns:** Mapping temperature variations throughout the 24-hour cycle to identify areas with limited night-time cooling, which present heightened health risks.
4. **Heat Intensification Factors:** Overlay maps

identifying factors that intensify heat effects:

- Building material thermal properties
- Albedo (surface reflectivity) distribution
- Anthropogenic heat sources (industrial facilities, transportation corridors)
- Urban morphology and wind corridor obstruction

When existing heat maps are unavailable, a multi-scalar approach is recommended:

- Metropolitan-scale analysis (1:25000)
- Neighbourhood assessment (1:10000)
- Micro-level analysis (1:2000) for critical hot spots

B. Comprehensive Heat Impact Assessment

Moving beyond traditional temperature records (Maximum, Minimum, Average), a holistic assessment should incorporate:

1. **Cascading Impact Analysis:** Documenting how heat events trigger secondary crises:
 - Power grid failures during peak cooling demand
 - Water supply disruptions
 - Public transportation system breakdowns

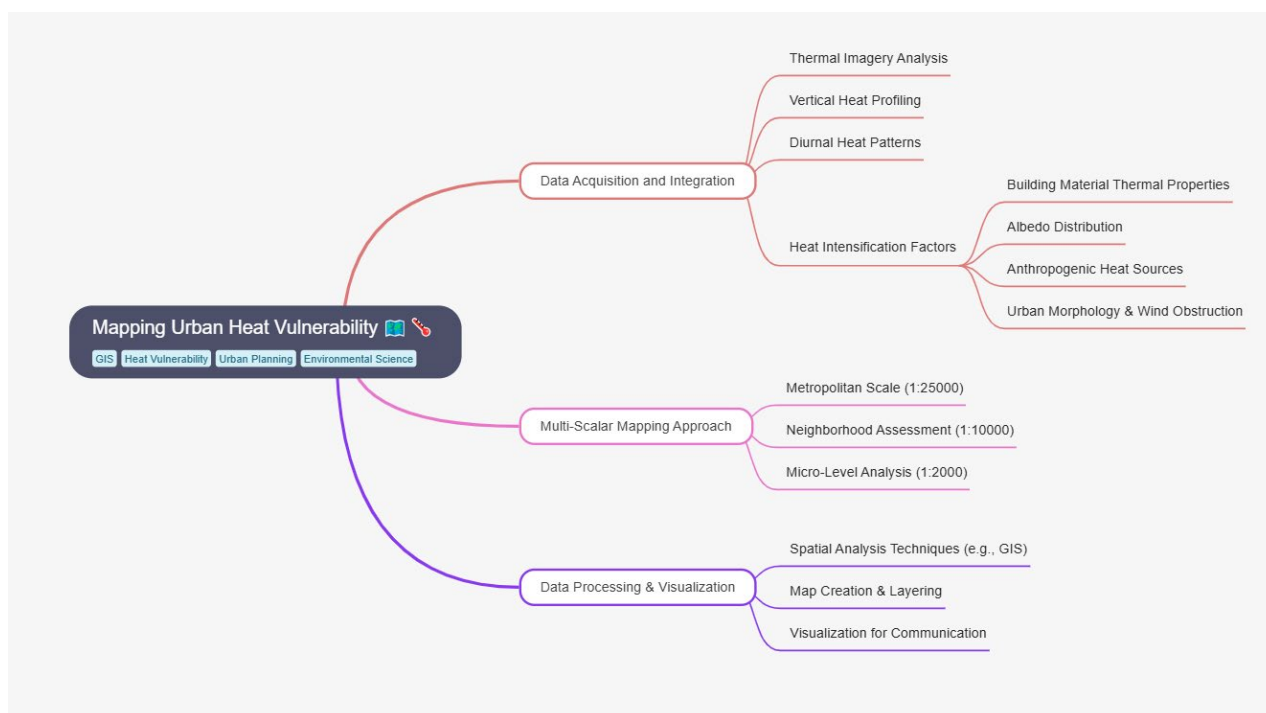


Figure 48: Mapping Urban Heat Vulnerability

Data compilation: NIUA

- Reduced labour productivity and economic losses
- 2. **Infrastructure Vulnerability Assessment:** Evaluating heat impacts on:
 - Transportation infrastructure (road surface deformation, rail buckling)
 - Energy distribution systems (transformer overheating, transmission efficiency loss)
 - Water supply systems (accelerated evaporation, quality degradation)
 - Communication networks (equipment overheating)
- 3. **Socio-economic Heat Stratification:** Analysing how heat impacts vary across social strata:
 - Housing quality disparities in heat retention
 - Cooling resource availability and energy poverty
 - Access to cooling centers and public cool spaces
 - Occupational heat exposure differences
- 4. **Heat-Morbidity Correlation Analysis:** Working with healthcare providers to establish localized temperature thresholds for significant health impacts, which vary based on acclimatization and cultural practices.

C. Innovative Participatory Heat Monitoring

Developing inclusive community engagement through:

1. **Citizen Science Temperature Networks:** Distributing low-cost temperature sensors to community members to create high-density urban temperature monitoring networks with user-friendly data collection platforms.
2. **Thermal Comfort Perception:** Collecting subjective thermal comfort data through mobile applications where residents report perceived comfort levels throughout the city.
3. **Cultural Heat Adaptation Documentation:** Recording traditional knowledge and cultural practices for heat management developed over generations.
4. **Vulnerable Population Ambassadors:** Establishing heat monitoring committees with representatives from populations most at risk:
 - Elderly resident groups
 - Childcare facilities
 - Communities with limited English proficiency
 - Homeless service providers
 - Chronic illness support networks

5. **Cross-sectoral Heat Task Force:** Creating a dedicated team with representatives from:
 - Urban planning departments
 - Public health agencies
 - Emergency management
 - Energy utilities
 - Transportation authorities
 - Parks and recreation
 - Housing agencies
 - Business associations
 - Academic institutions

D. Advanced Heat Mitigation Planning

Moving beyond mapping to integrate proactive intervention strategies:

1. **Heat-Resilient Urban Design Typologies:** Developing location-specific design interventions matched to each urban morphology and heat profile:
 - High-density commercial corridors
 - Multi-family residential blocks
 - Industrial zones
 - Transportation hubs
 - Historical districts with preservation requirements
2. **Cool Infrastructure Prioritisation Matrix:** Creating a decision-making framework for implementing cooling interventions based on:
 - Heat exposure severity
 - Population vulnerability
 - Implementation feasibility
 - Cost-benefit analysis
 - Co-benefits potential (air quality improvement, storm water management)
3. **Adaptive Governance Mechanisms:** Establishing flexible policy frameworks that respond to changing heat conditions:
 - Dynamic building codes that evolve with climate projections
 - Heat-responsive zoning regulations
 - Seasonal public space adaptations
 - Progressive cooling incentive programs
4. **Heat Early Warning System Integration:** Connecting hazard mapping directly to

communication protocols for vulnerable populations, ensuring those in highest-risk areas receive targeted alerts and resources.

5.3.1.3 Urban Heat Island Assessment

Urban heat island assessment evaluates the intensity and extent of UHIs within urban areas using satellite imagery and ground-level temperature measurements to map heat distribution across cities.¹¹⁷

An effective UHI assessment:

- Defines the intensity, extent, and patterns of urban heat islands
- Identifies factors contributing to temperature differences
- Helps cities prioritise cooling strategies based on heat intensity, population exposure, intervention feasibility, and available resources

UHI assessments should examine multiple scales—from street canyons to metropolitan regions—and can focus on surface temperature patterns,

air temperature variations, or night-time heat retention. These assessments must account for urban morphology, surface materials, vegetation coverage, and anthropogenic heat sources. Due to ongoing urban development and seasonal variations, UHI assessments require regular updates to capture changing conditions.

Three-Pillar Approach to UHI Assessment

A. Physical UHI Characterisation

Focuses on measuring and mapping temperature differences and identifying physical factors that create and intensify urban heat islands.

Primary Level:

- Create baseline thermal maps showing surface temperature differences between urban and rural areas
- Identify major hot spots and cool islands
- Map basic land cover types (built-up areas, vegetation, water bodies)

Secondary Level:

- Conduct seasonal UHI assessments

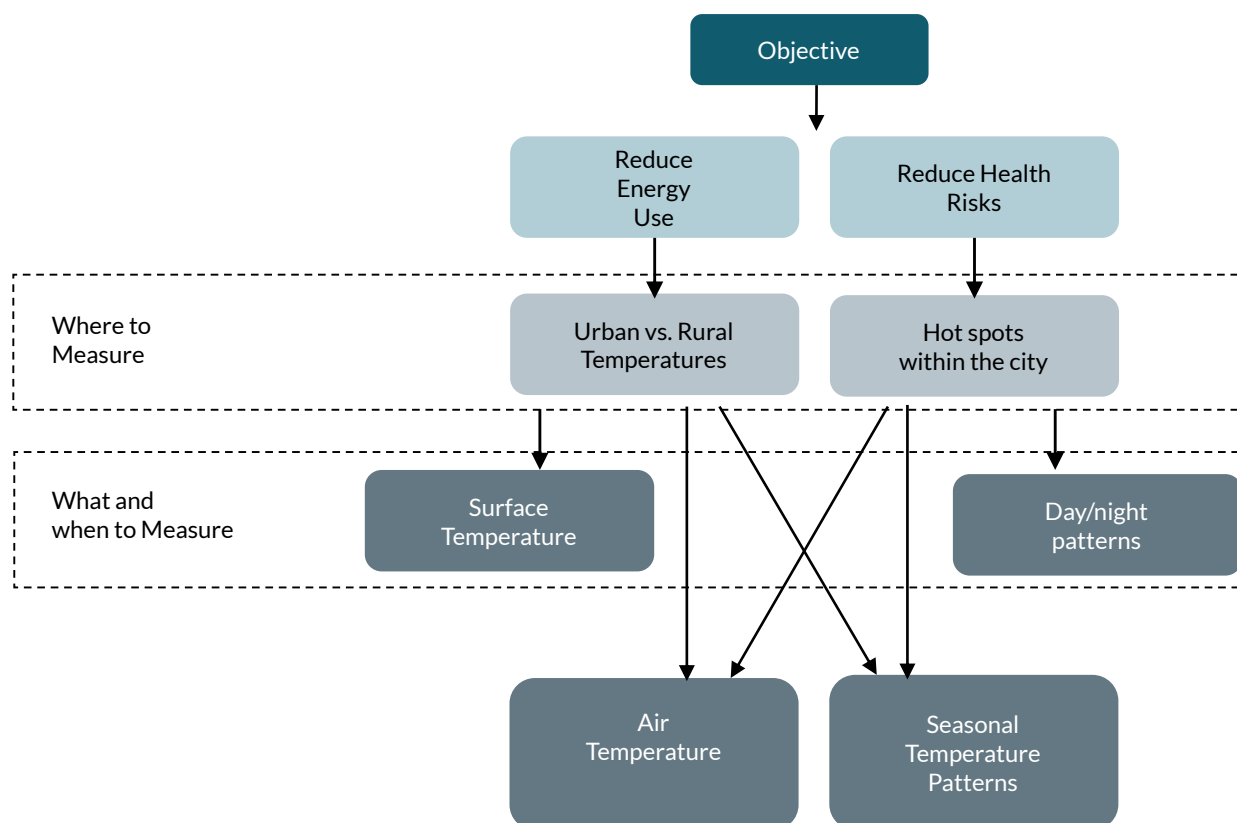


Figure 49: A simplified decision tree for selecting an approach to assessing a city's heat island.¹¹⁸

- Deploy temperature sensors at strategic locations
- Analyse urban form characteristics (building density, street orientation, height-to-width ratios, sky view factors)

Tertiary Level:

- Develop detailed 3D microclimate models
- Measure and map both daytime and night-time heat islands
- Analyse surface material properties (albedo, emissivity, thermal mass)

B. UHI Governance Assessment

Examines institutional capacity, policies, and strategies for managing and mitigating urban heat islands.

Primary Level:

- Identify responsible agencies and departments
- Map existing policies affecting urban temperatures

Secondary Level:

- Evaluate effectiveness of current UHI mitigation initiatives
- Assess technical capabilities and knowledge gaps
- Identify conflicts or synergies between departmental goals

Tertiary Level:

- Conduct comprehensive policy gap analysis
- Develop cross-departmental coordination mechanisms
- Create financial models for scaling up successful

pilot projects

C. UHI Social Impact Assessment

Focuses on how urban heat islands affect different populations and identifies vulnerable groups.

Primary Level:

- Map demographic characteristics overlaid with UHI intensity
- Assess access to cooling resources

Secondary Level:

- Analyse heat-related health outcomes by neighbourhood
- Evaluate energy burden and cooling costs across socioeconomic groups
- Document community perceptions of urban heat

Tertiary Level:

- Conduct detailed thermal comfort assessments in public spaces
- Develop neighbourhood-specific heat vulnerability indices
- Analyse how UHI effects may change under future scenarios

Implementation Approach

UHI assessment should be conducted at multiple spatial scales and integrated into GIS platforms. This approach supports the development of targeted mitigation strategies:

1. Urban Design Guidelines for heat-responsive

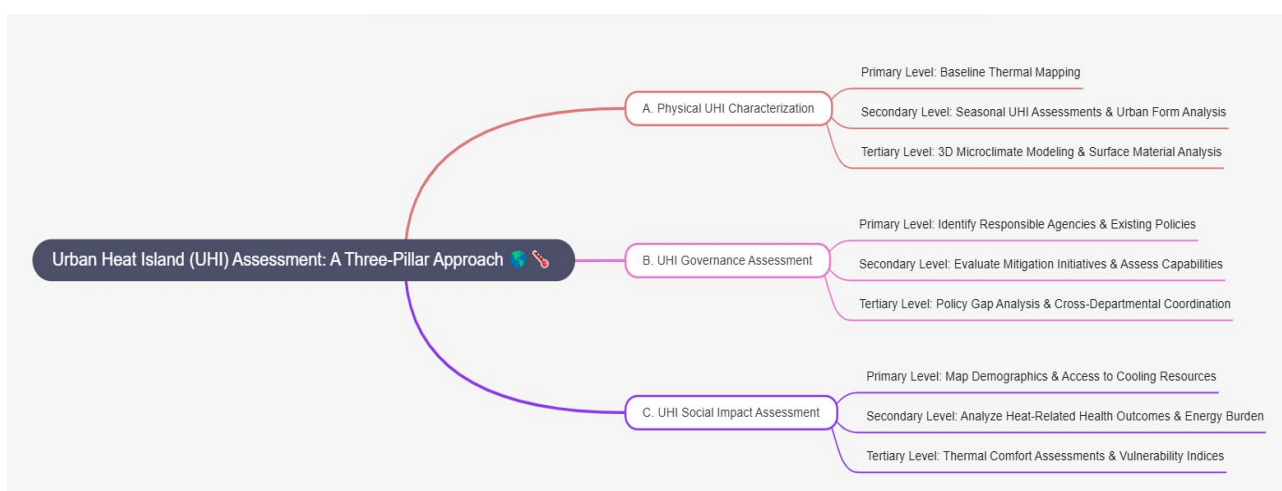


Figure 50: UHI Assessment Three Pillar Approach

development

2. Strategic Green Infrastructure Plans for maximum cooling benefit
3. Cool Materials Implementation Programs for public and private properties
4. Urban Canyon Ventilation Improvement Recommendations
5. Heat-Adaptive Land Use Planning to reduce anthropogenic heat and maximize cooling

By understanding where heat is most concentrated, planners can design targeted interventions such as increasing urban greening and enhancing cooling infrastructure in the most affected areas.^{119,120} Assessments should consider historical and projected climate data to anticipate future changes and adapt master plans accordingly.¹²¹

5.3.2 Analysis and Mapping

Analysis and mapping for heatwave masterplans, encompassing urban heat mapping and heat vulnerability matrices, are essential tools for addressing the challenges posed by the urban heat island effect. Urban areas experience significantly higher temperatures than surrounding rural regions due to human activities that replace natural landscapes with impervious surfaces, contributing to heat retention.

This phenomenon has profound implications for public health, infrastructure, and overall urban

sustainability, particularly during extreme heat events, as highlighted by incidents resulting in substantial mortality rates that underscore the urgent need for effective heat management strategies.^{122,123}

Combining urban heat mapping with heat vulnerability matrices has practical applications for urban planning. Cities like Richmond have utilized heat mapping to create a heat vulnerability index that informs climate action plans and integrated watershed management. Similarly, New York City's Cool Neighbourhoods NYC program targets heat-vulnerable neighbourhoods with specific interventions like street tree plantings and energy assistance programs.¹²⁴

5.3.2.1 Urban Heat Risk Assessment

An Urban Heat Risk Assessment evaluates and classifies heat risk levels based on two primary factors:

1. Intensity and frequency of extreme heat events
2. Potential health impacts on the affected population

This assessment provides a systematic framework for understanding urban heat risks and guides evidence-based decision-making, resilience planning, and intervention strategies. It can be utilised for:

- a. **Identifying Heat Vulnerability Zones:** Mapping temperature variations to pinpoint

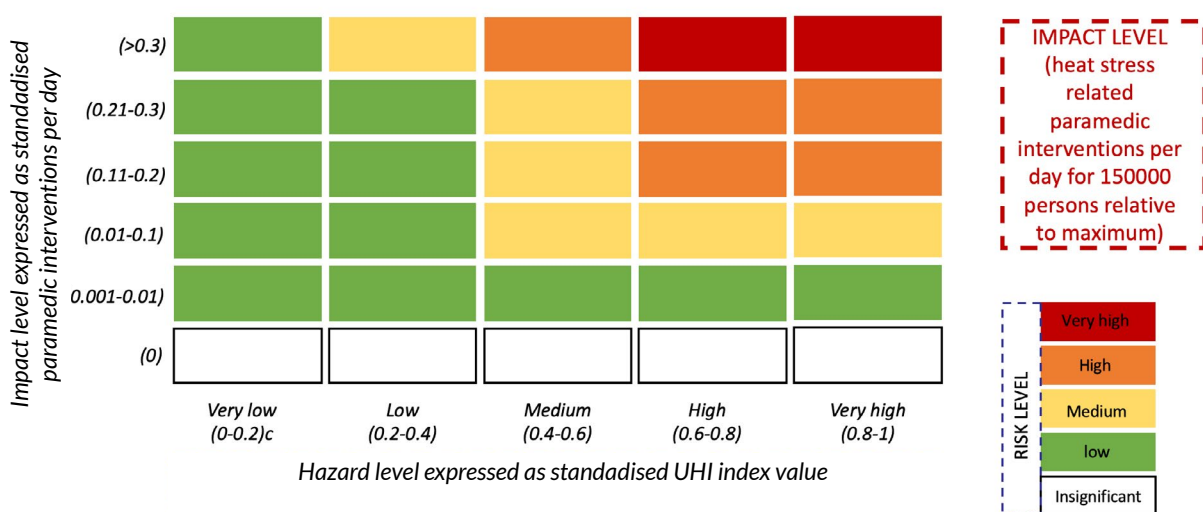


Figure 51: Risk matrix for heat waves for the municipality of Arad¹²⁵

neighbourhoods experiencing higher thermal stress and prioritising cooling interventions.

- b. **Informing Policy and Design Guidelines:** Helping municipal governments establish policies such as urban greening requirements, cool roof standards, and heat-responsive building codes.
- c. **Adaptation Strategy Development:** Determining appropriate heat mitigation measures based on risk severity, including increasing tree canopy, installing cool pavements, creating cooling centers, or expanding green infrastructure.
- d. **Public Health Response Planning:** Coordinating heat-health interventions, including early warning systems, outreach to vulnerable populations, and strategic placement of cooling resources.

Establishing a “Heat Vulnerability Matrix” involves determining appropriate risk categories to effectively manage and reduce heat-related health impacts. Areas with greater temperature variations may require more detailed risk classifications to account for microclimatic differences across neighbourhoods. The objective is to transform high-risk urban environments into “medium” or “low-risk” zones through strategic interventions.

Municipal health departments and planning agencies must collaborate to define how urban areas should be categorised into heat risk bands, utilising tools like a “Heat Vulnerability Index” to evaluate intervention scenarios.

The heat vulnerability assessment serves as a tool for prioritising areas based on their susceptibility

to heat-related impacts. Recent studies have highlighted limitations of traditional census unit-based indicators, leading to the development of a raster-based subdividing indicator (RSI) that evaluates vulnerability through three key aspects:

- Exposure
- Susceptibility
- Adaptive capacity

This allows urban planners to visualise which areas require immediate intervention and resources, particularly in communities with higher poverty rates and health risks associated with heat exposure.

Implementation of Urban Heat Risk Assessment

The Urban Heat Risk Assessment provides a structured approach to understanding urban heat islands, supporting effective urban design, cooling strategies, and public health interventions:

Low-Risk Areas: Urban zones with moderate peak temperatures, abundant shade, and populations with high adaptive capacity may require minimal interventions, such as seasonal public awareness campaigns and maintenance of existing green infrastructure.

Medium-Risk Areas: Neighbourhoods with moderate to high surface temperatures, limited vegetation, and populations with some vulnerability factors would benefit from targeted cooling interventions like strategic tree planting, cool surface treatments for roads and sidewalks, and community cooling centers.

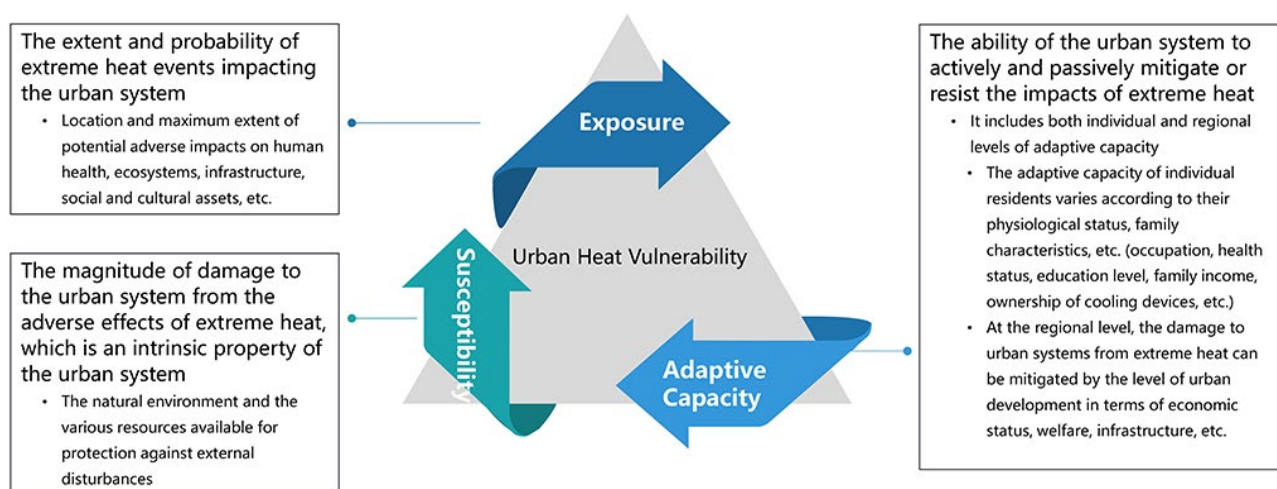


Figure 52: Conceptual Framework of Urban Heat Vulnerability¹²⁶

High-Risk Areas: Urban zones experiencing extreme surface temperatures (often 8-12°C above surrounding areas), minimal vegetation cover, and concentrations of vulnerable populations require comprehensive heat management strategies, including retrofit programs for residential cooling, extensive green infrastructure development, cool material mandates for new construction, and robust early warning systems.

5.3.3 Decision Making and Implementation

5.3.3.1 Planning Matrix for Heat Mitigation

Incorporating urban heat mitigation into master plans provides a comprehensive policy framework that guides all other planning tools. When integrating heat mitigation strategies, key considerations include:

- Urban heat mitigation extends beyond physical infrastructure to encompass community education, early warning systems, cooling centers, and other non-structural interventions.
- Heat mitigation strategies should prioritise natural cooling processes over energy-intensive engineered solutions when possible. For example, expanding urban tree canopy and green spaces is preferable to increasing air conditioning capacity.
- Special consideration must be given to heat-

vulnerable populations, addressing both extreme heat risks and other compounding social and environmental factors.

- Heat mitigation planning should integrate with other resilience initiatives, including water management, energy efficiency, and public health emergency response systems.

A “Planning Matrix for Urban Heat Mitigation” provides a framework for cities to address and manage urban heat based on different risk levels. The matrix is organised into four risk categories with corresponding temperature thresholds, health impacts, and recommended development controls:

Low Risk (< 30°C):

- **Health Impacts:** Minimal impact for most residents
- **Development Controls:** Basic tree planting and reflective surfaces for new construction

Moderate Risk (30-35°C):

- **Health Impacts:** Heat stress for vulnerable populations
- **Development Controls:** 30% minimum green space and shade requirements for public spaces

High Risk (35-40°C):

Risk Levels	Temperature Thresholds*	Health Impacts	Development Controls
Low Risk	<30 °C	Minimal impact for most residents	Basic tree planting; Reflective surfaces for new construction
Moderate Risk	30-35 °C	Heat stress for vulnerable populations	30% minimum green space; Shade requirements for public spaces
High Risk	35-40 °C	Heat-related illness for the general population	Cool roofs mandatory ; 50% minimum green space; Heat-resistant materials
Extreme Risk	>40 °C	Significant heat risks and potential fatalities	Building orientation requirements; Cooling centers within 1km; Enhance tree canopy protection

Integration with Other Planning Systems

Water Management | Energy Efficiency | Public Health | Emergency Response

Figure 53: Planning Matrix for Urban Heat Mitigation.

* Threshold depends on the topography and climatic conditions of the cities.
Data compilation: NIUA

- **Health Impacts:** Heat-related illness for the general population
- **Development Controls:** Cool roofs mandatory, 50% minimum green space, and heat-resistant materials

Extreme Risk (> 40°C):

- **Health Impacts:** Significant health risks and potential fatalities
- **Development Controls:** Building orientation requirements, cooling centers within 1km, and enhanced tree canopy protection

Cities should determine their own threshold temperatures based on specific climatic zones. The temperature thresholds shown are examples that can be adjusted to reflect local conditions, normal temperature ranges, and climate adaptation needs of different geographic areas.

Heat mitigation planning should be integrated with other city planning systems, including water management, energy efficiency, public health, and emergency response, for a comprehensive approach to urban resilience. The planning matrix helps quantify heat-related risks and guides municipalities in developing comprehensive heat management strategies. The final structure of heat risk bands should balance factors including temperature extremes, duration of heat events, humidity levels, and urban morphology characteristics specific to the area.

5.3.4 Strategies to tackle Urban Heat

Integrating heat risk reduction into urban master plans is essential for the development of resilient and sustainable cities, particularly within the context of India's rapidly urbanizing environment and the increasingly severe impacts of climate change. As urban heat islands become more pronounced and climatic conditions continue to fluctuate, comprehensive master planning emerges as a crucial framework for addressing urban heat vulnerabilities in a proactive manner. To safeguard public health and enhance urban resilience from Urban Heat, Indian cities have developed specific and unique standard strategies integrated into their master planning processes. Initiatives such as the Smart Cities Mission and the Atal Mission for Rejuvenation and

Urban Transformation (AMRUT) are at the forefront, promoting sustainable urban development through improved infrastructure and planning. Strategies include increasing urban greenery, utilizing reflective materials, and enhancing traditional construction techniques, such as chajjas and jaalis, to reduce heat absorption and improve thermal comfort^{127,128,129}, moreover, community engagement and local knowledge have been emphasized as vital components in formulating contextually relevant heat adaptation solutions, fostering a collaborative approach to urban resilience¹³⁰. Heat Action Plans (HAPs) represent a significant policy response, with over 100 plans established across various Indian cities. These plans incorporate a combination of infrastructural and nature-based solutions, but face challenges related to their reactive nature and the need for transformative, long-term strategies. Effective governance and coordination among various stakeholders are essential for overcoming barriers to implementation, such as limited data availability, conflicting urban goals, and inadequate community involvement¹³¹. City master plans serve as fundamental policy documents that systematically incorporate heat mitigation strategies across a range of urban development dimensions. Unlike traditional approaches that tend to focus narrowly on specific interventions, contemporary efforts to reduce heat risk necessitate a holistic perspective. This perspective encompasses various critical elements, including urban design, the incorporation of green infrastructure, modifications to the built environment, and robust community resilience strategies.

The strategic integration of heat risk management into master plans yields several significant advantages:

- **Comprehensive Policy Guidance:** It provides a coherent framework for coordinated urban development, ensuring that all stakeholders work towards common goals in addressing heat-related challenges.
- **Proactive Mitigation:** This approach prioritizes proactive measures to mitigate heat risks—such as improving urban greenery and enhancing building designs—over reactive public health interventions, which are often initiated only in response to adverse events.
- **Sustainable Urban Growth:** By fostering

the creation of thermally efficient urban environments, integrating heat risk strategies contributes to sustainable urban development that not only addresses immediate challenges but also anticipates future needs.

- **Cross-Sectoral Collaboration:** It encourages collaboration among various sectors—such as urban planning, public health, and environmental management—leading to more integrated and innovative solutions.

5.3.4.1 Planning Level Strategies

a. Urban Form and Layout: Density and Mixed-Use Planning

To effectively mitigate urban heat in dense cityscapes, urban planning must integrate **climate-zoned FAR regulations** that respond to local climatic conditions. In hot and dry or warm-humid zones, urban blocks and plots with **lower perimeter-to-area (P/A) ratios**—such as compact, square or rectangular forms—are preferable. These shapes reduce surface exposure to direct solar radiation and minimize heat absorption along building edges and roadways, making neighborhoods more thermally efficient. Conversely, elongated or fragmented plots (high P/A ratios) increase heat retention and reduce shading potential.

Further, a **staggered density gradient**—by decreasing building density around identified urban heat islands (UHIs)—can redistribute thermal pressure and improve airflow. This spatial modulation should be complemented by **mixed-use zoning strategies, with flexible land use ratios** (e.g., 40% residential, 30% commercial, 15% institutional, 15% open space)

to encourage compact, walkable, and functionally diverse neighborhoods. Together, these measures promote climate-responsive urban form, reduce surface temperatures, and enhance liveability in heat-vulnerable areas.

b. Green Cover Network

To address the intensifying impacts of urban heat, city planning should incorporate recommended **green cover targets** as a core climate adaptation strategy. The **National Forest Policy** suggests that **ideally 33% of India’s land area**, and up to 66% in hilly regions, be maintained under forest and tree cover to sustain environmental balance. These benchmarks serve as valuable guidelines for urban areas to adopt incremental green cover goals—such as achieving 35% by 2030 and 40% by 2035—to reduce ambient temperatures, enhance shade, and mitigate the urban heat island effect.

Global examples reinforce the importance of accessible green infrastructure in cooling cities. **London, with 47% green cover and 31.6 sq.m of open space per person**, demonstrates how urban greenery can meaningfully contribute to heat mitigation and livability. **In contrast, Shanghai, despite having 58% green cover, offers just 8.5 sq.m per person**, highlighting that the distribution and usability of green spaces matter as much as total coverage. Indian cities can effectively respond to these challenges by integrating green cover targets into Master Plans and Development Control Regulations (DCRs), ensuring not only increased vegetation but also equitable, strategically located open spaces such as parks, green corridors, and shaded streetscapes.

Organisations	Area of open space per person
World Health Organisation (WHO)	9 sq.m
Public Health Bureau & the Ministry of Housing (USA)	18 sq.m
European Union	26 sq.m
United Nations	30 sq.m

City	Open space per 1000 people (Ha)	Open space per person (sq.m)	% Green Cover	Total no. of parks
London	3.1	31.6	47	376
New York	0.6	6.07	35	1700
Shanghai	0.8	8.5	58	532
Hong Kong	0.1	1	40	26
Singapore	0.75	7.5	46	300

Figure 54: Open space per person for various organizations and cities

Source: NIUA Compilation

Urban Park Category	Constituents	Size Guideline (Hectare)	Population
City Park	Aqua park/water sports park, Arboretum, Botanical Garden, National Memorial (approved by Cabinet/ Govt. of India), Amphitheatre, Open Playground, Aquarium, other activities same as permitted in District Park.	100	10 lakh
District Park	Theme park, Recreational Club, National memorial, open-air food court, Children Park, Orchard, Plant Nursery, Area for water harvesting, Archeological Park, Specialized Park, Amusement Park, Children Traffic Park, Sports activity, Playground, Amenity structures.	25	5 lakh
Community Park	Park, Children Park, Open-air food court, Playground, etc.	5	1 lakh

Figure 55: Case of Delhi; Category establishment of planning norms, standards for recreational areas/parks at the city level

Urban Park Category	Constituents	Size Guideline (Hectare)	Population
Neighborhood park	Common open space	0.1	10000
50000.5 Anganwadi / Tot Lot and convenience shopping area			
Housing Area Park			
2500.0125 Tot lot Housing Cluster level			

Figure 56: Case of Delhi; Category establishment of planning norms, standards for recreational areas/parks at the neighbourhood level

Adopting such climate-responsive planning measures will help reduce surface temperatures, improve microclimates, and build long-term resilience against extreme heat in urban India.

c. Urban park network

Cities should adopt a **hierarchical urban park network** that ensures equitable access to green spaces at various functional levels. Based on Delhi's planning norms and supported by global research (Wiedemann, 2003)¹³², urban planning should prioritise the integration of **green spaces within walkable distances** from residences. Specifically, residential-level green areas should be accessible within 150 meters, and neighbourhood-level parks should be reachable within 400 meters, equivalent to a 5-minute walk. This approach ensures that every resident benefits from the microclimate-regulating functions of green spaces, including shade, evapotranspiration, and reduced surface temperatures.

Delhi's model offers a clear framework for implementation. At the city level, it recommends a tiered structure: **City Parks (100 hectares per million population)**, **District Parks (25 hectares per**

0.5 million), and **Community Parks (5 hectares per 0.1 million)**. At the neighbourhood level, standards include **Neighbourhood Parks (0.1 ha per 10,000 population)**, **Housing Area Parks (0.5 ha per 5,000)**, and **Tot Lot Parks (0.0125 ha per 250)**. These standards ensure that green spaces serve both large-scale recreational needs and localised thermal comfort.

Adopting this layered, accessibility-focused approach in urban planning and Development Control Regulations (DCRs) will not only optimise the spatial distribution of greenery but also promote thermal equity, walkability, and long-term heat resilience across diverse urban geographies.

d. Biodiversity Corridors

To effectively mitigate the impacts of urban heat, cities should prioritize the development of **ecological and climate-responsive green infrastructure networks**. One vital approach is the creation of **biodiversity corridors**, which are continuous green linkages 30–50 meters wide that connect scattered urban green spaces¹³³. These corridors should consist of **at least 80% native plant species**, which are better adapted to local climate conditions, support urban biodiversity,

and require less maintenance and water. By linking parks, community spaces, and natural areas, these corridors enhance ecological connectivity and allow for the movement of wildlife, while also contributing to urban cooling through increased vegetation cover.

Complementing these corridors, the **strategic implementation of Urban Green Infrastructure (UGI)**—such as street trees, green roofs, shaded facades, and pocket parks—can significantly reduce surface and air temperatures in built-up areas¹³⁴. These green elements act through shading and evapotranspiration, helping to lower the urban heat island effect. Additionally, UGI delivers multiple co-benefits including **air pollution reduction, enhanced stormwater management, carbon sequestration, and improved urban aesthetics**.

Together, biodiversity corridors and well-distributed green infrastructure form a multifunctional urban ecosystem that supports both human well-being and environmental sustainability. Integrating these strategies into urban planning processes and regulations ensures long-term resilience to rising temperatures and promotes a healthier, more livable urban future.

e. Urban Forest Management

Urban forest management should be adopted as a core component of city-level master plans. This involves the development of **Urban Forest Master Plans** that prioritize the use of **native, heat-resistant tree species** such as Neem, Banyan, and Peepal¹³⁵, which are well-suited to Indian climatic conditions. These trees not only provide shade and reduce surface temperatures but also support biodiversity and air purification.

As a strategic intervention, cities should be guided to:

1. **Conduct a spatial heat vulnerability assessment** to identify priority zones where tree cover is minimal and urban heat islands are most intense.
2. **Integrate urban forest zones into the land-use planning process**, ensuring green buffers around high-density and vulnerable areas.
3. **Design multi-functional green spaces** with a minimum designated size that serve both **ecological functions** (cooling, drainage, habitat)

and **social functions** (community recreation, gathering spaces).

4. **Create tree inventory databases** and mapping systems to monitor species type, health, canopy coverage, and maintenance needs.
5. **Engage local communities and stakeholders** in the planning and stewardship of these spaces through awareness campaigns and participatory budgeting.
6. **Include green infrastructure guidelines** and tree preservation norms within building bylaws and development control regulations (DCRs).

By institutionalizing urban forestry at the master plan level, cities can establish a proactive, nature-based solution to mitigate heat risks, enhance liveability, and contribute to sustainable urban development.

f. Water Sensitive Urban Planning

Establish an **Urban Blue Network** by creating a connected **blue grid system**, comprising natural and man-made water bodies such as lakes, ponds, channels, and wetlands within city layouts. It is recommended that at least **8–10% of the total land area is dedicated to water features**, this ensures not only hydrological balance and flood mitigation but also enhances urban microclimates and biodiversity. The blue network should be designed to be hydrologically connected, allowing for seasonal water movement, overflow channels, and groundwater recharge zones.

Strategically planned placement of **artificial lakes** serves both ecological and socio-cultural functions in urban landscapes, with a minimum of **5 ha every 5km**. As per the NLCP development statement for the urban lakes, the **25%** area should be developed for **human interaction and socio-cultural or recreational space** (MoEFCC Report, 2013). These lakes function as stormwater retention basins, help mitigate the Urban Heat Island (UHI) effect and provide critical habitats for avifauna and aquatic species.

Rainwater Harvesting Infrastructure is an effective way to capture and manage rainwater, urban road infrastructure must incorporate rainwater harvesting features, such as bios wales, rainwater channels, and pervious edge drains. These should be implemented along **60–70% of road lengths**. These features help slow down surface runoff, promote infiltration, and

reduce the burden on stormwater drainage systems, while simultaneously improving water quality through natural filtration processes.

Large developments can incorporate **constructed wetlands** as a nature-based solution which can be used for treating a **percentage of on-site greywater**. These systems can effectively reduce pollutant loads while supporting urban greening. Design specifications should include appropriate side slopes (1:4), water depth of 1–2 meters not exceeding 2.5 meters, and account for sediment accumulation.

g. Heat-Responsive Urban Design

● Cooling Action Plans

To address the intensifying Urban Heat Island (UHI) effect, cities must adopt **microclimate-based zoning**, develop **UHI-intensity zoning maps** updated periodically, with development restrictions based on temperature differential categories. Zoning categories can correspond to temperature thresholds and can also be directly linked to development control regulations. In high UHI zones, planning controls can limit floor area ratios (FAR), restrict impervious surface coverage, and mandate the integration of heat-mitigating features such as green roofs, high-albedo materials, and tree canopies. This will allow cities to proactively control heat-stress proliferation while integrating thermal comfort into the development process.

Urban street layout significantly influence airflow and thermal regulation. To improve wind-driven natural ventilation in dense urban fabrics, it is recommended to **align streets at a 45° angle to the prevailing wind direction**, creating **ventilation corridors** that channel cool air into heat-prone urban zones¹³⁸. This design helps reduce stagnation zones and enhances the flushing out of heat and air pollutants. Such corridors are particularly vital in compact city forms, where high-rise and mid-rise buildings can obstruct air movement. Street grids, green boulevards, and open spaces aligned with wind paths can together function as passive cooling systems, reducing the demand for mechanical ventilation and contributing to urban thermal resilience.

Implement setback requirements that account for airflow, setback regulations must move beyond

generic building code compliance and adopt a climate-sensitive approach by integrating **heat-responsive setback** standards. Double-side double setbacks (i.e., building setbacks on both sides of the structure) can significantly influence airflow patterns around buildings—reducing wind velocity by 28–30% at the front and 68–70% at the rear of buildings¹³⁹. In hotter urban zones, setbacks should be strategically increased to promote cross-ventilation, prevent heat entrapment, and reduce wall surface exposure to direct solar radiation.

● District-Level Cooling

To address rising urban temperatures and growing cooling demand, cities should explore the implementation of **District Cooling Systems (DCS)**—a centralized infrastructure solution that provides chilled water or air to multiple buildings through an underground insulated pipe network. DCS can significantly improve energy efficiency in urban areas by reducing peak electricity load, lowering carbon emissions, and cutting operational costs for individual buildings¹⁴⁰. DCS is particularly suited for high-density, mixed-use developments such as business districts, institutional campuses, airports, upcoming Tier 1 and Tier 2 cities with high-density residential developments. By aggregating the cooling load, district cooling allows for the use of energy-efficient chillers, thermal energy storage, and the integration of non-conventional energy sources such as treated wastewater. This model can reduce electricity consumption for cooling by up to 50% compared to conventional air conditioning systems¹⁴¹. As a scalable and sustainable solution, district cooling should be considered in urban development plans. **Development covenants** can be used to apply positive covenants on land to facilitate **district cooling connections** in new and redeveloped urban areas. Positive covenants require property owners or occupiers to perform certain actions or meet specific responsibilities tied to land use.

5.3.4.2 Building and Infrastructure Strategies

a. Heat-Day Building Codes:

As global temperatures rise, many regions are experiencing an increasing number of extreme heat days (>40°C). Implement additional tiered construction standards that activate when the

number of annual extreme heat days exceeds predefined thresholds (30, 45, or 60 days). These codes ensure buildings remain habitable and safe during prolonged heatwaves.

Building codes should implement progressive thermal resilience standards triggered by annual heat day thresholds. When a region experiences **30 days** of $>40^{\circ}\text{C}$, Basic Heat Resilience measures activate, prioritising passive cooling through optimised ventilation, strategic window orientation (particularly south- and west-facing), and solar shading to reduce indoor heat accumulation. At **45 days** of $>40^{\circ}\text{C}$, Enhanced Heat Mitigation requirements take effect, mandating high thermal mass materials (e.g., insulated

concrete forms, brick)¹⁴² and green roofs to minimise dependence on mechanical cooling. For extreme climates with **60+ days** $>40^{\circ}\text{C}$, Advanced Climate-Adaptive Design becomes essential, integrating survivability-focused features such as cool corridors, district cooling systems, and off-grid passive cooling strategies to ensure habitability during prolonged heatwaves¹⁴³.

b. Vertical Green Coverage:

With cities facing rising temperatures due to climate change, vertical gardens on buildings offer a sustainable solution to cool buildings and improve urban liveability. Government buildings in urban areas should incorporate vertical green coverage



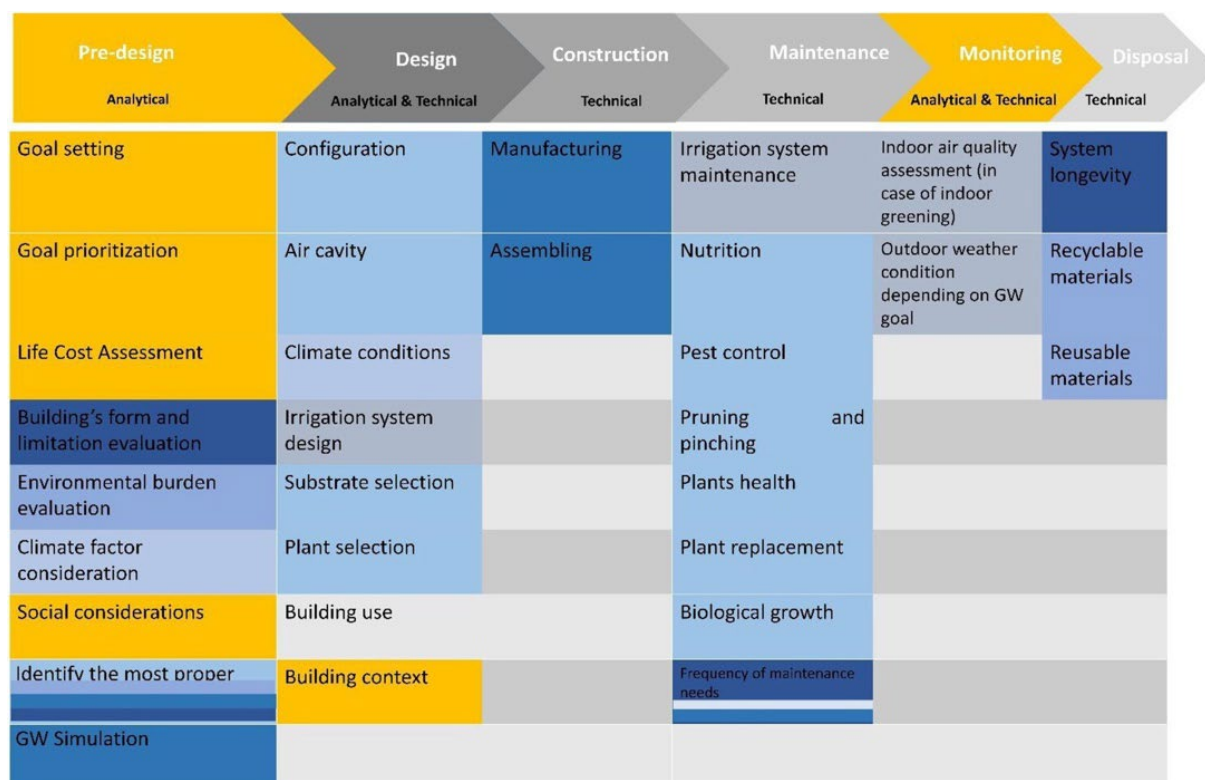
Figure 57: Abstract Picture of four green walls¹⁴⁵

Benefits of Vertical Greening Systems

Research shows vertical greening can provide:

- Solar radiation reduction of up to 37% for a wall with a single layer of leaves and 86% for five layers
- Reduced energy consumption by up to 20%
- Reduction of wall surface temperatures by up to 12°C and ambient temperatures by as much as 4°C (within 2m)

Figure 58: Framework for Installing Vertical Greening System (VGS)



systems across a minimum of **30% of their available wall surface area**. In dense urban areas the area of building's facade is much higher compared to the land surface, hinting significance of green wall systems. These systems reduce surface and ambient temperatures through evapotranspiration, provide insulation benefits, and contribute to improved air quality by filtering particulate matter and absorbing carbon dioxide. Their contribution to mitigating the Urban Heat Island (UHI) effect is particularly relevant in areas with low tree canopy coverage and high impervious surface ratio¹⁴⁴. Moreover, these systems can provide therapeutic effect by inducing psychological wellbeing through the presence of vegetation.

Comparative studies demonstrate that super soil-based Living Wall System (LWS) (d) outperforms other designs, reducing indoor temperatures by 4.5°C and achieving 19.92% energy savings, while traditional green facades (b) offer limited cooling (6.29% savings). The modular box system (c) provides intermediate benefits (15.37% savings).

c. Green Roof Requirements:

Establish green roof coverage based on building type and structural capacity (example threshold: 50% of net roof area or 2,000 square feet of contiguous roof area). Green roofs offer substantial thermal regulation benefits by reducing rooftop surface temperatures and lowering internal cooling loads, thereby contributing to energy efficiency and

According to the US Green Building Council (USGBC), India led globally in 2023 with over 7 billion square feet of green building space. The US Environmental Protection Agency (EPA) reports that green roofs can reduce ambient urban temperatures by up to 5°F and decrease conventional roof temperatures by 30-40°F. Integrating green roofs into major Indian urban development initiatives such as the Pradhan Mantri Awas Yojana and Smart Cities Mission represents a significant opportunity. This strategic implementation could substantially reduce urban energy demands while supporting the objectives of India's Cooling Action Plan to mitigate heat and lower energy consumption.

Source: <https://www.ispp.org.in/green-roofs-a-sustainable-solution-for-reclaiming-urban-spaces/>

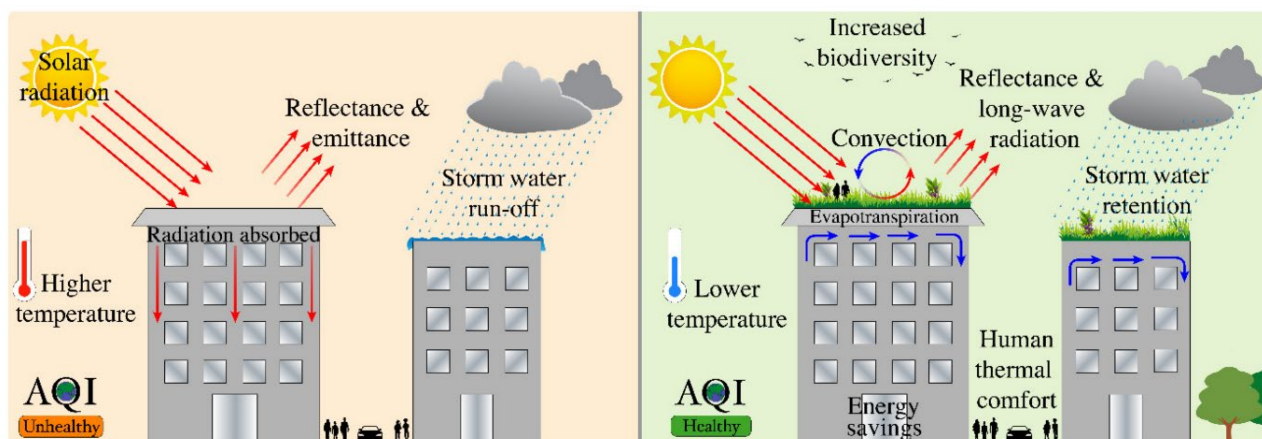


Figure 59: Schematic representing the diverse processes involved in conventional roofs and GRs (AQI—Air Quality Index).¹⁴⁷

occupant comfort. In addition to mitigating the Urban Heat Island (UHI) effect through evapotranspiration and solar radiation absorption, green roofs serve a dual function as decentralized stormwater retention systems—capturing rainfall, reducing runoff, and relieving pressure on urban drainage infrastructure¹⁴⁶.

- **Cool Roof Implementation:** Cool roofs use solar-reflective surfaces to maintain lower roof temperatures. Traditional dark roofs can reach temperatures of 66 °C or more in the summer sun, a **cool roof under the same conditions could stay more than 28 °C cooler**¹⁴⁸. Solar Reflectance Index (SRI) is another metric for comparing the “coolness” of roof surfaces¹⁴⁹. The higher the SRI, the cooler the roof will be in the sun. Dark roofs usually have an SRI less than 20. Cool roof requirements depend on the roof’s slope. Steep-sloped roofs are generally subject to less stringent cool roof standards due to their limited direct solar exposure and faster runoff. Similarly, roofs with heavier surface materials, such as concrete pavers, ballast, or vegetative cover—also have less stringent standards. These materials possess

a higher thermal mass, which enables them to absorb heat more gradually during the day and release it slowly at night, thereby mitigating peak daytime heat gain and reducing overall thermal impact. Establish minimum Solar Reflectance Index (SRI) values based on roof type (example: $SRI \geq 78$ for flat roofs, $SRI \geq 29$ for sloped roofs)¹⁵⁰.

d. Building Envelope Standards: Thermal Performance

- **Wall and Roof Insulation:** A material’s effective insulation property can be measured as U-value with lower U-value indicating a better heat insulation. The U-value gives us how much heat moves through a given material per square metre per hour illustrating how effective a material is as a heat insulator by indicating how quickly it will lose heat. So establishing maximum effective U-value of 0.5 W/m²K for walls and 0.3 W/m²K for roofs in new constructions are suggested¹⁵¹.
- **Thermal Mass Specifications:** Thicker and denser materials with appropriate thermal conductivity can store more heat and release it slowly, enhancing the thermal lag which is the delay

Thermal Performance Metrics

U-value indicates heat transfer rate through building materials:

- Lower U-values indicate better insulation properties
- Materials with high thermal mass and low thermal conductivity are preferred for hot climates
- Retrofit targets should be established for existing buildings (example: 0.8 W/m²K for walls and 0.5 W/m²K for roofs by 2030)

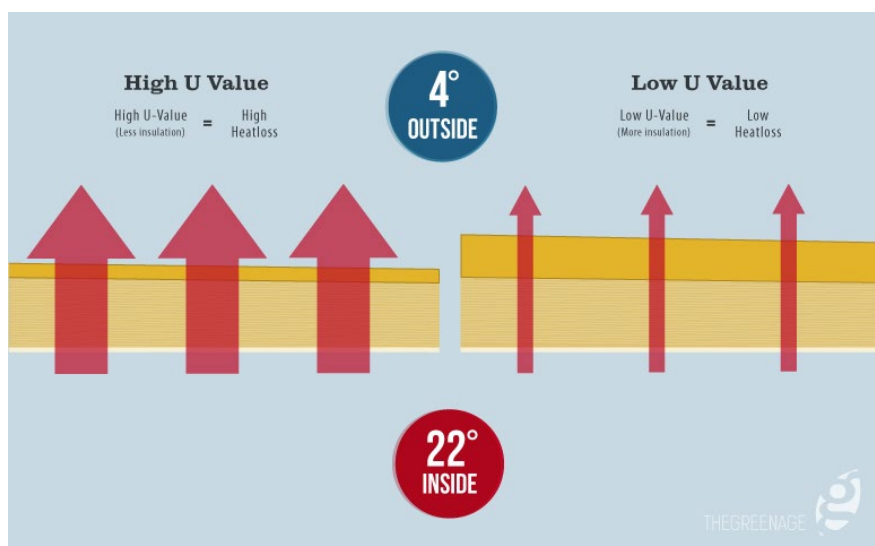


Figure 60: The lower the U-value is, the better the material is as a heat insulator

between the peak external temperature and the resultant peak internal temperature. This delay allows buildings to moderate indoor temperatures, reducing reliance on mechanical cooling systems. Ensure that external walls are designed to achieve an appropriate thermal time lag of minimum 8 hours through material compositions, such as 230 mm for brick walls, 200 mm for concrete walls to effectively delay heat transfer and enhance indoor thermal comfort¹⁵².

Traditional Cooling Techniques

Passive cooling and natural ventilation are time-honoured techniques that have been employed for centuries to achieve climate control without reliance on mechanical systems. By incorporating these methods into contemporary architectural design, architects and builders are able to create energy-efficient structures that prioritise both thermal comfort and sustainability. This approach emphasises natural ventilation, strategic building orientation, and architectural geometries that optimise thermal comfort. The implementation focuses on multiple design interventions, including reflective exterior materials, advanced building envelope technologies, intelligent shading techniques, and sophisticated thermal mass management. These strategies involve developing multi-layered insulation systems, creating dynamic shading mechanisms, utilising phase-change materials, and designing architectural configurations that leverage thermal inertia. The objective is to transform buildings from passive structures to active

thermal regulation systems.

e. Cooling of Public Transit

Transit stops and stations especially those in open urban settings must be retrofitted with passive and active cooling technologies to reduce surface and ambient temperatures like **solar-powered misting systems** for evaporative cooling during peak hours, **heat-reflective** paints and coatings to reduce radiative heating, vertical greenery, green roofs, **vegetation** integration for natural shading and microclimate improvement. These interventions improve waiting conditions and encourage continued use of public transport during extreme heat days.

To ensure thermal comfort inside transit vehicles, implement upgrades like **advanced cooling, ventilation systems** suited for high ambient temperatures, **specialised window treatments** (e.g., reflective films, electrochromic glass). Use of thermally insulating interior materials to maintain stable indoor temperatures and reduce cooling energy demand.

Install thermally active or **heat-responsive public furniture**, such as seating elements that regulate surface temperature. Innovations in phase-change materials or ceramic composites now allow benches to maintain surface temperatures **below 35°C**, regardless of ambient conditions¹⁵⁷.

Develop an **Urban Shade Network Plan** ensuring

- **Jaali Implementation Standards:** Require jaali screens with scientifically optimized perforation ratios (30-50%) that maximize ventilation while minimizing heat gain⁵⁴



Figure 61: The traditional architecture of Baolis, or stepwells, integrated groundwater access and storage with passive cooling techniques to maintain a cool environment⁵⁵

- **Courtyard Design Parameters:** Establish courtyard dimension standards with minimum width-to-height ratio to optimize shade and ventilation⁵⁶
- **Thermal Buffer Zones:** Require transitional spaces (verandahs, balconies) comprising 15-20% of total building area, with minimum depth of 1.8 m.
- **Passive Night-time Cooling:** Implement design features enabling minimum 50% of building envelope to participate in radiative cooling during night hours.

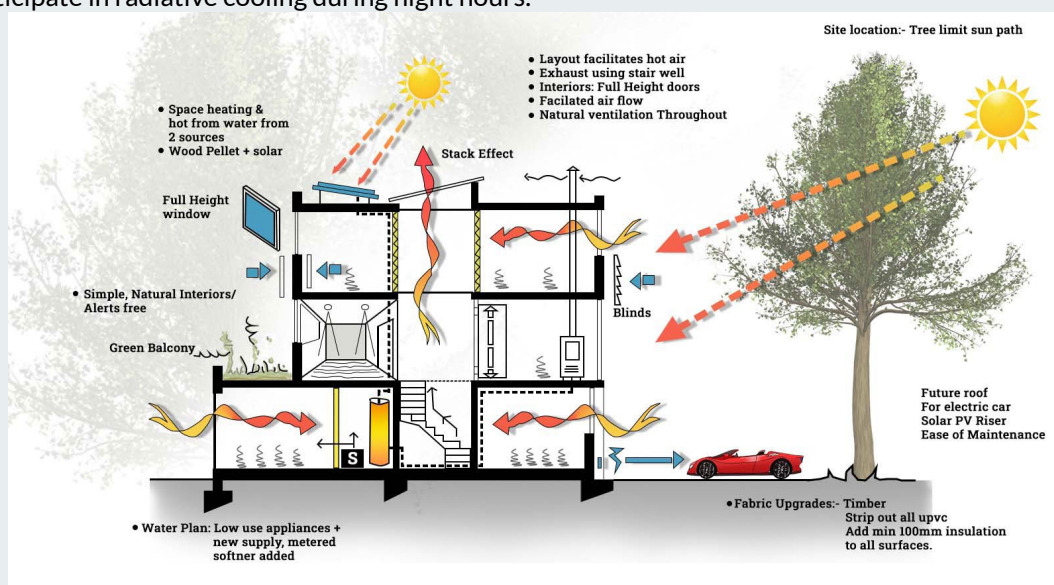


Figure 62: Passive cooling techniques¹⁵⁷

Source: 153,154,155

no point is more than **100 meters** away from a shaded area in high-footfall commercial, transit, and pedestrian zones. This can include tree-lined streets and arcades, shaded bus queues and sidewalks, modular shade structures near intersections and

parking zones. Such networks should be planned using **urban heat mapping** and pedestrian flow data, enabling equitable distribution of shading infrastructure. Detailed information on the existing built environment and shade infrastructure will be

required to assess the human thermal exposure and then equitably place new shade infrastructure¹⁵⁸.

Deploy **reflective canopies** made of high-albedo tensile fabric or metal-mesh materials over **critical public gathering spaces** such as transit hubs, markets and vendor zones, school entrances and healthcare facility perimeters. These canopies can help reduce ambient temperatures, enabling thermal relief while allowing natural ventilation and daylight penetration¹⁵⁹.

f. Cool Roadways

Urban roads, pavements, and parking surfaces contribute significantly to surface heating and the Urban Heat Island (UHI) effect due to their extensive coverage and high thermal inertia.

Use **high-albedo (solar-reflective) materials** in road construction, these materials reflect a greater portion of incoming solar radiation, significantly lowering

surface temperatures. Colour can affect the albedo of the same material. For example, an asphalt shingle of Dark Mahogany colour has an albedo of 0.08 (lower) while in the white colour, its albedo becomes 0.33 (higher)¹⁶⁰.

To mitigate stormwater runoff and reduce thermal mass, reduce impervious surfaces and **permeable paving** should be integrated where appropriate like sidewalks, parking lots, and low-traffic roads. These pavements allow water infiltration, improving groundwater recharge and cooling through evaporative processes. Porous concrete, permeable interlocking pavers, and open-grid systems are effective materials that also enhance urban resilience to flash floods¹⁶¹.

Develop extensively shaded mobility pathways through the strategic use of **multi-layered shade** solutions, like street trees with wide canopies, pergolas or tensile structures along high-footfall

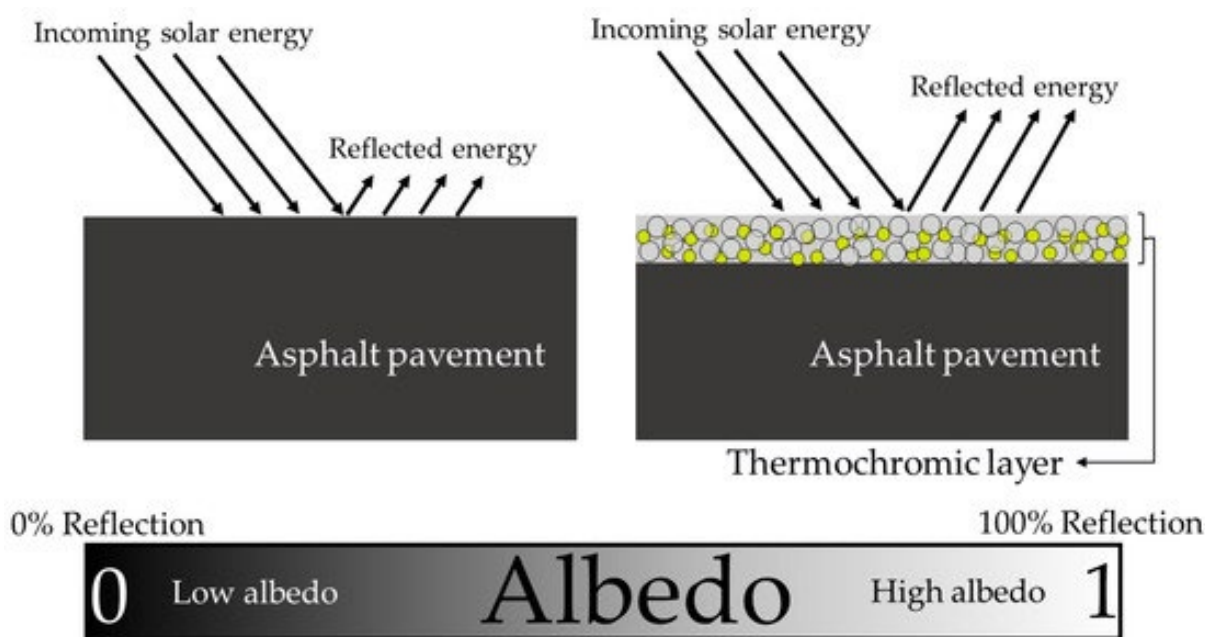


Figure 63: Asphalt pavement with thermochromic ability¹⁶³

Thermal Comfort in Transportation Planning

Creating thermally comfortable transportation infrastructure requires:

- Detailed mapping of essential mobility routes
- Computational modelling of solar angles and temperature patterns
- Integration of diverse vegetation types along transportation corridors
- Selection of drought-resistant native plant species

routes, building-integrated shading devices like arcades or balconies. These **Shaded Corridors** not only protect pedestrians and cyclists from heat stress but also reduce the radiant heating of pavement surfaces, enhancing microclimatic comfort.

Urban local bodies should adopt **high-performance pavement standards** that emphasize solar reflectance, material durability, and maintenance feasibility. With the development of urban road networks, asphalt pavement has become one of the main factors affecting the urban heat island effect, new construction and road retrofits should include specifications for reflective asphalt and concrete mixtures. Reflective asphalt pavements can reduce the high temperature by increasing the solar reflectance of the pavements, reducing **5°C–15°C**¹⁶².

In heat-critical zones such as school routes, hospital approaches, and transit stations, implement

thermochromic pavements, surfaces that change reflectivity when temperatures exceed critical threshold of 40°C. These **Temperature-Responsive Surfaces** offer dynamic adaptation, improving thermal comfort during peak heat while providing a visible, behavioural cue to pedestrians about heat levels.

5.3.4.3 Financial Mechanisms

- Develop tiered economic incentives for heat-resilient development based on scope and complexity, for example, Pune municipal administration has declared a tax rebate of up to 10% for the installation of rainwater harvesting, solar, and vermicomposting units. Similar initiatives can be followed for cool roofs and other cooling infrastructure¹⁶⁴;
- Establish Urban Heat Resilience Support Centers offering technical guidance to businesses;
- Create dedicated funding mechanisms for urban

The EIB approach can effectively mobilize the necessary resources to drive climate adaptation solutions. With this, the private sector, governments, and philanthropic investors raise the upfront capital and repayment is contingent on the project's success in meeting predefined goals. By distributing financial risk among stakeholders in the private sector, government, and philanthropy, EIBs encourage investment in pioneering projects that might struggle to attract traditional funding due to their novel or unproven nature.

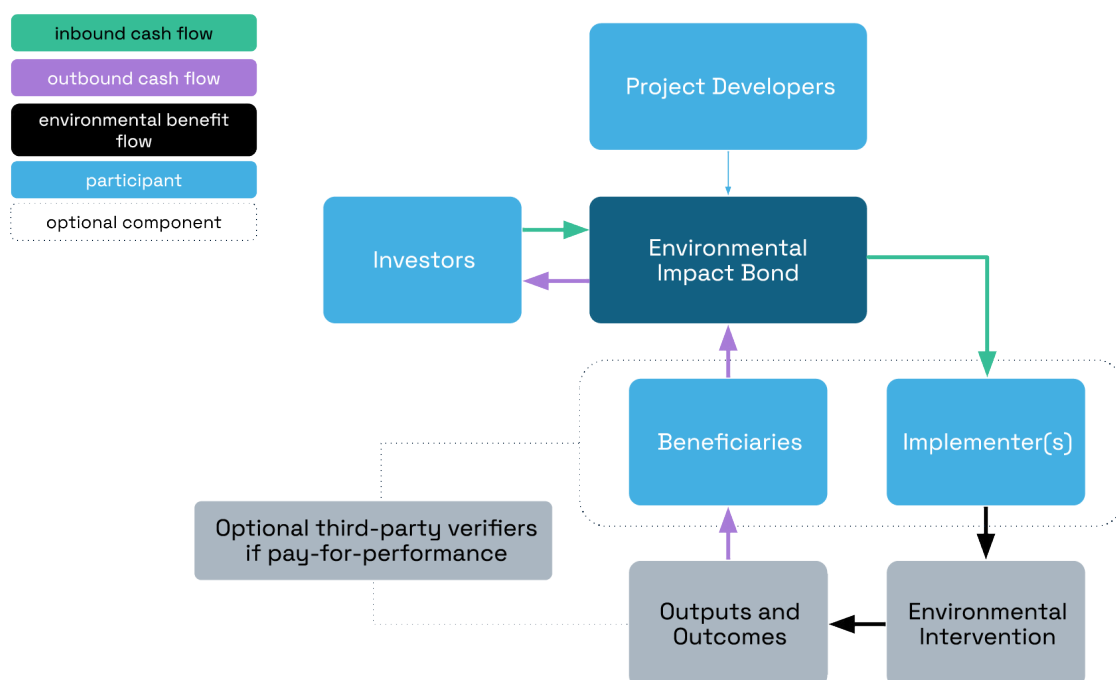


Figure 64: Environmental Impact Bonds (EIBs) structure, including cash flow (purple and green arrows) and environmental benefits (black arrows)¹⁶⁵

- restructuring projects targeting heat mitigation;
- Explore public-private partnership models and green municipal bonds for cooling infrastructure;
- Review and leverage tax-raising authority to capture new revenues for urban cooling interventions;
- **Green Development Bonuses:** Offer FAR bonuses for developments that exceed heat resilience standards by 25%;
- **Cool Roof Subsidy Program:** Provide subsidies covering cool roof implementation costs for buildings in vulnerable communities
- **Performance-Based Incentives:** Establish a carbon credit system for urban heat reduction, offering incentives per ton CO₂-equivalent reduction
- **Heat Resilience Insurance:** Create insurance premium discounts for properties implementing certified heat adaptation measures. (Eg: Nagpur and Ahmedabad)

Direct public investment will play a pivotal role in supporting these initiatives. Cities should designate **specific portions of their budgets** for urban restructuring projects aimed at mitigating heat island effects, climate-proofing public infrastructure, and fostering research and development of adaptation technologies. Investment opportunities could include the creation of urban cooling corridors, the establishment of green infrastructure networks, and the promotion of technological innovations in heat mitigation.

A robust monitoring and evaluation framework is vital for assessing the effectiveness of these strategies. Cities should undertake **annual heat resilience assessments** for businesses, evaluate the performance of economic incentive programs, establish feedback mechanisms for ongoing

improvement, and publish comprehensive reports detailing progress in urban heat adaptation. This transparent approach not only fosters accountability but also facilitates dynamic policy adjustments.

Funding these initiatives requires innovative and collaborative strategies. Cities should explore a variety of financing models, including **dedicated municipal climate adaptation budgets, public-private partnerships, green municipal bonds, and state or national climate resilience grants**. Collaborative governance, which brings together municipal authorities, business associations, research institutions, and community stakeholders, will be crucial in devising holistic and adaptive strategies.

To effectively **Mainstream Environmental Impact Bonds (EIBs)** and other innovative financial instruments, it is important to pilot and explore more EIB projects. Cool roofs are an excellent candidate for scaling through an EIB, thanks to their proven effectiveness as a climate adaptation solution. They offer numerous co-benefits and their environmental impacts can be relatively easily measured, including indoor temperature reductions, energy savings, and improvements in the heat island index.

5.3.4.4 Institutional and Governance

- Implement targeted outreach programs reaching vulnerable populations (elderly, outdoor workers, low-income communities);
- Develop comprehensive heat literacy programs in schools;
- Create citizen reporting systems for heat-related issues with mandatory response timelines;
- **Municipal Heat Managers:** Require designated heat resilience officers in municipalities exceeding 100,000 population;
- Develop a mobile platform enabling citizens to

Innovative Financial Mechanisms

- **Heat Adaptation Fund:** Establish a dedicated municipal fund for heat adaptation projects
- **Graduated Tax Incentives:** Implement tiered property tax rebates based on heat reduction performance
- **Green Development Bonuses:** Offer FAR bonuses for developments exceeding standards
- **Performance-Based Incentives:** Create carbon credit systems for urban heat reduction
- **Environmental Impact Bonds:** Structure financing around measurable heat reduction outcomes
- **Heat Resilience Insurance:** Create premium discounts for properties with adaptation measures

report heat-related issues with georeferenced data, with mandatory municipal response within 48 hours;

- Establish micro-grant programs for community-led greening initiatives in vulnerable areas;
- Create volunteer networks to assist vulnerable populations during extreme heat events;
- Develop professional certification programs for urban planners, architects, and engineers;
- Implement cross-sector training programs across health, energy, transportation, and building sectors.

5.3.4.5 Governance & Coordination

- Adopt Comprehensive Heat Action Plans outlining long-term strategies for heat risk reduction;
- Establish interagency coordination committees involving multiple government departments;
- Require designated heat resilience officers in municipalities exceeding certain populations;
- Create regional technical assistance hubs providing expertise to smaller municipalities;
- Establish international knowledge exchange partnerships with cities facing similar heat

challenges;

- Develop international standards for measuring heat resilience progress;
- Establish phased implementation schedules with immediate (1-2 years), short-term (3-5 years), and long-term (6-10 years) actions;
- Create comprehensive monitoring systems measuring temperature reductions, surface changes, and human comfort;
- Mandate annual heat adaptation reporting against established key performance indicators;
- Establish five-year review cycles for heat adaptation strategies based on performance data;
- Create public dashboards showing real-time heat conditions and adaptation progress.

5.3.4.6 Regulatory Frameworks

- **Heat Impact Assessment Protocol:** Establish comprehensive HIA requirements for larger developments with mandatory mitigation for projected temperature increases above 0.5°C;
- **Urban Cooling Certification System:** Develop a multi-tier certification system (Bronze, Silver, Gold, Platinum) with clear performance metrics

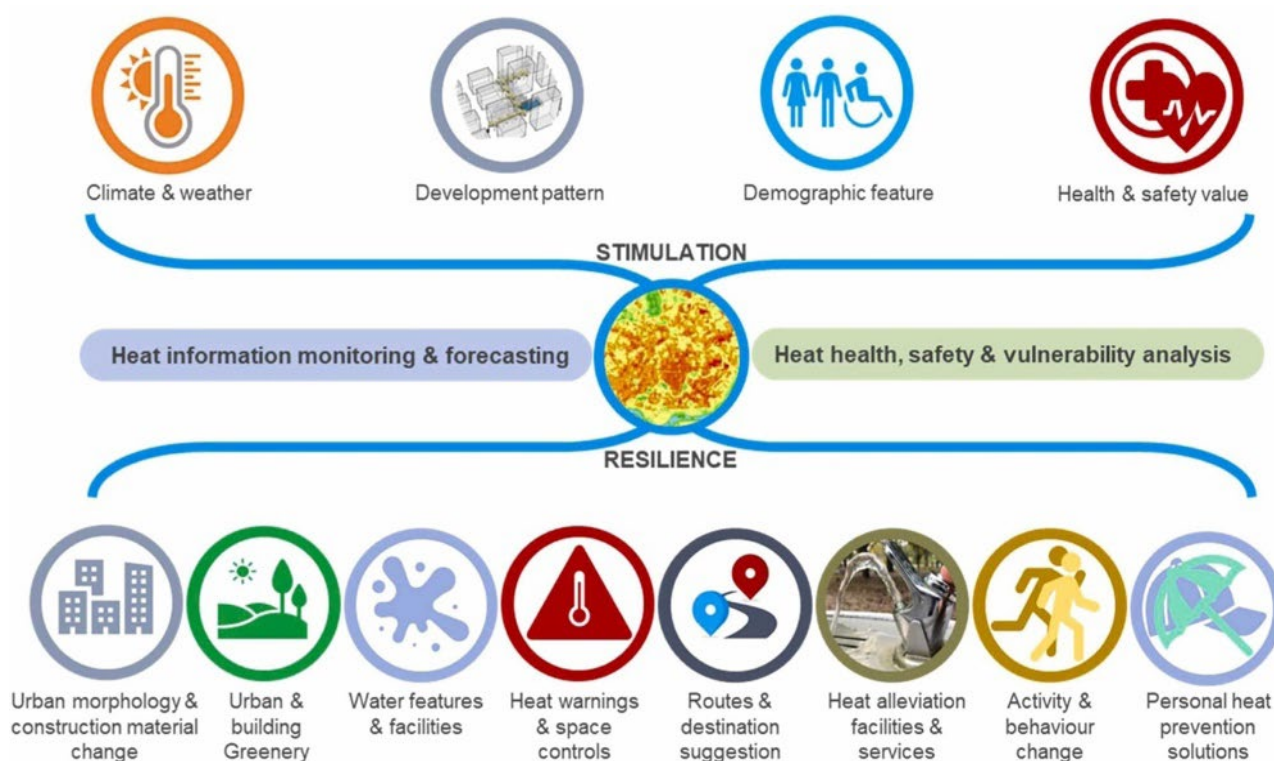


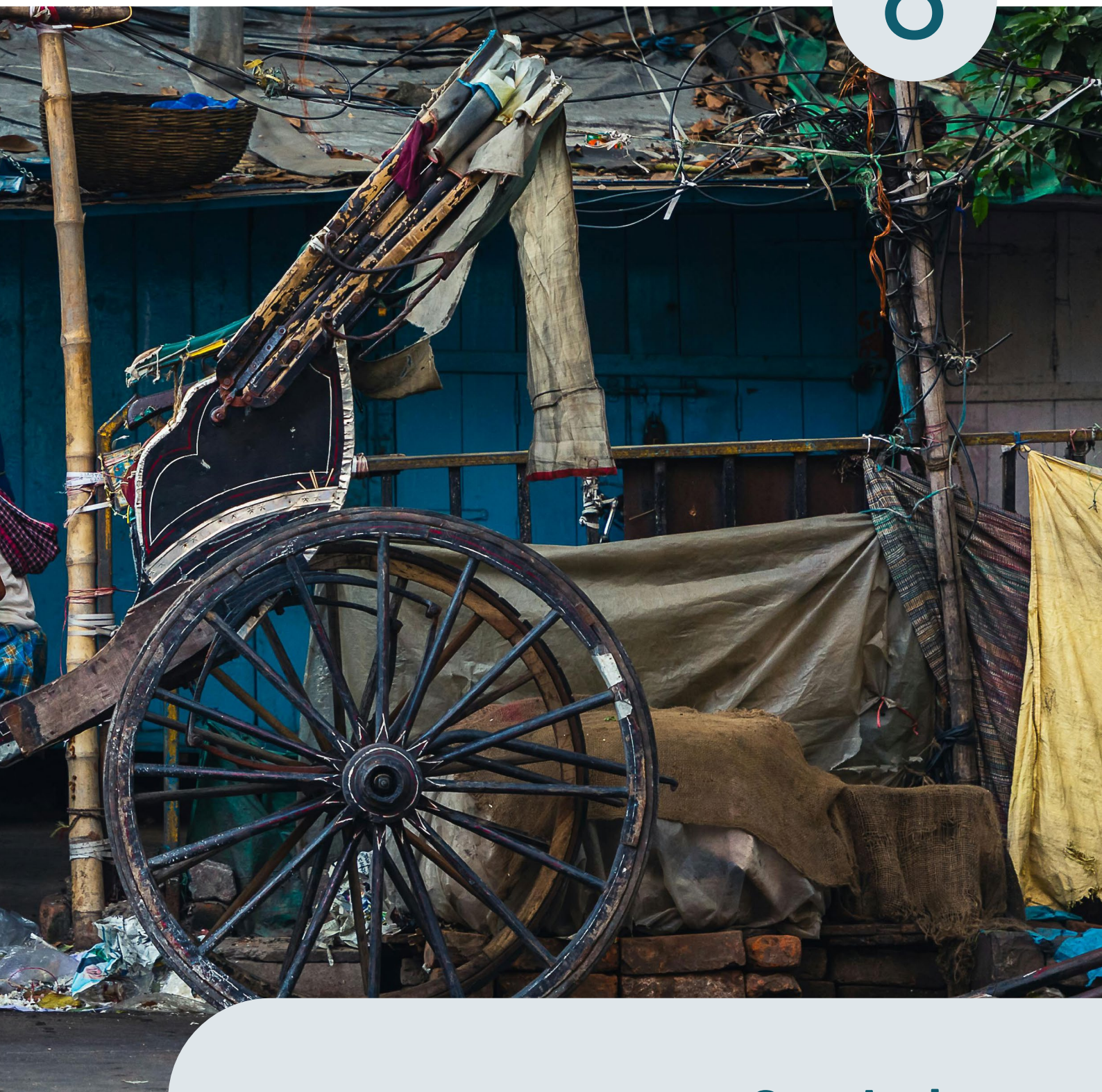
Figure 65: Demonstration of decision support tools for achieving performance-based heat planning, design and governance¹⁶⁶

for buildings and neighbourhoods;

- **Mandatory Cooling Action Plans:** Require all industrial, commercial, and institutional buildings on larger establishments to develop and implement heat management plans;
- **UHI Mitigation Ordinances:** Establish legally binding ordinances requiring new developments to demonstrate net-zero heat impact through a combination of mitigation strategies;

- **Heat Vulnerability Zoning:** Create heat vulnerability overlay zones with prescribed additional development standards based on demographic vulnerability indices.





Conclusion

6. Conclusion

Effectively addressing the escalating challenges of urban flooding and urban heat in Indian cities requires a transformative shift in urban planning and policy-making, moving beyond reactive measures towards proactive, preventative strategies deeply embedded in spatial plans and development guidelines. This report, **“Mainstreaming disaster risk reduction in spatial plans: a comprehensive guide for urban heat and urban flooding,”** provides a framework for integrating disaster risk reduction (DRR) strategies, specifically for these two critical hazards, into the very fabric of Indian cities. As detailed in the report, India’s vulnerability to natural disasters is significant, with 28 states and 8 union territories exposed to recurrent hazards. The year 2024 witnessed an alarming increase in extreme weather events, highlighting the urgency for proactive planning and mitigation measures.

The report underscores the need to move beyond traditional, siloed approaches and embrace an integrated, multi-sectoral framework that recognizes the complex interplay of factors contributing to flood and heat risks in urban areas. Rapid and often unplanned urbanization, coupled with the intensifying impacts of climate change, are exacerbating these challenges, leading to increased frequency and severity of extreme events. The consequences are profound, impacting critical infrastructure, disrupting economic activity, and disproportionately affecting vulnerable populations. The report argues that master plans and policy guidelines must transition from static documents to dynamic instruments that proactively anticipate and mitigate risks, ensuring that urban development aligns with the principles of resilience and sustainability.

This approach necessitates a fundamental shift in perspective, recognizing that urban environments are not merely static landscapes but complex, interconnected systems where decisions in one domain can have cascading effects across others. By integrating DRR into spatial plans, cities can create a framework for informed decision-making that prioritizes long-term resilience and promotes

sustainable urban growth.

Key recommendations outlined in the report include:

- **Flood Risk Reduction:** Spatial plans must adopt a flood risk-informed lens, integrating hazard mapping, vulnerability assessments, and climate projections into land-use planning and development control regulations. The report advocates for the implementation of innovative strategies such as overlay zoning, cluster subdivisions, and conservation easements to guide development away from flood-prone areas. It emphasizes the critical role of green and blue infrastructure in creating resilient sponge cities capable of managing excess rainwater, reducing runoff, and mitigating flood impacts. Investing in resilient building and infrastructure design that can withstand flood events is also paramount.
- **Urban Heat Mitigation:** The report emphasizes the importance of urban heat risk assessments to identify vulnerable areas and populations, informing targeted interventions. Promoting urban green infrastructure strategies, including urban forestry, green corridors, and vertical greening, is essential for reducing the urban heat island effect, providing shade, and enhancing evapotranspiration. Building codes and architectural design guidelines must mandate cool roofing technologies and incorporate passive cooling techniques to reduce heat absorption and improve energy efficiency. Integrating water management strategies, such as the creation of interconnected water bodies and the strategic placement of water elements, can enhance evaporative cooling and create micro-climate cooling zones. The report advocates for leveraging technology and monitoring systems to collect real-time data on urban heat, informing dynamic interventions and adaptive management strategies. Developing community resilience and public health strategies, including heat action plans, urban cooling centers, and public awareness campaigns, is crucial for protecting vulnerable populations during extreme heat

events. Integrating heat considerations into transportation and mobility planning is also necessary to ensure comfortable and safe transit options. Finally, developing economic and policy frameworks that incentivize heat-resilient development and provide financial support for adaptation initiatives is essential for creating a supportive environment for sustainable urban growth.

The report emphasises that effectively addressing urban flood and heat risks in India demands a collaborative, multi-sectoral approach that transcends

traditional planning paradigms. This requires bringing together urban planners, policymakers, engineers, architects, public health professionals, community stakeholders, and technology experts to develop holistic, integrated strategies that address the complex interplay of social, environmental, and economic factors. By embracing this transformative approach and integrating the guide's recommendations into spatial planning practices, Indian cities can chart a course toward greater resilience, sustainability, and liveability, ensuring the well-being of their citizens in the face of a changing climate.

Annexure-1

Table 4: Number of Deaths due to natural and man-made disasters

S. No.	Causes	2017		2018		2019		2020		2021		2022	
		Number of Deaths	% of total deaths	Number of Deaths	% of total deaths	Number of Deaths	% of total deaths	Number of Deaths	% of total deaths	Number of Deaths	% of total deaths	Number of Deaths	% of total deaths
1	Avalanche	38	0.50	5	0.10	35	0.40	13	0.18	8	0.11	29.00	0.36
2	Cyclone/ tornado/ Tsunami	147	2.10	161	2.30	48	0.60	53	0.72	120	1.68	9.00	0.11
3	Earthquake	2	0.00	0	0.00	1	0.00	0	0.00	0*	0.00	0.00	0.00
4	Epidemic	3	0.00	0	0.00	1	0.00	0*	0.00	0*	0.00	0.00	0.00
5	Exposure to Cold	738	10.30	757	11.00	796	9.80	776	10.48	618	8.67	720.00	8.93
6	Flood	496	6.90	500	7.30	948	11.60	959	12.95	656	9.21	547.00	6.79
7	Forest Fire	19	0.30	10	0.10	9	0.10	13	0.18	23	0.32	7.00	0.09
8	Heat Stroke	1127	15.80	890	12.90	1274	15.60	530	7.16	374	5.25	730.00	9.06
9	Landslide	231	3.20	404	5.90	264	3.20	295	3.98	380.0	5.33	269.00	3.34
10	Lightening	2885	40.40	2357	34.20	2876	35.30	2862	38.65	2880.0	40.42	2887.00	35.82
11	Starvation/ Thirst	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0.00	0.00
12	Torrential Rains	259	3.60	101	1.50	69	0.80	43	0.58	63	0.88	89.00	1.10
13	Causes other than above	1198	16.80	1706	24.80	1824	22.40	1861	25.13	2004	28.12	2773.00	34.40
	Total	7143	99.90	6891	100.10	8145	100.00	7405	100.00	7126	100.00	8060.00	100.00

Source: National Crime Record Bureau, Ministry of Home Affairs

Annexure-2

Table 5: Year-wise damage due to Natural Extreme Events in India

S. No.	Year	Human Live Lost (in No.)	Cattle Lost (in No.)	Houses damaged (in No.)	Cropped Areas Affected (in Lakh hectares)
1	2001-02	834	21269	346878	18.72
2	2002-03	898	3729	462700	21.00
3	2003-04	1992	25393	682209	31.98
4	2004-05	1995	12389	1603300	32.53
5	2005-06	2698	110997	2120012	35.52
6	2006-07	2402	455619	1934680	70.87
7	2007-08	3764	119218	3527041	85.13
8	2008-09	3405	53833	1646905	35.56
9	2009-10	1677	128452	1359726	47.13
10	2010-11	2310	48778	1338619	46.25
11	2011-12	1600	9126	876168	18.87
12	2012-13	946	24293	667319	14.44
13	2013-14	5677	102998	1210227	63.75
14	2014-15	1674	92180	725390	26.85
15	2015-16	1460	59057	1313371	31.09
16	2016-17	1487	41965	546518	25.49
17	2017-18	2057	46488	915878	47.44
18	2018-19	2045	123014	1557908	17.09
19	2019-20*	2391	15729	800067	63.98
20	2020-21**	1782	45844	1150677	50.89
21	2021-22#	2206	54946	146935	23.68
22	2022-23##	2104	14166	318253	19.16

Source: Disaster Management Division, Ministry of Home Affairs

Note: 1. * as on 31.12.2019, 2. **as on 02.12.2020, 3. # as on 31.12.2021, 4. ##25.11.2022

Annexure-3

Table 6: State wise damage due to natural extreme events

S. No.	State/UTs	2017 -18				2018 -19*			
		No. of Human lives lost	No. of Cat- tle heads lost	No. of Houses damaged	Cropped area affected (lakh hect- ares)	No. of Human lives lost	No. of Cat- tle heads lost	No. of Houses damaged	Cropped area affected (lakh hect- ares)
1	Andhra Pradesh	31	55	6557	0	81	5884	47855	2
2	Arunachal Pradesh	48	3564	1379	0	33	47	1647	0
3	Assam	160	2763	111070	3	53	122	77948	0
4	Bihar	514	275	118410	8			920	-
5	Chhattisgarh	52	102	909	0	7	11	145	-
6	Goa	1	0	61	0	-	-	74	-
7	Gujarat	229	16381	42834	11	72	361	5202	-
8	Haryana	-	-	-	-	3	2	43	-
9	Himachal Pradesh	75	199	2195	1	343	416	5886	0
10	Jammu & Kashmir^	7	4	90	-	31	32	42	-
11	Jharkhand	12	3	2668	-	-	-	-	-
12	Karnataka	70	745	1533	-	67	240	7865	4
13	Kerala	130	77	5880	-	477	76830	654062	1
14	Madhya Pradesh	-	-	-	-	31	2	191	-
15	Maharashtra	134	164	-	-	106	1560	-	-
16	Manipur	16	2902	17821	1	25	142	10820	0
17	Meghalaya	11	-	163	-	9	4632	13100	0
18	Mizoram	13	14	3452	0	-	-	-	-
19	Nagaland	22	665	7700	0	12	896	5202	0
20	Odisha	8	399	562	0	102	4812	62341	4
21	Punjab	4	6	34	-	14	29	229	1
22	Rajasthan	80	5711	54776	8	17	8	-	-
23	Sikkim	11	80	810	0	3	-	83	-
24	Tamil Nadu	48	8671	13465	0	97	21790	567453	1
25	Telangana	-	-	-	-	-	-	-	-
26	Tripura	17	13	3222	-	22	4167	40897	0
27	Uttar Pradesh	110	101	21545	4	105	140	28063	3
28	Uttarakhand	57	737	1380	-	69	770	2648	1
29	West Bengal	197	2857	497362	11	266	93	23964	0
30	Puducherry	-	-	-	-	-	28	1228	-
	Total	2,057	46,488	9,15,878	47.440	2045	123014	1557908	17.10

Source: Disaster Management Division, Ministry of Home Affairs

Note: 1. ^: This is the unified data for UT of Jammu and Kashmir & UT of Ladakh. 2. -: Nil/Data not provided. 3. *: As on 25.03.2019

Annexure-4

Table 7: Government Expenditure on account of Natural Calamities (Rs.Lakh)(as on 11.12.2023)

S. No.	State/ UT	2018-19 (Accounts)	2019-20 (Accounts)	2020-21 (Accounts)	2021-22 (Accounts)	2022-23 (Budget Estimates)	2022-23 (Revised Estimates)	2023-24 (Budget Estimates)
1	Andhra Pradesh	1,45,783.5	1,10,379.3	2,82,412.3	1,85,096.9	2,00,898.0	1,02,196.7	2,08,057.3
2	Arunachal Pradesh	16,880.3	7,150.0	32,544.2	18,155.0	27,600.0	30,382.1	32,643.0
3	Assam	52,504.4	56,001.1	62,031.4	59,740.1	1,91,630.2	3,47,493.2	1,42,895.8
4	Bihar	1,60,713.8	1,10,940.6	6,63,564.6	3,80,298.7	3,65,963.1	4,11,608.1	5,08,502.5
5	Chhattisgarh	32,220.8	34,427.9	37,813.4	51,973.1	43,846.6	43,846.6	68,524.7
6	Delhi	2,110.4	4,656.0	65,921.7	1,19,704.7	39,456.0	49,647.5	24,521.0
7	Goa	287.5	991.6	3,852.3	3,428.6	2,547.2	2,547.2	2,369.7
8	Gujarat	74,306.0	1,55,089.0	1,76,082.0	2,84,309.0	76,897.0	74,703.0	1,06,197.0
9	Haryana	40,862.8	40,305.5	69,576.8	75,459.2	57,250.3	74,488.5	74,002.2
10	Himachal Pradesh	50,558.8	74,399.0	45,716.8	36,300.0	47,600.0	76,680.0	50,100.0
11	Jammu & Kashmir^	28,240.5	51,469.3	31,158.2	31,108.0	31,990.2	31,142.3	31,138.7
12	Jharkhand	46,854.6	22,123.6	97,898.5	0.3	1,49,684.2	1,49,686.2	1,59,027.7
13	Karnataka	1,62,892.0	4,48,594.8	2,31,581.2	5,20,227.6	1,15,178.1	2,96,085.1	1,20,643.8
14	Kerala	3,13,376.1	22,146.5	46,072.2	46,397.1	45,500.0	47,819.1	47,060.0
15	Madhya Pradesh	1,43,399.6	2,83,801.5	4,94,436.7	2,77,183.5	2,04,030.7	1,43,345.1	3,14,671.1
16	Maharashtra	8,65,424.1	10,95,847.6	8,48,848.3	8,08,587.7	6,79,745.8	7,94,831.2	7,53,777.9
17	Manipur	6,117.9	8,766.4	4,484.1	779.6	8,688.9	10,107.4	5,849.4
18	Meghalaya	1,651.9	4,470.8	5,640.9	9,780.1	7,872.3	9,323.1	16,406.6
19	Mizoram	1,054.4	3,490.2	3,727.9	682.9	5,450.0	7,186.0	5,850.0
20	Nagaland	20,784.1	20,622.7	4,821.9	5,068.9	6,245.0	16,335.0	14,145.0
21	Odisha	1,27,700.7	4,29,024.6	2,65,330.2	2,67,457.8	3,23,096.0	3,29,596.0	3,73,000.1
22	Puducherry	2,118.7	6,066.5	1,237.1	1,649.3	1,500.3	3,329.7	1,123.7
23	Punjab	44,284.6	50,893.7	62,005.3	1,42,776.0	91,868.2	1,00,119.7	93,428.2
24	Rajasthan	2,05,400.0	2,60,947.4	2,83,621.0	2,02,026.3	2,08,476.8	2,29,693.3	2,68,850.5
25	Sikkim	9,337.3	4,114.4	14,171.1	6,436.1	14,614.0	10,902.0	16,035.3
26	Tamil Nadu	2,23,847.1	85,930.8	12,02,169.6	9,70,444.3	1.9	63,688.2	1.7
27	Telangana	29,728.1	1,83,616.0	3,65,110.8	11,893.6	63,616.7	63,616.7	63,608.2
28	Tripura	5,858.6	3,960.0	8,697.6	6,514.7	8,101.0	8,924.2	8,466.1
29	Uttar Pradesh	59,934.2	1,31,679.0	1,10,281.9	3,39,900.4	3,76,266.2	3,75,775.6	4,28,400.9
30	Uttarakhand	40,350.9	35,829.4	1,32,150.7	1,29,758.0	1,40,313.6	1,40,194.7	1,33,311.7
31	West Bengal	68,185.3	1,68,256.3	3,60,618.0	1,70,376.0	1,42,309.9	85,816.5	1,80,240.2
	Total	29,82,769.0	39,15,991.5	60,13,578.7	5,26,676.3	7,81,543.6	8,12,681.8	7,63,330.8

Source : State Finances: A Study of Budgets, Reserve Bank of India (RBI),

Note: ^ :This is the unified data for UT of Jammu and Kashmir & UT of Ladakh

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