



CII-ITC Centre of Excellence
for Sustainable Development



Confederation of Indian Industry

Disaster Resilience Framework

For Eluru and
West Godavari Districts

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Foreword



Mr. Chandrajit Banerjee

Director General

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The state of Andhra Pradesh, with its strategic location along India's southeast coast, makes it a vital industrial and economic hub with immense opportunities in maritime trade, fisheries, and port-led development. This advantageous location fuels the state's growth and connectivity, positioning it for accelerated progress. Andhra Pradesh' rich ecology, spanning from the Eastern Ghats, the Coringa mangrove forests, and Krishna River delta wetlands, not only supports the state's critical nature capital, including endangered & endemic species, but also forms a vital part of its socio-economic fabric.

However, alongside these prospects, Andhra Pradesh faces formidable challenges, due to its extensive coastline, which is highly vulnerable to tropical cyclones and coastal hazards. The increasing intensity of extreme climate events creates significant risks for the state's economic landscape. More critically, the growing occurrences of severe climate events are jeopardising the livelihood and well-being of communities that form the backbone of the state's vibrant socio-economic fabric.

The districts of West Godavari and Eluru, with their growing agro-processing, aquaculture, and manufacturing sectors, illustrate the dual challenge of development and vulnerability. As industries continue to expand in the region, especially in sectors such as food processing, textiles, logistics, petroleum, chemicals, and renewable energy, embedding climate resilience into planning and operations will be key to sustainable growth. However, frequent floods and storms damage the industrial infrastructure, disrupt operations, and affect workforce stability in both regions, making targeted risk assessment and adaptation planning critical for the regions.

Through the report "Disaster Resilience Framework for Eluru and West Godavari Districts", CII shares insights and replicable models for coastal industrial zones across India. By synthesising climate analytics, spatial mapping, and community engagement, CII presents a comprehensive resilience framework, demonstrating that climate risk planning must be locally contextualised, scientifically informed, and institutionally supported.

Strengthening early warning systems, investing in resilient infrastructure, adopting nature-based solutions, and promoting livelihood diversification will be critical, as they can address two concerns – risk mitigation and business continuity. CII believes that such integrated approaches can safeguard industrial growth while ensuring environmental sustainability and social well-being. Building climate resilience in Andhra Pradesh is not just a social imperative; It is an economic necessity. CII calls for urgent, united action to safeguard the state's growth, natural ecosystems, and social well-being.

Message



Shri Prakhar Jain

Director (Disaster Management) Ex-Officio Deputy Secretary to Government, Revenue (DM) Department, Managing Director (FAC), Andhra Pradesh disaster Management Authority (APSDMA)

Climate change is increasingly reshaping the nature and frequency of hydro-meteorological disasters in Andhra Pradesh. The State has long been a leader in strengthening disaster risk management and enhancing resilience against climate-induced hazards. Through proactive governance, strong institutional mechanisms, and empowered community networks, Andhra Pradesh has built significant capacity to anticipate and respond to natural disasters.

Despite these efforts, the impacts of climate change, demand continued investment in participatory planning, integrated risk management, and long-term resilience strategies.

This report, “Disaster Resilient Framework – West Godavari and Eluru Districts,” provides evidence-based insights into local vulnerabilities and adaptive capacities. It underscores the importance of localized risk assessments, resilient housing, enhanced early warning systems, and ecosystem-based solutions to mitigate the effects of cyclones and other climate hazards.

The study further highlights the need for inter-departmental coordination, private sector participation, and active community engagement to ensure inclusive and sustainable resilience efforts. It calls for integrating risk information into district and sectoral planning while promoting community-led resilience.

Findings from West Godavari and Eluru are particularly valuable in shaping future strategies for both coastal and inland resilience. These insights, reflecting the State’s diverse socio-economic and geographic contexts, can inform broader resilience planning across Andhra Pradesh.

The Government remains firmly committed to fostering multi-stakeholder partnerships and advancing data-driven policy actions that enhance the resilience of communities and critical infrastructure.

I commend the collaborative efforts of all partners and institutions involved in this study, and look forward to continued cooperation in building a safer and more resilient Andhra Pradesh.

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List of Abbreviations

Abbreviation	Full Form
APSAC	Andhra Pradesh Space Applications Centre
APSDMA	Andhra Pradesh State Disaster Management Authority
ASCE	American Society of Civil Engineers
ASHA	Accredited Social Health Activist
AWS	Automated Weather Station
CRED	Centre for Research on the Epidemiology of Disasters
CSE	Centre for Science and Environment
DDMP	District Disaster Management Plan
DRIPS	Disaster Risk Transfer Parametric Insurance Solutions
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
DRTPS	Disaster Risk Transfer Parametric Solution(s)
DST	Department of Science and Technology
EQC	Earthquake Commission (New Zealand)
ESA	European Space Agency
ESCS	Extremely Severe Cyclonic Storm
EUR	Euro
EWS	Early Warning System
FAO	Food and Agriculture Organization
FC	Finance Commission (of India)
GFDRR	Global Facility for Disaster Reduction and Recovery
GIC	General Insurance Corporation of India (GIC Re)
GIS	Geographic Information System

GRB	Godavari River Basin
HAM	Amateur Radio (Ham Radio)
HAM	Amateur Radio (Ham Radio)
HFA	Hyogo Framework for Action
HPC	High Power Committee (on Disaster Management)
HPN	Humanitarian Practice Network
IAG	Insurance Australia Group
IAS	Indian Administrative Service
IDF	Intensity–Duration–Frequency (rainfall)
IDMC	Internal Displacement Monitoring Centre
IEC	Information, Education and Communication
IMD	India Meteorological Department
IRDAI	Insurance Regulatory and Development Authority of India
ISF	InsuResilience Solutions Fund
ISRO	Indian Space Research Organisation
IUCN	International Union for Conservation of Nature
MHT	Mahila Housing Trust
MPCS	Multi-Purpose Cyclone Shelter(s)
NDMA	National Disaster Management Plan
NDMP	National Disaster Management Plan
NGO	Non-Governmental Organisation
NIO	North Indian Ocean
NOAA/TPC	National Oceanic and Atmospheric Administration / Tropical Prediction Centre
NREGA	National Rural Employment Guarantee Act
NSDMA	Nagaland State Disaster Management Authority

NTR	Nandamuri Taraka Rama Rao District (Andhra Pradesh)
NZD	New Zealand Dollar
OHC	Ocean Heat Content
PHC	Primary Health Centre
PMP	Probable Maximum Precipitation
PMSS	Probable Maximum Storm Surge
SBI	State Bank of India
SDMA	State Disaster Management Authority
SDMP	State Disaster Management Plan
SEOC	State Emergency Operations Centre
SFDRR	Sendai Framework for Disaster Risk Reduction
SOP	Standard Operating Procedure
SRTM-DEM	Shuttle Radar Topography Mission – Digital Elevation Model
SST	Sea Surface Temperature
UN	United Nations
UNDP	United Nations Development Programme
UNDRR	United Nations Office for Disaster Risk Reduction
UNEP	United Nations Environment Programme
UNICEF	United Nations Children’s Fund
UNISDR	United Nations International Strategy for Disaster Reduction
USD	United States Dollar
VSCS	Very Severe Cyclonic Storm
WBCIS	World Meteorological Organization
WMO	World Meteorological Organization
WRIS	Water Resources Information System



Executive Summary

This report synthesizes key findings and actionable recommendations for strengthening disaster risk reduction (DRR) and building resilience in the districts of Eluru and West Godavari, Andhra Pradesh. Both districts face recurring challenges from seasonal floods and cyclones, compounded by infrastructural weaknesses, socio-economic vulnerabilities, and environmental degradation. The analysis draws from on-ground consultations, government inputs, and community insights.

In Eluru, frequent overflows from the Budameru and Tamileru canals disrupt life during the flooding season. Disruptions to agriculture and fishing-based livelihoods result in seasonal migration and economic insecurity. Kolleru Lake, a key aquaculture hub, suffers from both flooding in monsoons and drying during summers, underscoring the need for sustainable water management. The district also struggles with weak communication infrastructure during a disaster, such as non-functional HAM radios, or mobile communications vans/ satellite phones affecting real-time disaster response. ns limited. Despite these gaps, Eluru benefits from strong traditional knowledge on flooding, with local administration, panchayat members, ASHA (Accredited Social Health Activist and Anganwadi workers playing a pivotal role in community-led responses. Traditional knowledge on flood progression based on the River Godavari's behaviour is often used by local administration. The District Collector emphasized the importance of improved Early Warning Systems (EWS), detailed stream mapping, and enhanced inter-agency coordination. Since the flooding is from River Godavari, the EWS established needs to be transboundary i.e. across states and districts. Post-disaster vulnerabilities like snake bites, poor sanitation, and lack of life-saving gear exacerbate the risk for women, children, and elderly. Communities voiced the need for better road access, resilient housing, ground-level weather monitoring, and long-term livelihood support to address systemic vulnerabilities.

In West Godavari, coastal mandals such as Narsapuram and Mogalthuru frequently experience flooding and waterlogging due to blocked canals like Nandamuru and poor drainage systems. Many cyclone shelters are either in disrepair or have been repurposed, with power outages and outdated communication tools further hampering emergency preparedness. The district's economic base in aquaculture and paddy farming faces climate-induced risks, and traditional fishers lack basic infrastructure like fish landing jetties. Migration for employment is common, disrupting household stability.



The District Collector especially highlighted better solid waste management in order to reduce the clogging of storm water drains. Additionally, pollution from fish processing units and unregulated aquaculture has degraded water quality and biodiversity. There is currently no formal mangrove restoration initiative in place, and coastal erosion continues to threaten vulnerable settlements despite some ongoing gabion wall construction projects. Women in fishing communities face gender-specific vulnerabilities, working in difficult conditions in fish processing units while contributing to household incomes. On a positive note, community preparedness initiatives, such as mock drills conducted by the Red Cross, have begun improving awareness and response capacity, although coverage remains limited.

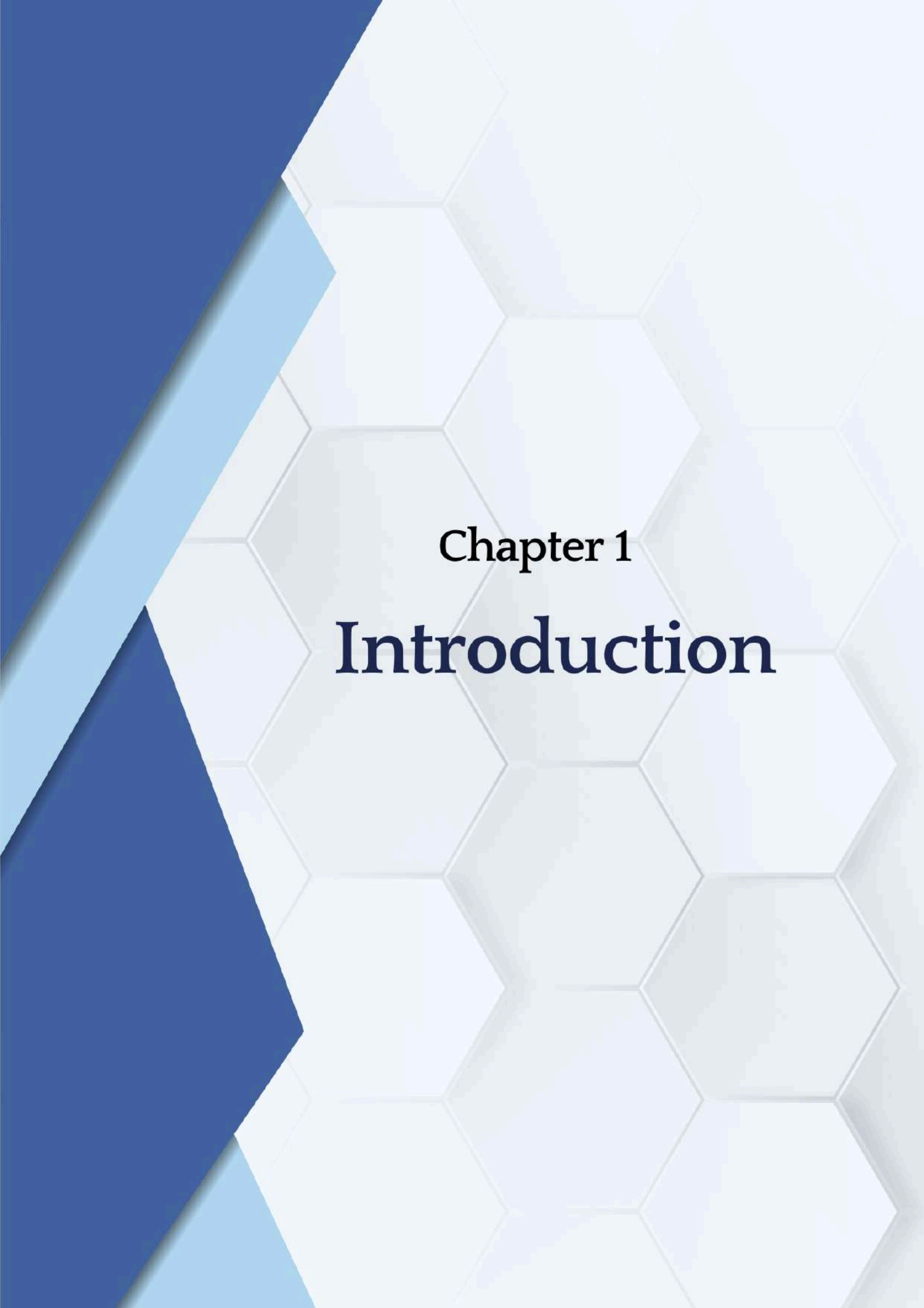
The report recommends a multi-pronged strategy to enhance resilience in both districts. A detailed hazard and vulnerability assessment should be undertaken to inform local planning. Establishing all-weather District Emergency Operation Centres (DEOCs) with real-time data access, expanding Automated Weather Stations (AWS), and enabling cell broadcast-based EWS are essential. Investments in retrofitting critical infrastructure such as schools and hospitals are necessary to withstand future climate events. From an ecosystem and infrastructure perspective, wetland conservation—particularly of Kolleru Lake—and afforestation of floodplains are crucial. Small water retention structures in forest areas and nature-based embankments using Vetiver grass can reduce runoff and mitigate flooding. Regular desilting and maintenance of drainage systems are critical to prevent waterlogging.

For livelihood resilience, the report recommends promoting parametric insurance products for agriculture, fisheries, and MSMEs (Micro, Small and Medium Enterprises), along with eco-certification in aquaculture and solar-powered cold storage for fishers. In agriculture, promoting climate-resilient seeds and impact-based early warnings aligned with cropping cycles will help reduce loss. Community-level preparedness can be scaled through structured training in evacuation, health risk management, school safety, and shelter operations. Developing village-level disaster management plans, mock drills, and inter-agency coordination protocols will help institutionalize preparedness. Furthermore, a clear Standard Operating Procedure (SOP) for early warnings using local language and color-coded alerts will improve last-mile communication.

From a govt standpoint, updating the State and District Disaster Management Plans (SDMP/DDMP) with recent learnings, and integrating DRR into land-use zoning and planning, is imperative. Building inclusive DRR policies and offering basic DRR training to local government staff, ASHA workers, and frontline officials will enhance institutional capacity.



A focus on gender-responsive policies and community volunteer networks will improve equity and outreach. Finally, the report calls for a structured post-disaster recovery and rehabilitation framework. Together, these measures can pave the way for a more resilient, inclusive, and climate-prepared future for Eluru and West Godavari. On a positive note, community preparedness initiatives, such as mock drills conducted by the Red Cross, have begun improving awareness and response capacity, although coverage remains limited.



Chapter 1

Introduction



Introduction

According to the World Meteorological Organisation (WMO), the growing impacts of a changing climate are reshaping how we live, work, and respond to risk. The frequency of disasters linked to climate has increased by fivefold in the last half-century (Amrita Goldar, 2024). Findings from UNDRR-CRED report published in 2020, that compares the frequency of disasters in two time spans, 1980–1999 and 2000–2019, indicate an intensive increase in the frequency of disasters. Between the two observed periods, a significant increase in disaster events and associated impacts has been recorded. During the earlier period, 4,212 disasters were reported, resulting in 1.19 million fatalities, affecting 3.25 billion people, and causing economic losses amounting to USD 1.63 trillion. In contrast, the later period witnessed a sharp rise with 7,348 disasters, leading to 1.23 million deaths, impacting 4.03 billion individuals, and generating economic losses estimated at USD 2.97 trillion.

Similarly, in the context of India, the situation remains equally concerning. According to the Centre for Science and Environment (2022), the country has experienced a notable increase in both the frequency and intensity of disasters, reflecting broader global trends in climate-induced and natural hazards. India is among the most exposed countries to climate change, both from its physical vulnerability to climate-related hazards and the economic reliance of most of its people on climate-sensitive sectors like agriculture and allied industries. The different disasters India is prone to is also immense with 65% of its land drought-prone, 12% flood-prone, and 8% cyclone-prone. This underscores increasing need to prioritise on a building system to address the a robust disaster risk reduction mechanism which is scientific, community centric, nature based which is supported by strong and coherent policy frameworks.

1.1. Resilience Framework at Global Level

As per the terminology suggested by (UNDRR, 2017), resilience is defined as ‘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 preservation and restoration of its essential basic structures and functions through risk management’. Resilience is developed through proactive measures like risk identification, preparedness planning, and integrating risk management into development policy so that communities are better prepared for uncertainties and have minimized risks and vulnerabilities (UNDRR, 2017).

The Sendai Framework for Disaster Risk Reduction (SFDRR), following Hyogo Framework for Action (HFA) as shown in *Figure 1 and Figure 2*, underlines the value of assessing disaster risk, risk governance, investing in resilience, and disaster preparedness.

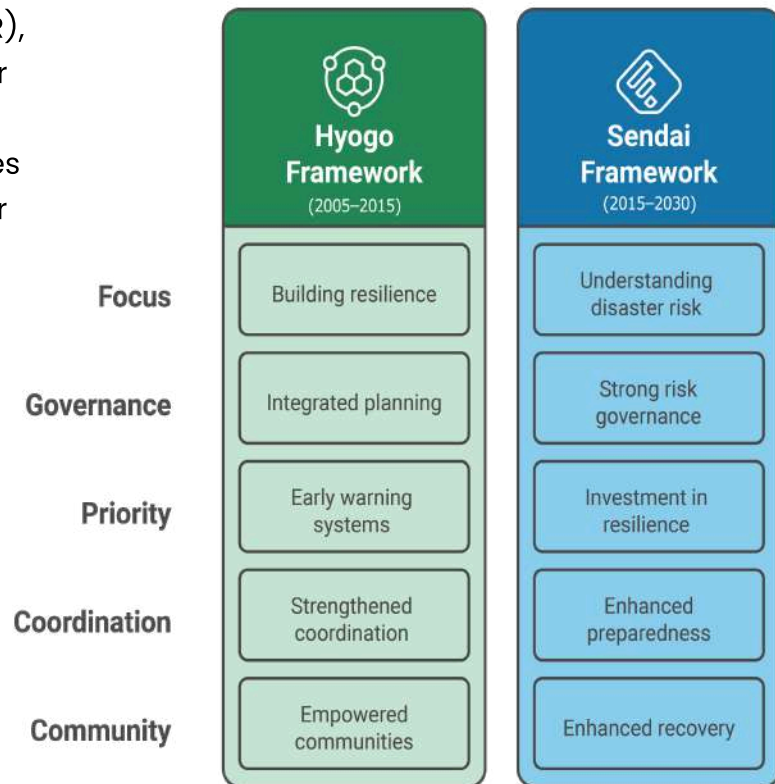


Figure 1: Strengthening Resilience: A Comparison of Hyogo and Sendai Approaches.



Figure 2: 4 SFDRR Priorities & 7 Targets.



1.2. Disaster Risk Reduction in India

Over time, managing disasters has changed from being response and relief-centric to a greater emphasis on preparedness and mitigation. Some key milestones are:

- **High Power Committee**

The Government of India set up the High-Power Committee (HPC) on Disaster Management in 1999 under the Chairmanship of J.C. Pant to study and advise on a holistic and integrated disaster management approach. HPC characterized 30 types of disasters and recommended sector-specific and cross-cutting preparedness and mitigation strategies. It provided the platform for the institutional setups that emerged in subsequent years (Government of India, 2001).

- **Disaster Management Act, 2005 and Amendment 2024**

The Disaster Management Act, 2005 extending to the whole of India, provides the effective management of disasters and for matters connected therewith or incidental thereto'. The Disaster Management Act, 2005 lays down the institutional structure in India. National Disaster Management Authority (NDMA) and State Disaster Management Authority (SDMA) as the bodies responsible for disaster management at National and state levels. The new amendment also mandates creation of Urban Disaster Management Authority along with the district disaster Management Authority to ensure disaster risk management is equally prioritised in urban areas. Ministry of Home Affairs retains responsibility for overall steering of national level disaster response through the National Disaster Response Force. The Act, 2005 also mandates disaster management plan to be developed at National, State and District level. Creating financial provisions too are envisioned under the Act.

- **National Policy on Disaster Management, 2009**

The National Policy on Disaster Management of 2009 entails the National vision to build a safe and disaster resilient India by developing a holistic, proactive, multi-disaster and technology driven strategy for disaster management. The policy intends to achieve disaster management through a culture of prevention, mitigation and preparedness. The policy emphasises on participation of communities and Non-Governmental Organizations (NGO) for disaster management. It aligned itself to international frameworks such as the HFA, 2005.



- **National Disaster Management Plan (NDMP) – 2016 & 2019**

India's NDMP 2016 was the very first national plan to align with the SFDRR. NDMP 2019 reaffirmed this in its alignment, focusing on four SFDRR priority areas of understanding disaster risk, disaster governance strengthening, investing in disaster risk reduction for resilience, and disaster preparedness to ensure effective response and recovery. It underlined the "whole-of-society" approach and the integration of climate risk, gender, disability, and ecosystem-friendly strategies (NDMA, 2019).

- **15th Finance Commission (FC) – Disaster Risk Financing**

The 15th Finance Commission (2021–26) made significant provisions for disaster risk management under its recommendations for setting up State and National Disaster Risk Management Funds. It emphasized risk mitigation, capacity development, and sanctioned ₹1.6 lakh crore for disaster management. The Commission underscored the role of disaster risk financing and urged the development of early warning centres, resilient infrastructure, and nature-based solutions (15th FC Report, 2020). The commission also recommended special funds for management of urban floods and coastal and river erosion.

1.3. Disaster Management Andhra Pradesh

1. Institutional Structure of Disaster Management

At the highest level, the Chief Minister and the State Cabinet lead the Crisis Management Group. This group works in close coordination with national agencies such as IMD, ISRO, and NDMA, as well as major state departments and international partners like United Nations Development Programme (UNDP) and United Nations Children's Fund (UNICEF). The structure of disaster management in the State is given in *Figure 3*, illustrating a multi-level and multi-institutional system to support response, mitigation and recovery actions. Operational responsibility is handled by the Revenue Department and the State Emergency Operations Centre (SEOC), which guides and oversees emergency actions. These district-level authorities collaborate with the Andhra Pradesh State Disaster Management Authority (APSDMA), the District Disaster Management Authorities (DDMAs), and various line departments to ensure effective response planning and execution.



STATE LEVEL CYCLONE MANAGEMENT STRUCTURE

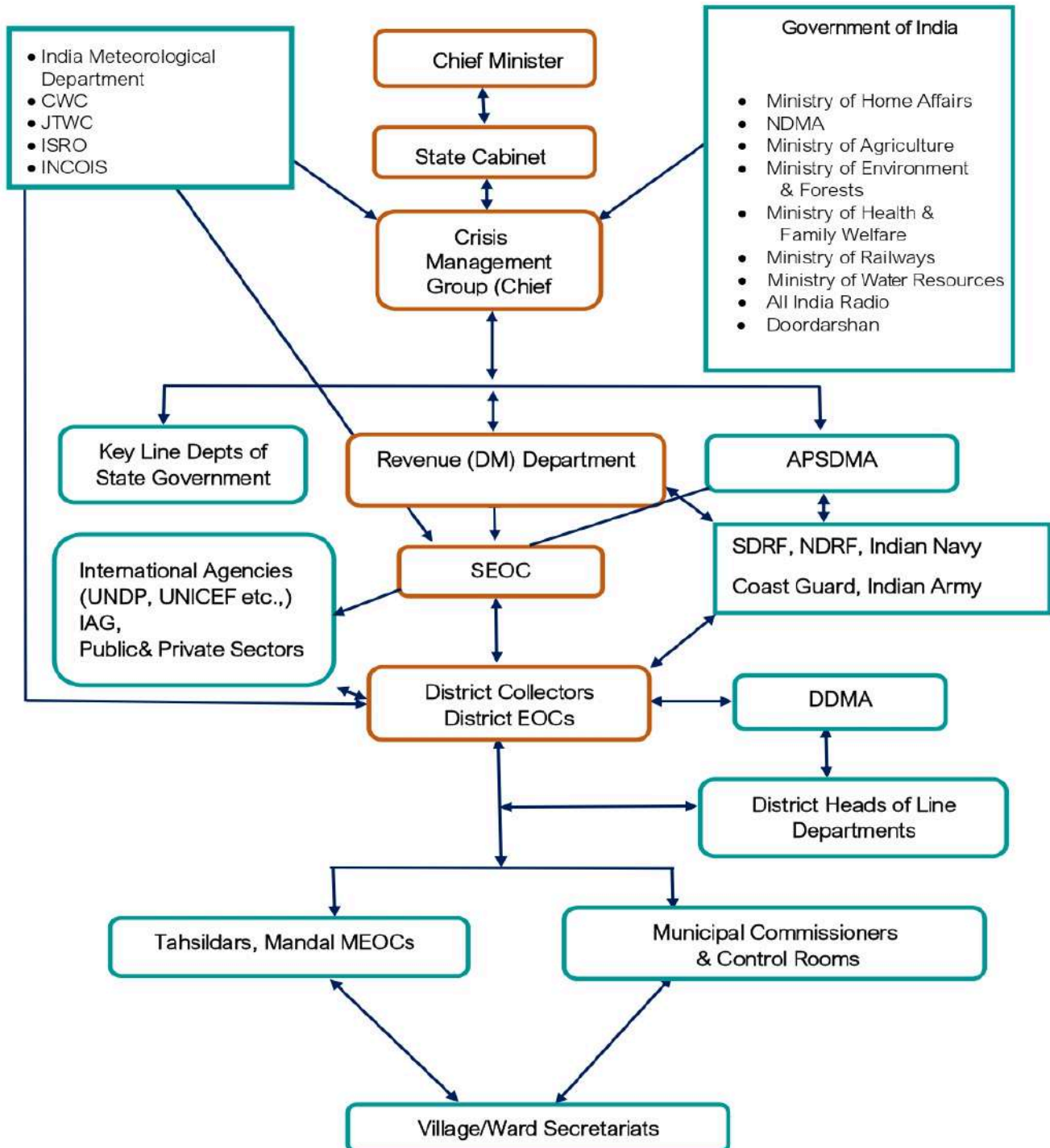


Figure 3 : Cyclone Level Management Structure.

2. Andhra Pradesh State Disaster Management Plan (APSDMP) (2017-18)

The State of Andhra Pradesh has taken proactive measures to be prepared and minimise damage in the event of a disaster. It adheres to the Sendai Framework, a global strategy, and incorporates climate change, which is now too prevalent to be disregarded. *Figure 4*, has been adopted from APSDMP 2017-18 that shows the key components of APSDMP. A moderate to severe cyclone makes landfall every two to three years. Nearly 44% of the state is vulnerable to tropical storms and their associated impacts. Drought conditions are also a major concern, with 34 mandals identified as severely affected, 353 as critically affected, and another 284 as semi-critical. Delta areas of the Godavari and the Krishna rivers, experience recurrent flood and drainage problems. The entire coastal belt of Andhra Pradesh falls under Seismic Zone III, placing it in the moderate-risk category for seismic activity (SDMA, 2017–2018). The Plan ensures that people are aware of what to do in the event of a flood or cyclone by collaborating with local communities and authorities. The State Emergency Operations Centre, or SEOC, is the command centre.



Figure 4 : Key Components of APSDMP

3. Cyclone Preparedness and Response Plan, 2018-19

The Cyclone Preparedness and Response Plan focuses on improving institutional systems to enable swift and well-coordinated action during cyclone events. A key element of the strategy is the involvement of local communities through village-level committees, which play a vital role in spreading information and preparing localized response plans. The plan focuses on the importance of readiness and prevention by providing clear evacuation protocols, establishing relief shelters, and ensuring the upkeep of critical infrastructure, such as river bunds. It includes a continuous learning approach—drawing on lessons from disasters occurred in the past to strengthen future planning.



The plan also focuses on conducting accurate risk assessments and ensuring the timely and fair distribution of relief supplies. It also promotes the use of modern technologies and digital information systems to support Early Warning Systems (EWS) and improve the overall effectiveness of emergency operations.

4. District Disaster Management Plan (DDMP) of West Godavari and Eluru Districts

The district of West Godavari was bifurcated into West Godavari and Eluru in 2021. The DDMP identifies cyclones, floods, landslides, fires, earthquakes, cloudbursts, Landslides, mudslides, and hailstorms as hazards affecting the district. But Cyclones have been identified as most destructive hazard in the district, with floods as second most affecting lives and livelihoods. The DDMP has identified role and responsibilities of the various district departments highlighting the steps/measures to be taken to manage disasters effectively. The DDMP identifies responsibilities and measures of Revenue Department, Irrigation Department, Fire Department, Home Department, Medical and Health Department, Civil Supplies Department, Rural Water Supply Department, Energy Department, and others. The measures are divided into three phases of warning, during, and after disaster, specifying steps to be followed by respective departments in each phase.

The first cyclone warning is issued when a storm is expected to affect the coast within 48 hours, prompting immediate communication to district and local officials for wide publicity and departmental preparedness. Upon receipt of the second warning, the storm's severity is classified as a cyclone, severe cyclone, or hurricane, indicating escalating risk. At this stage, the Revenue Department is responsible for evacuating people from low-lying areas to safer locations like cyclone shelters, schools, or religious buildings, and ensuring proper rehabilitation arrangements.

5. Swarna Andhra @2047

Swarna Andhra @ 2047¹ is an ambitious vision unveiled by Andhra Pradesh Chief Minister N. Chandrababu Naidu, aiming to transform the state into a "wealthy, healthy, and happy" society by the centenary of India's independence in 2047. The plan sets a target to elevate the state's per capita income from below \$3,000 to \$42,000, positioning the global Telugu community at the forefront of development. The plan envisions "one family, one entrepreneur" to foster widespread economic participation. In addition, at the heart of this

¹ <https://swarnaandhra.apcfss.in/SwarnandhraLogin> - Accessed on 11/07/2025



vision is a climate-first approach to development, emphasizing resilience, sustainability, and ecological balance. The state aims to build robust mitigation and adaptation capacities to minimize disaster-induced damages and economic losses by 2029.

1.4. Objectives of the Study

- To **understand the changing attributes** (frequency, intensity, spread, and loss & damage, etc.) of **tropical cyclones** and **floods** in line with the uncertainties under various climate change scenarios.
- To **propose measures** to enhance community-based programs in Disaster Risk Reduction (DRR), improve the SEOC for ease of communication between State-District and Mandal/Gram Panchayat, Capacity building programs on DRR, insurance, and leverage technology for DRR.
- Develop a **resilience framework** for the District of West Godavari and Eluru with a specific focus on infrastructure/ built environment, community, natural systems, and institutions.

1.5. Study Area

West Godavari District, with its headquarters at Bhimavaram, lies in the western delta region of the River Godavari and comprises 20 mandals. Bounded by the River Godavari to the east, Eluru to the west, Rajahmundry to the north, and Krishna District and the Bay of Bengal to the south, the district is characterized by fertile alluvial plains. It has a moderate climate with temperatures ranging from 19.0°C to 36.2°C and receives an average annual rainfall of 1106.9 mm from both southwest and northeast monsoons. Agriculture in the district heavily depends on the Godavari Western Delta irrigation system. Covering 2,178.4 sq. km, the district accounts for 1.34% of the state's area and has a population of 1.78 million as per the 2011 Census, with a population density of 817 persons per sq. km.

Eluru District, established in 2022 with its headquarters at Eluru, was formed by reorganizing parts of the old West Godavari District and incorporating eight mandals from the old Krishna District, totalling 27 mandals and three revenue divisions. Spanning an area of 6,411.56 sq. km, the district accounts for 3.9% of Andhra Pradesh's total area and has a population density of 312 persons per sq. km based on 2011-Census data. It comprises 655 revenue villages, of which 624 are inhabited, along with 550 gram panchayats. The district reflects a diverse geographic and socio-economic profile shaped by its recent administrative formation as shown in *Figure 5*.

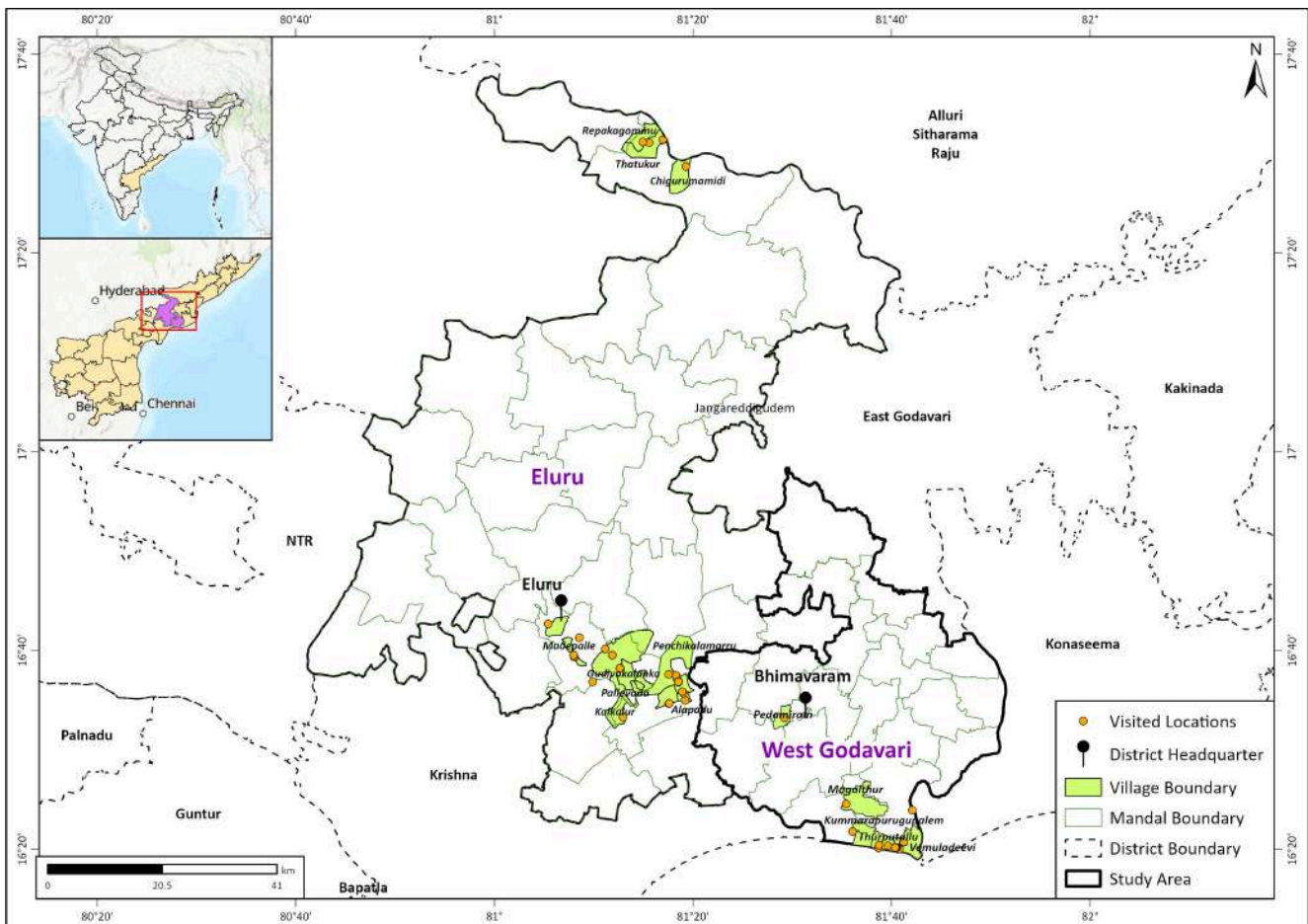


Figure 5 : Map of West Godavari and Eluru District.

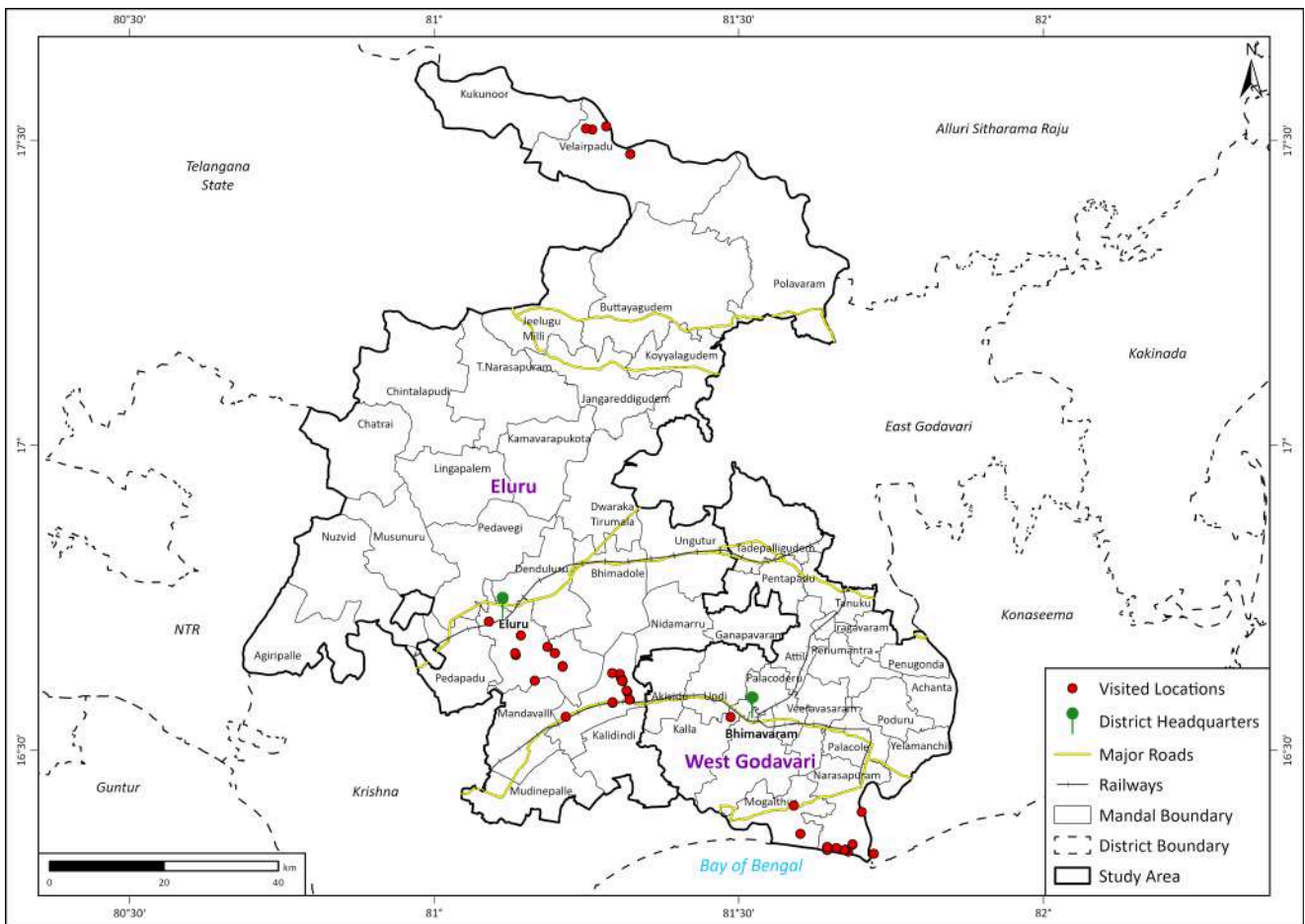


Figure 6 : Locations Identified During Field Visit and Stakeholder Engagement.

The key visited locations, as shown in Figure 6, include **Madepalle, Gudivakalanka, Penchikalmarru, Alapudu, Kaikalur, Pallevada, Rapakagommu, and Chigurumamidi** in Velairpadu Mandal, distributed across different parts of the district. Table 1 shows the features of West Godavari and Eluru for both districts. The data for West Godavari and Eluru districts presented in this report has been sourced from official records. Population, literacy rate, and sex ratio figures are based on Census Data, 2011, while administrative details, forest cover, major rivers, main occupations, and industrial activities have been obtained from the District Survey Report, 2023 Andhra Pradesh Space Applications Centre (APSAC).

Table 1: Features of West Godavari and Eluru

Features	West Godavari	Eluru
Area	2178 Sq. Km	6679 Sq. Km
Population	17,79,935	20,71,647
Revenue Divisions	3	3
Mandals	20	28
Revenue Villages	324	693
Forest Cover	3.25 Sq. Km (0.15%)	1400 Sq. Km (20.9%)
Major Rivers	Godavari, Yerrakalva, and Kovvada Kalva	Godavari, Yerrakalva, and Upputeru
Literacy Rate	61	63.73
Main Occupations	Agriculture, fisheries, horticulture, and manufacturing	Agriculture, horticulture, and manufacturing
Industries	Agro & food processing and service	Agri & food processing, and manufacturing
Sex Ratio	1004 females per 1000 males	1002 females per 1000 males

1.6. Approach and Methodology

The research used mixed methods, which combined qualitative observations and quantitative data to understand resilience in districts. The data collection and review of existing data related to population, environment, and local economies. Sources included scientific literature, census 2011, official disaster plans, and recent satellite images to help identify trends and risk zones.



1.6.1. Key Steps for undertaking the Study

Given below is Figure 7 showing the schematic diagram on how the study was approached and undertaken to develop a resilience framework and provide key policy recommendation.

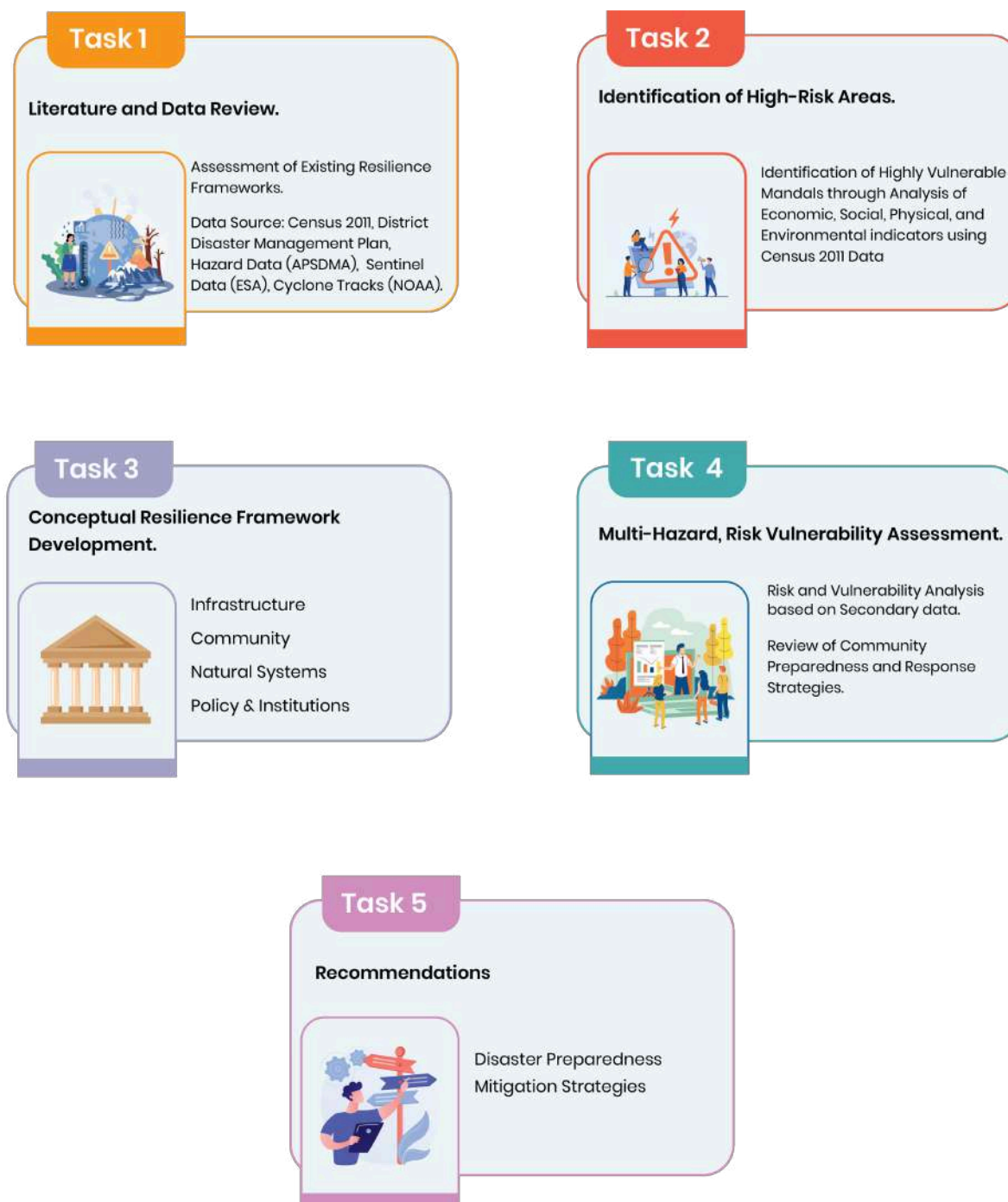


Figure 7: Key Steps for Undertaking the Study



1.6.2. Literature Review

A comprehensive literature review was undertaken to understand the current landscape of disaster resilience practices and frameworks relevant to the region. The review covered a wide range of sources including reports, policy documents, and technical guidelines from the APSDMA, district-level disaster management plans, and national policy frameworks. These documents provided critical insights into existing institutional arrangements, hazard vulnerability assessments, EWS, and community-based resilience strategies. Scholarly articles, case studies, and global best practices were also reviewed to identify effective approaches to DRR and climate adaptation.

1.6.3. Data Collection and Analysis – Secondary Data, Field Visits and Community Interaction

The team visited several mandals across West Godavari and Eluru districts, including Eluru, Bhimavaram, Kaikaluru, and Velairpadu, which represent a diverse set of geographic, socio-economic, and hazard-prone conditions. These field visits provided an opportunity for first-hand assessment of vulnerabilities, infrastructure gaps, and institutional capacities. Engagements included structured and informal interactions with a range of stakeholders such as district administration officials, Panchayati Raj representatives, civil society organisations, health workers, and local families. The discussions focused on understanding local perceptions of risk, the effectiveness of EWS, community coping strategies, and access to relief and rehabilitation services during past disaster events such as floods and cyclones. The secondary data was collected from government records, district-level disaster management plans, census data, satellite imageries, location of critical infrastructure, and historical hazard patterns. These insights were triangulated with on-ground observations to identify gaps in preparedness and response mechanisms.

1.6.4. Identification of High-Risk Area

The identification of high-risk zones was carried out by integrating hazard data with vulnerability analysis. Hazard data, sourced from the APSDMA website (Authority, 2022), provided insights into multiple risks such as floods, droughts, cyclones, heatwaves, and storm surges.



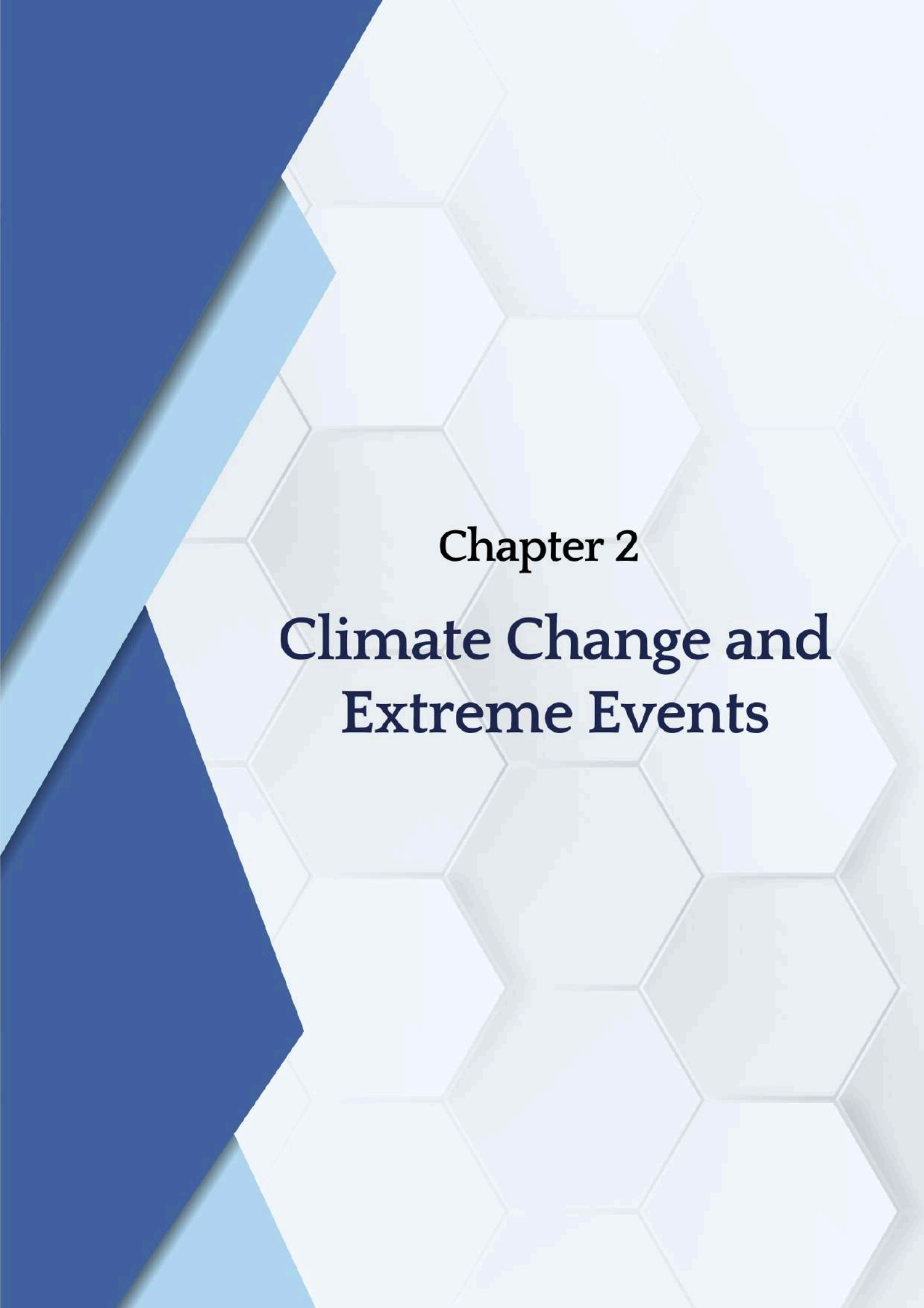
This data was georeferenced and processed in ArcGIS Pro to analyze the spatial patterns of each hazard.

Vulnerability analysis was conducted using information from Census 2011 (Data, 2011), Sentinel 1 (Sentinel-1, ESA), Sentinel-2 (Sentinel-2, ESA), and India WRIS data (WRIS, 2024). Mandals exhibiting vulnerabilities across more than two dimensions were classified as highly vulnerable, while those with vulnerabilities in only one or two dimensions were categorized as moderately or less vulnerable (Wiwandari Handayani, 2017; Anamika Barua, 2018–19).

The integration of hazard and vulnerability assessments enabled the identification of the most at-risk areas.

1.6.5. Best Practices and Case Studies

The study examined a range of global and national best practices in Disaster Risk Reduction to inform the recommendations that can be undertaken in both the districts to build resilience (Annexure I). The review focused on how different regions leverage cross-sectoral coordination, inclusive planning, capacity building, and nature-based solutions to enhance resilience. Special attention was given to practices that incorporate ecosystem-based approaches, such as the restoration of wetlands, mangroves, and natural drainage systems, which serve both as protective barriers and as livelihood resources. These cases highlighted the importance of integrating scientific knowledge with traditional wisdom, fostering community participation, and ensuring institutional accountability. Key elements from these best practices have been adapted to suit the local socio-economic, ecological, and institutional context of the study area, helping to shape a scalable and sustainable model for disaster resilience planning.



Chapter 2

Climate Change and Extreme Events



Climate Change and Extreme Events

2.1 Cyclones

The average frequency of Extreme Weather Events (EWEs) has shown an increasing trend over the past 50 years. Between 2007–2016, the annual occurrence of EWEs rose by 18% compared to the previous decade (1997–2006) (R. Krishnan, 2021). The Indian Ocean is one of the six most cyclone-prone regions in the world, experiencing an average of five to six cyclones per year (Sahoo and Bhaskaran, 2018). Consequently, tropical cyclones rank among the most frequent and destructive natural disasters in India.

Cyclones are far more frequent in the Bay of Bengal than in the Arabian Sea, occurring at a ratio of 4:1 (Rao et al., 2020). This makes the east coast of India, stretching along the Bay of Bengal, highly vulnerable due to its geographical position and tropical climate. The region is regularly exposed to cyclonic storms, heavy monsoon rainfall, and coastal flooding, with Odisha, Andhra Pradesh, Tamil Nadu, and West Bengal among the worst affected states. Recent cyclones such as Fani (2019), Amphan (2020), and Yaas (2021) have inflicted widespread damage on infrastructure, agriculture, and livelihoods. The regional climate system over the Indian subcontinent involves complex interactions between the atmosphere, ocean, land, and cryosphere across multiple spatial and temporal scales (R. Krishnan, 2021).

A classification of 96 districts highlights the extent of cyclone proneness. Among them, 72 coastal districts and 24 districts within 100 km of the coast were evaluated. Of these, 12 are categorized as very highly prone, 41 as highly prone, 30 as moderately prone, and 13 as less prone. The classification considered cyclone frequency, wind speed, Probable Maximum Storm Surge (PMSS), and Probable Maximum Precipitation (PMP) (Mohapatra, 2015). For instance, West Godavari is identified as highly prone.

Tropical cyclones are typically characterized by storm surges, coastal flooding, high winds, inundation, and shoreline erosion. The extent of inundation often depends on the local topography of the landfall area. For example, despite a surge height of 5 m, inundation from the 2007 super cyclone Gonu was limited due to steep coastal bathymetry (Fritz et al., 2009). In contrast, low-lying coastal areas experience extensive inland penetration: Cyclone Nargis (Myanmar, 2008) inundated up to 50 km inland (Fritz et al., 2009), while the 1999 Odisha super cyclone reached 20 km (Dash, 2002).

Inundation during the 2005 cyclone in the U.S. (Knabb et al., 2005) extended up to 9 km along bays and rivers. Comparatively, Cyclone Phailin (2013) inundated up to 1 km, and Cyclone Hudhud (2014) less than 500 m (NDMA, 2019).

According to the report published by Ministry of Earth Sciences, Government of India titled “Assessment of climate change over the Indian Region” (R. Krishnan, 2021) following trends can be observed in the characteristics of tropical cyclones in Indian region:

- **Increase in Sea Surface Temperature and Ocean Heat Content:**

Increased SSTs and ocean heat content underpin these trends by providing energy for cyclone development and intensification. Since tropical cyclones primarily draw their energy from evaporation at the ocean surface, SST and OHC strongly constrain cyclone intensity (Rajeevan M, 2013).

- **Increase in the Intensity of Tropical Cyclones:**

(1951–2018) indicate a significant reduction in annual frequency of tropical cyclones (TCs) in the North Indian Ocean (NIO) basin [–0.23 per decade over the entire NIO; –0.26 per decade over the Bay of Bengal]. A significant rise [+0.86 per decade] in the frequency of post-monsoon (October–December) season very severe cyclonic storms (VSCS) is observed in the NIO during the past two decades (2000–2018) (high confidence). Climate model simulations project a rise in TC intensity (medium confidence) and TC precipitation intensity (medium-to-high confidence) in the NIO basin.

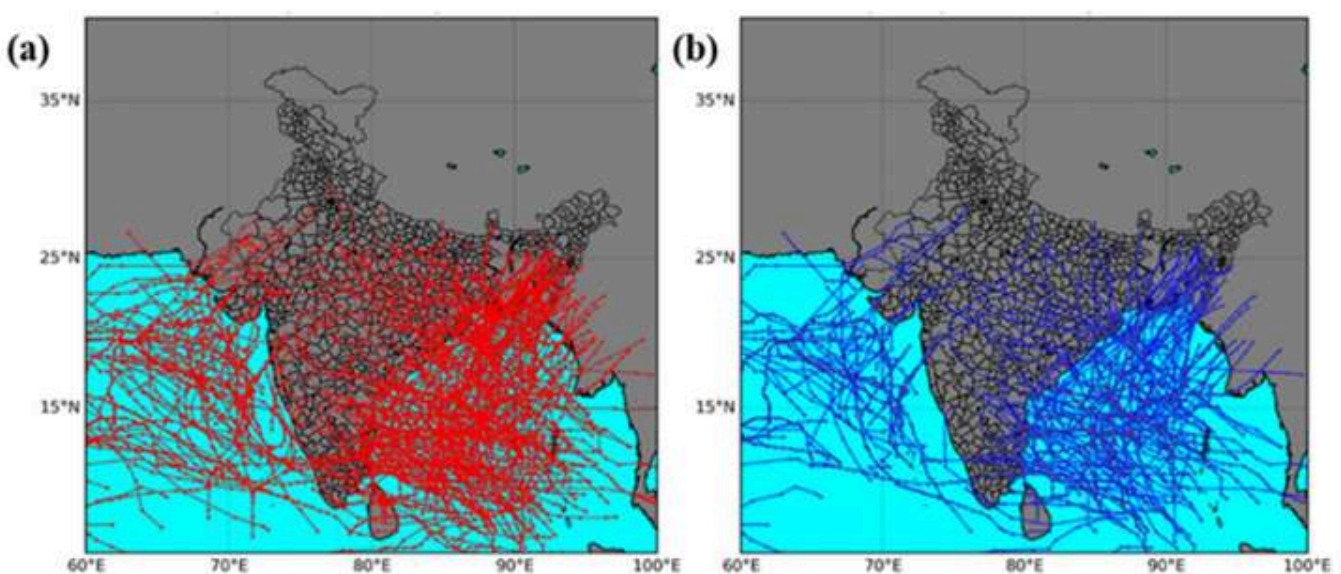


Figure 8 : Tropical Cyclone Tracks over NIO during a. 1961– 2020 and b. 1981– 2020 periods

• Increase in frequency of Tropical Cyclones:

Frequency of extremely severe cyclonic storms (ESCS) over the Arabian Sea has increased during the post-monsoon seasons of 1998–2018 (high confidence) as shown in *Figure 9* for which the data has been taken from RMSC-IMD and *Figure 10* (Rao et al., 2020). According to Mondal et al. (2021) the trend of cyclone frequency in the Bay of Bengal (BoB) over the past five decades (1971–2020) reveals significant variations in the occurrence and intensity of tropical cyclones (TCs). A total of 121 tropical cyclones were recorded in the Bay of Bengal during the period from 1971 to 2020.

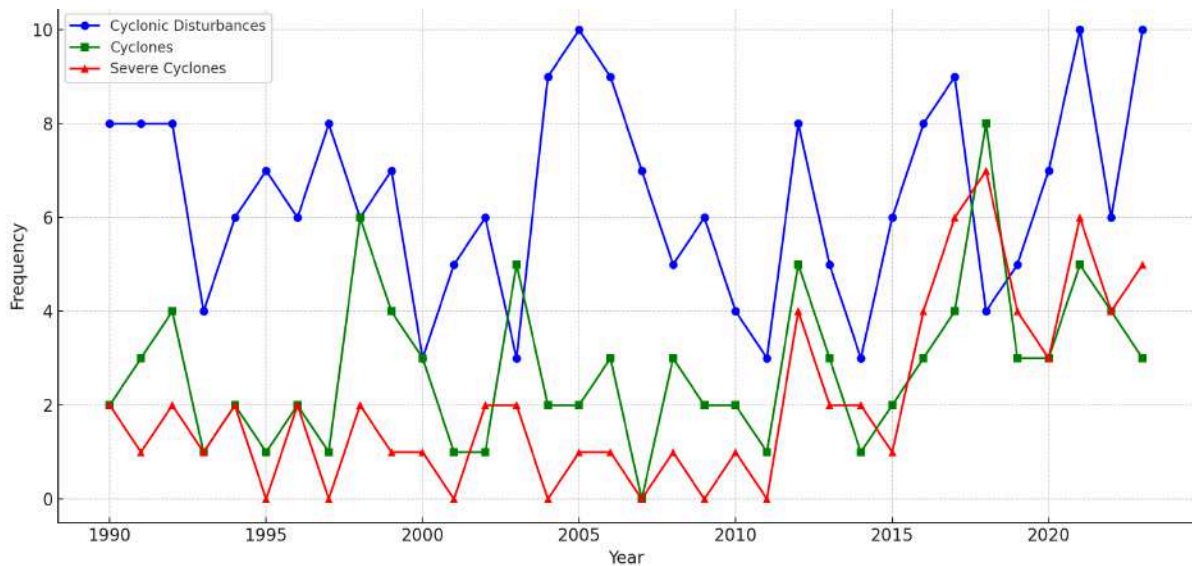


Figure 9 : Annual Frequency of Cyclones, Severe Cyclones, and Disturbances (1990 - 2023)

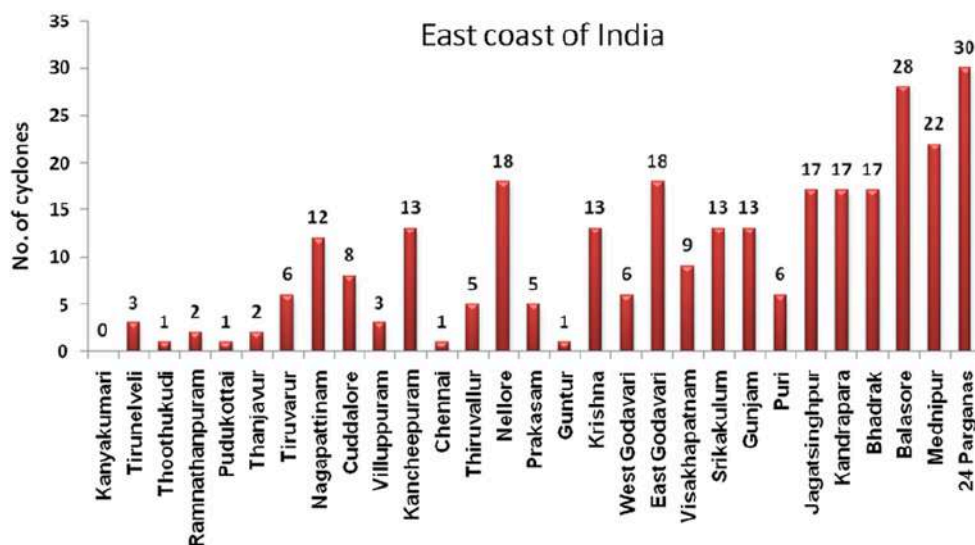


Figure 10 : Showing Number of Cyclones in East Coast of India



2.1.1. Cyclone Prone Mandals

The Andhra Pradesh coast has experienced more than 62 cyclonic events, including depressions, cyclonic storms, and severe cyclonic storms. Of these, 32 significantly impacted the Krishna–Godavari region, which comprises the districts of East Godavari, West Godavari, Krishna, and Guntur (Basheer et al., 2019).

According to Rao et al. (2020), the maximum recorded wind speeds during cyclonic events were 228 km/h in West Bengal, 265 km/h in Odisha, 240 km/h in Andhra Pradesh, and 204 km/h in Tamil Nadu. Their study further identified East Godavari, West Godavari, and Krishna districts as highly prone to elevated storm tides. Due to their location in low-lying deltaic regions, Krishna and Guntur districts are especially vulnerable, with coastal flooding extending up to 60 km inland under climate change conditions. In West Godavari, storm surge heights of 5.6–7.6 m has been projected, with the potential to cause severe local inundation.

Cyclone strike frequency also highlights the vulnerability of coastal districts. The highest landfall rate between 1961 and 2020 was recorded in South 24 Parganas, which experienced 6–9 cyclonic storms during this period. Other highly vulnerable districts, with 3–6 storms over the same timeframe, include Kendrapara, Ganjam, Srikakulam, East Godavari, Krishna, Prakasam, Nellore, Villupuram, Nagapattinam, Ramanathapuram, and Devbhoomi Dwarka, along with the Andaman Islands (Boragapu, Guhathakurta, & Sreejith, 2023).

2.2. Floods

India is the worst flood - affected country in the world after Bangladesh and accounts for one fifth of global death count due to floods. The increase in flood magnitude due to the warming climate has resulted in considerable economic losses and the financial loss will likely increase by 17 % globally in the next 20 years due to climate change (Sven Norman Willner, 2018). For instance, more than 7 % of road and railway assets globally are exposed to a 100-year return period flood (Koks et al., 2019). Around 40 million hectares of land in the country are subject to floods according to National Flood Commission, and an average of 18.6 million hectares of land is affected annually. The annual average of crop area affected is approximately 3.7 million hectares (Bhanumurthy, V., Manjusree, P., & Srinivasa Rao, G.). Floods are classified into different types such as riverine (extreme rainfall for longer periods), flash (heavy rainfall in cities or steep slopes), urban (lack of drainage), coastal (storm surge) and pluvial (rainfall over a flat surface) flooding.



Regions prone to frequent floods mainly include river basins, hilly, coastal areas and in some instances, cities. In India, different types of floods frequently occur primarily during the SW monsoon season, the major rainy season. In addition, south peninsular India experiences floods during the NE monsoon season.

Floods in India are primarily driven by hydro-meteorological and geographical factors. Intense monsoonal rainfall, cloudbursts, and cyclonic storms often lead to river overflows and urban flooding. In the coastal regions storm surges further exacerbate flood risks. Human-induced factors significantly aggravate flood impacts. Rapid urbanization, encroachment on floodplains and wetlands, deforestation, and poor land-use planning reduce natural drainage and increase surface runoff. Climate change is amplifying these challenges by increasing the frequency of extreme rainfall events and altering monsoon patterns.

Changing Pattern of Flooding in India.

Increase in Flooding Events Since 1950: Observations for the period 1985–2015 reported an increase in frequency as well as long duration floods over the globe with a fourfold increase in frequency of floods in tropics after 2000 (Devineni, 2018). Flooding events over India have increased since 1950, primarily driven by enhanced occurrences of localized, short-duration intense rainfall events.

Rising Intensity of Rainfall: There is a documented increase in the frequency of intense precipitation occurrences contributing to flooding risks, particularly during the summer monsoon season.

Increase in Flood Events: The projected changes in the frequency of extreme flooding events of 1-day, 3-day and 5-day duration for the periods 2020–2059 and 2060–2099 estimated based on the 20-year return period streamflow values with respect to the historical base period (1966–2005) are provided in *Figure 11*, that shows the changes in flood patterns in major river basin under different climate change scenarios taken from the report of the Ministry of Earth Sciences (MoES), Government of India.

Increase in High-Intensity Rainfall Occurrence: Analyses from the observations show a decline in number of thunderstorm days (1981–2010 relative to 1950–1980) by 34% over the Indian region, while there is a rise in short-span high-intensity rain occurrences (Deshpande, 2021). Increased frequency of localized heavy rainfall on sub-daily and daily timescales has enhanced flood risk over India. Increased frequency and impacts of floods are also on the rise in urban areas (Mujumdar, 2021).

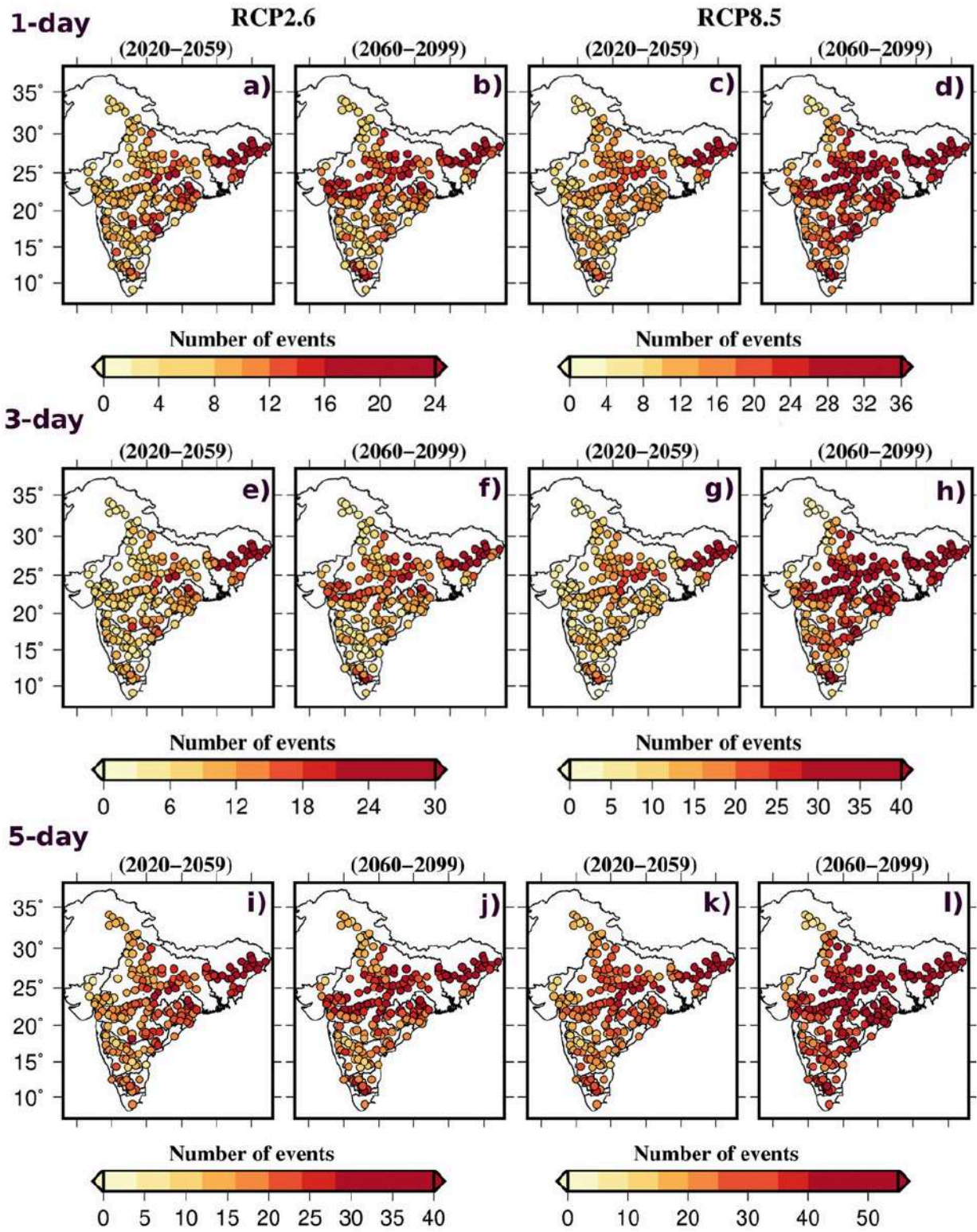


Figure 11 : Changes in flood patterns in major river basin under different climate change scenarios

The rainfall intensity–duration–frequency (IDF) curves are graphical representations of the probability that a given average rainfall intensity will occur within a given period (Dupont, 1999). The IDF guides flood prediction by showing the relationship between frequency, intensity, and duration of rainfall data. The impacts of changes in the IDF relationship due to climate change impact can be understood as increased frequency of extreme precipitation leading to more severe flooding, rise in intensity of rainfall in short span of time leading to inundations and flood like situations (R. Krishnan, 2021).

Climate change has led to a significant increase in the frequency and intensity of extreme precipitation events in the Godavari River Basin (GRB) of Andhra Pradesh (Mishra, 2019). A report by the Department of Science and Technology released in 2024 identifies 51 districts ('Very High' flood risk) and 118 districts fall in the 'High' flood risk category. About 85% of the districts in the 'Very High' or 'High' flood risk category are in Assam, Bihar, Uttar Pradesh, West Bengal, Gujarat, Odisha, and Jammu and Kashmir as provided in *Figure 12*. In Andhra Pradesh, West Godavari is categorised as very high risk from floods (DASGUPTA, 2024).

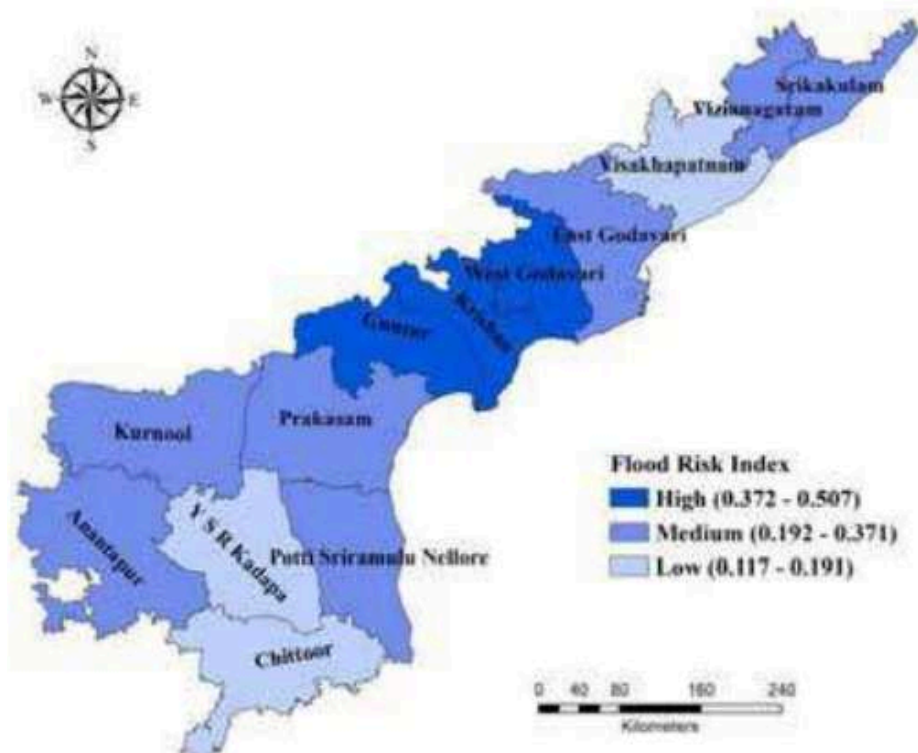


Figure 12 : Flood risk in Districts of Andhra Pradesh



Looking trends and impact of floods in Andhra Pradesh region, Godavari and Krishna river basins the observations can be noted as:

- **Increasing Flood Incidence and Intensity**

Flooding events have been increasing in frequency and magnitude in Andhra Pradesh's delta regions. The Krishna River Basin has experienced major floods notably in 2005, 2006, and 2009, with peak discharges at Prakasam Barrage exceeding historic levels. The flatbed slope of floodplains and heavy rainfall due to cyclones in the East Coast region contribute significantly to these flood events (Panchal, 2018).

- **Hydrological and Topographical Causes**

Floods are primarily caused by extreme precipitation events often associated with cyclones, and sometimes by water releases from dams in upper catchments. The inadequate width and depth of river channels, siltation, and obstructions in flow paths exacerbate flooding. The flat topography in many delta areas makes them naturally flood-prone (Mishra, 2019).

- **Social Vulnerability to Floods**

The coastal districts of Andhra Pradesh, including Krishna Delta mandals such as Bapatla, Nizampatnam, Ponnur, Repalle, Machilipatnam, Parchur, Bhimavaram, and Eluru, are identified as highly vulnerable to floods due to social and economic factors (Ramana Murty M V, 2023). The poorer populations lack adequate capacity to cope with extreme events, increasing their vulnerability.

- **Environmental and Ecological Impact**

Floods and water quality issues due to effluent discharge and agricultural runoff have impacted river ecosystems. In the Krishna Delta, seawater intrusion and changes in fresh-to-saltwater ratios have altered mangrove communities (Panchal, 2018).

- **Role of Cyclones**

Andhra Pradesh's long coastline (about 974 km) is prone to tropical storms and cyclones, which bring intense rainfall and flooding risks. Cyclone vulnerability assessments have been conducted to aid disaster risk management (Ramana Murty M V, 2023).

2.3. Impact of Disasters

The impact of disasters is beyond mortalities and transcends into the economic and social spheres of communities. The graph below in *Figure 13*, illustrates the trend of total damages in India due to floods and heavy rains from 1990 to 2016 (FFMD-GOI, 2018). There is a clear increase in damages over time, with a peak around 2015, reflecting a significant impact during that year. This trend underscores the growing economic burden of such disasters.

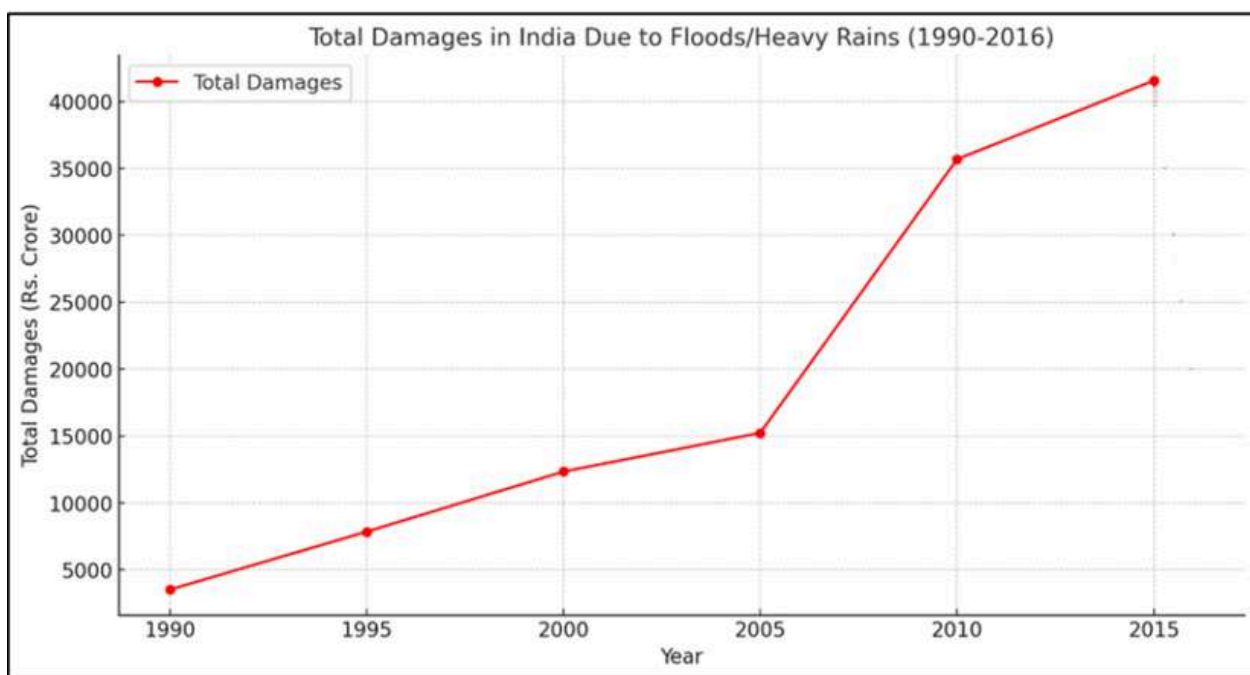


Figure 13 : Damages caused by floods and heavy rains in India

The devastating impact of cyclones on Andhra Pradesh is evident from recent assessments. Cyclones Titli and Pethai in 2018 caused damages exceeding ₹600 crores, affecting over 10 lakh hectares of crops and impacting more than 20 lakh people (DASGUPTA, 2024). The Cyclone Hudhud, 2014, inflicted far greater destruction, with damages surpassing ₹ 21908.49 crores and affecting more than 90 lakh people across the state (APSDMA, History of Storms)². The financial toll from floods since 1990 has been even more staggering, with total damages estimated at around ₹60,000 crores (FFMD-GOI, 2018).

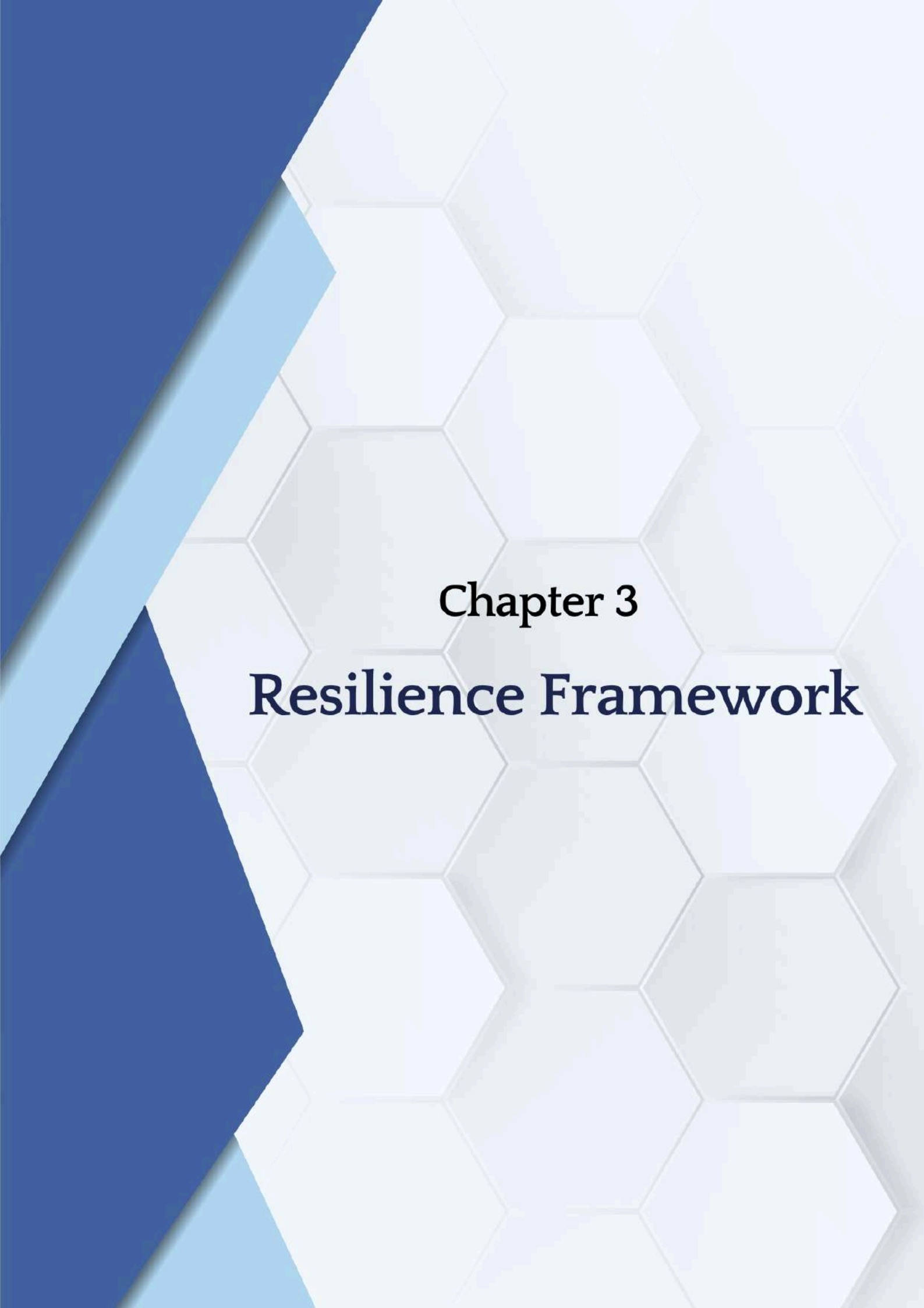
² https://apsdma.ap.gov.in/history_of_storms.php#:~:text=Total%20estimated%20loss%20was%202697.97%20cr.&text=6%20Districts%2C%2042.68%20lakh%20population,estimated%20loss%20was%20765.92%20cr.&text=1%20District%2C%201.89%20lakh%20population,livestock%20loss%203%2C%20425%20houses%20damaged. APSDMA - Accessed on 11/09/2025



In year 2024 only according to initial estimates Vijaywada Floods caused damages to 1.8 lakh Ha of agricultural land and 2 lakh farmers directly (PIB, 2024). APSDMA estimated the loss due to cyclone and its related activity from the year 1977 to 2018 PETHAI cyclone over the Andhra Pradesh (pertaining to before and after bifurcation of state) region. Approximately Rs. 87,741.37 crore economic loss happened and highest lost occurred during Hudhud cyclone period provided in Table 2. This type of natural hazards makes the state the loss of tremendous investment causing concentration of mitigation measures to increase the development of the state (APSDMA, 2017–2018). It is important to note that though there has been immense loss of life and property the assistance received by the state is hardly enough to cover the loss and damage and to recover.

Table 2 : Loss Estimation During Hudhud and Machilipatnam APSDMA, 2017–2018.

Category	Details
Time Period Assessed	1977 to 2018 (up to Cyclone Pethai)
Total Economic Loss	₹87,741.37 crore
Highest Loss Event	HUDHUD Cyclone
Total Houses Damaged	77,78,547 houses
Most Damaging Cyclone (Houses)	Machilipatnam Cyclone
Human Casualties (Last 40 Years)	16,402 deaths
Population Affected	1,266.8 lakh people
Impact on Development	Heavy investment loss has led to increased focus on mitigation for state development (APSDMA, 2017–2018)
Central Assistance (2025)	₹1,554.99 crore approved on 13th February 2025 from NDRF
Adjustment Clause	Subject to 50% adjustment of the opening SDRF balance for the year
Share Approved for Andhra Pradesh	₹608.08 crore (Ministry of Home Affairs, 2025)



Chapter 3

Resilience Framework



Resilience Framework

Academic discourse on disaster resilience is diverse and active, arising partly from disciplinary treatments of resilience concepts. Constructing a robust disaster resilience framework necessitates a comprehensive, multi-faceted approach that integrates diverse disciplines and perspectives. The framework should integrate theoretical and empirical knowledge of factors contributing to resilience with processes for translating those concepts into practice (Tyler & Moench, 2012). Moreover, resilience intersects with vulnerabilities, risks, and adaptability, particularly within the context of climate change, necessitating the framework to address these interconnected elements (Kim & Lim, 2016).

The disaster management has been oriented towards post-disaster response and recovery (Cronstedt 2002; Cutter et al. 2014), rather than pre-event initiatives such as prevention and preparedness (Hyunjung 2018). These approaches primarily aim to enhance community resilience by either reducing the characteristics of the hazard itself (e.g., frequency and intensity) or by addressing the underlying vulnerability factors of communities, including sensitivity and exposure. The approach remains a part of a reactive framework (Hyunjung 2018). According to many (for example, Innocenti and Albrito 2011), a more progressive and proactive approach to risk reduction is needed and the risk paradigm should no longer focus solely on reducing vulnerability, but also on building resilience (McEntire et al. 2002; Cutter et al. 2008; Olwig 2012; Twigg 2015; Williams and Shepherd 2016). The concept of resilience then gained importance until it was used 60 times in the Sendai Framework for Disaster Risk Reduction 2015–2030. The Sendai Framework makes it its third priority for action: “Investing in disaster risk reduction for resilience” (UNISDR 2015). Till now, climate change adaptation, sustainable development, and disaster risk reduction were viewed as three distinctive global challenges, resilience planning can be a cross-cutting approach (MacAskill and Guthrie 2014; Weichselgartner and Kelman 2015; Bollettino et al. 2017). Moreover, while risk management has long been associated with a rather short time horizon (Thomalla et al. 2006), the conceptual evolution of resilience towards adaptation and anticipation action leads to a longer-term planning, allowing a better linkage with climate change adaptation objectives.

From the review of the literature and field observation on disaster resilience, we propose a disaster resilience framework around four core themes—infrastructure and built environment, community resilience, natural systems, and institutional governance for a holistic and effective disaster management approach. These themes align closely with the five phases of disaster management: prevention/mitigation, preparedness, response, recovery, and rehabilitation.



For instance, resilient infrastructure and ecosystems contribute to risk reduction and mitigation by buffering hazard impacts, while strong community networks and awareness enhance preparedness and early response capacities. Institutional systems that enforce regulations, share knowledge, and enable inclusive governance to ensure coordinated response and transparent recovery efforts. Integrating ecosystem-based approaches and robust governance into land use, livelihood, and planning decisions also supports long-term rehabilitation, reinforcing adaptive capacities against future risks. Thus, a multi-thematic resilience framework strengthens the disaster management cycle by embedding resilience into each phase, creating a proactive and sustainable foundation for reducing disaster impacts.

Conceptual Resilience Framework Development

The four Key pillars of the Disaster Resilience Framework have been summarised in tables below—Infrastructure, Community, Institutions/Governance and Natural Systems— along with their associated indicators. Each indicator reflects critical aspects of preparedness, adaptive capacity, and risk reduction, providing a structured approach to assess and strengthen resilience at multiple levels.

1. Infrastructure / Built Environment

S No.	Indicators	Reference
i	Ability of critical infrastructure to withstand floods and cyclones (hospitals, schools, roads, bridges)	UNDRR, 2019
ii	Accessibility and adequacy of emergency shelters and Early Warning	Zhang, Y., & Wang, H. (2024).
iii	Multihazard Emergency Centres	Li, X., & Liu, Y. (2021)
iv	Resilience of housing (housing type-kutcha/pucca, building codes, Material used, retrofitting)	Ismail et al.(2017)
v	Protocol for basic services continuity (water, sanitation, electricity, telecommunications)	Steen, R., Haug, O. J., & Patriarca, R. (2024)
vi	Land use planning and zoning regulations (risk-sensitive land use)	Roy, D., & Ferland, Y. (2015).
vii	Stormwater drainage and flood protection systems	Zhou, Q., & Wang, Y. (2021)
viii	High wind-resistant building for business continuity (DEOC)	Aquino, Wilkinson, Raftery, & Potangaroa



2. Community

S No.	Indicators	Reference
i	Community awareness and disaster risk knowledge	Paton, D., & Johnston, D. (2001).
ii	Social networks and mutual aid structures	Aldrich, D. P. (2012).
iii	Inclusiveness and representation of vulnerable groups (women, the elderly, the disabled)	Wisner, B., Blaikie, P., Cannon, T., & Davis, I. (2004)
iv	Livelihood diversification and economic resilience	Tanner, T., Bahadur, A., & Moench, M. (2017).
v	Access to education and health services	Norris, F. H., Stevens, S. P., Pfefferbaum, B., Wyche, K. F., & Pfefferbaum, R. L. (2008)
vi	Disaster preparedness and household-level planning	Kapucu, N. (2008)
vii	Population mobility and displacement risk	IDMC(2021)
viii	Community engagement in resilience planning and decision-making	Manyena, S. B. (2006).
ix	Cultural attitudes toward risk and safety	Krüger, F., Bankoff, G., Cannon, T., Orłowski, B., & Schipper, L. F. (2015).



3. Institutions / Governance

These indicators capture the enabling environment for disaster risk reduction and resilience.

S No.	Indicators	Reference
i	Existence and enforcement of DRR and climate adaptation policies (SDMP/ DDMP/ SOP)	Nalau, J., Preston, B. L., & Maloney, M. C. (2015)
ii	Inter-agency coordination and governance mechanisms	Mohammed Zain, R., Mohd Zahari, H., & Mohd Zainol, N. A. (2023)
iii	Availability and use of risk information (hazard mapping, vulnerability analysis)	Anelli, D., Tajani, F., & Ranieri, R. (2022)
iv	Presence of EWS and response mechanisms	Šakić Trogrlić, R., van den Homberg, M., Budimir, M., McQuistan, C., Sneddon, A., & Golding, B. (2022).
v	Budgetary allocations for DRR and resilience	UNDRR (2023)
vi	Regulatory frameworks for building codes, land use, and environmental protection	Pantić, M., Živanović Miljković, J., & Milijić, S. (2019)
vii	Capacity of local governments and institutions	UNDRR (2023)
viii	Capacity of local governments and institutions	Aldunce, P., Beilin, R., Handmer, J., & Howden, M. (2021)
ix	Training and institutional knowledge-sharing systems	Monsalve, L. F. D., Valladares, C. P. N., & Díaz, J. S. (2024).

4. Natural Systems

S No.	Indicators	Reference
i	Forest Cover	Robledo, C., Clot, N., Hammill, A., & Riché, B. (2012).
ii	No. Natural buffers for hazards (coastal dunes, floodplains, vegetated slopes)	UNDRR (2010)
iii	Environmental degradation levels (water pollution)	UNEP (2016)
iv	Integration of ecosystem-based approaches in DRR and land use planning	Renaud, F. G., Sudmeier-Rieux, K., & Estrella, M. (Eds.). (2013).
v	Number of ongoing restoration and conservation programs	Union for Conservation of Nature (IUCN). (2015)
vi	People engaged in primary livelihood	FAO (2013)

The Resilience Framework based on these indicators is depicted below in *Figure 14* and the proposed framework can be used for understanding and building a resilience strategy at the district level.



Figure 14 : Disaster Resilience Framework.

The proposed framework can be used for understanding and building a resilience strategy at the district level. The table in Annexure II, suggests how each indicator corresponds to the different phases of disaster management cycle.

Chapter 4

**Multi-Hazard and
Vulnerability Analysis of
District Eluru**



Multi-Hazard and Vulnerability Analysis of District Eluru

Understanding hazards and vulnerabilities becomes important for reducing disaster risks and planning for climate adaptation. As per our field observation, we have found these indicators as relevant in understanding local vulnerabilities across Eluru District. These indicators include **social, economic, physical, and environmental** where literacy rate, marginal and agricultural workers, industry and non-workers, kutcha and semi-kutcha housing, road and medical access, forest cover, and proximity to rivers, coasts, and large water bodies. The hazard data was obtained from the APSDMA website (Authority, 2022), covering floods, droughts, cyclones, heatwaves, and storm surges. These maps were georeferenced and digitized using ArcGIS Pro, enabling each hazard type to be analysed individually to identify the most exposed mandals.

Simultaneously, vulnerability was assessed using Census 2011 (Data, 2011), Sentinel 1 (Sentinel-1, ESA), Sentinel-2 (Sentinel-2, ESA), and India WRIS data (WRIS, 2024), interpreting high or low values of the aforementioned indicators to classify mandals. A mandal was categorized as highly vulnerable if it showed weakness in more than two dimensions, moderate in more than one, and low in one dimension (Wiwandari Handayani, 2017)(Anamika Barua, 2018-19). This combined hazard exposure and vulnerability mapping enabled the development of a **risk profile** for Eluru District. Mandals such as **Mandavali, Kaikalur, and Polavaram** emerged as high-risk zones due to their multi-hazard exposure and vulnerabilities.

4.1. Hazard Analysis of Eluru

Eluru district is vulnerable to multiple natural hazards, particularly cyclones, floods, and heat waves. Northern mandals of Eluru District experience flooding due to the River Godavari. High hazard zones are the mandals that are prone to multiple hazards that are considered such as cyclones, floods, heatwaves etc. While moderate hazard zones are susceptible to more than two hazards, and low hazard zones are areas which are susceptible to two or less hazards.

4.1.1. Multi-Hazard Prone Mandals of Eluru

The Multi-Hazard Map in *Figure 15*, developed using data from the APSDMA and GIS-based analysis, classifies regions based on their susceptibility to various natural disasters.

Eluru district is classified as moderately hazard zone with high susceptibility to cyclones and floods (APSDMA, 2016). The intricate canal systems around Kolleru lake (Raghunandan, 2021) also, experience flooding, especially during the rainy season. The communities in the flooded regions (*Figure 25* and *Figure 26*) and in recent Vijayawada floods also affected the tehsils around Kolleru Lake.

However, when after analysing at the sub- district level the mandals like Mandavalli as a High Hazard Zone indicating a spatial asymmetry in terms of distribution of hazards within the districts. This implies a high susceptibility to a combination of hazards, including floods and cyclones. Though the study was on floods and cyclones - other natural hazards, specifically heatwaves, earthquakes, droughts, and storm surges are also considered while preparing the multi-hazard map for the Eluru district.

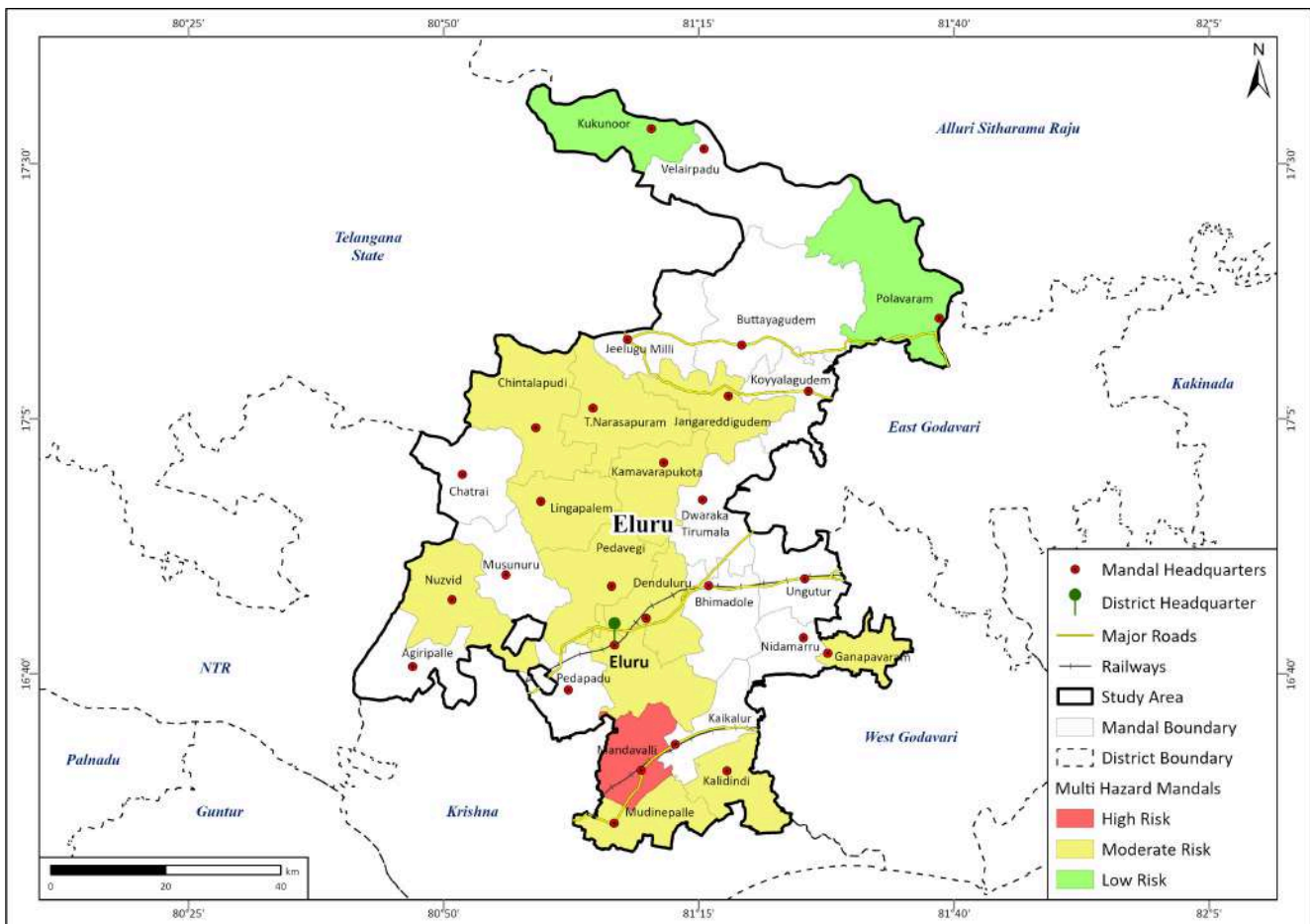


Figure 15 : Map showing Multi-Hazard Prone Mandals of Eluru

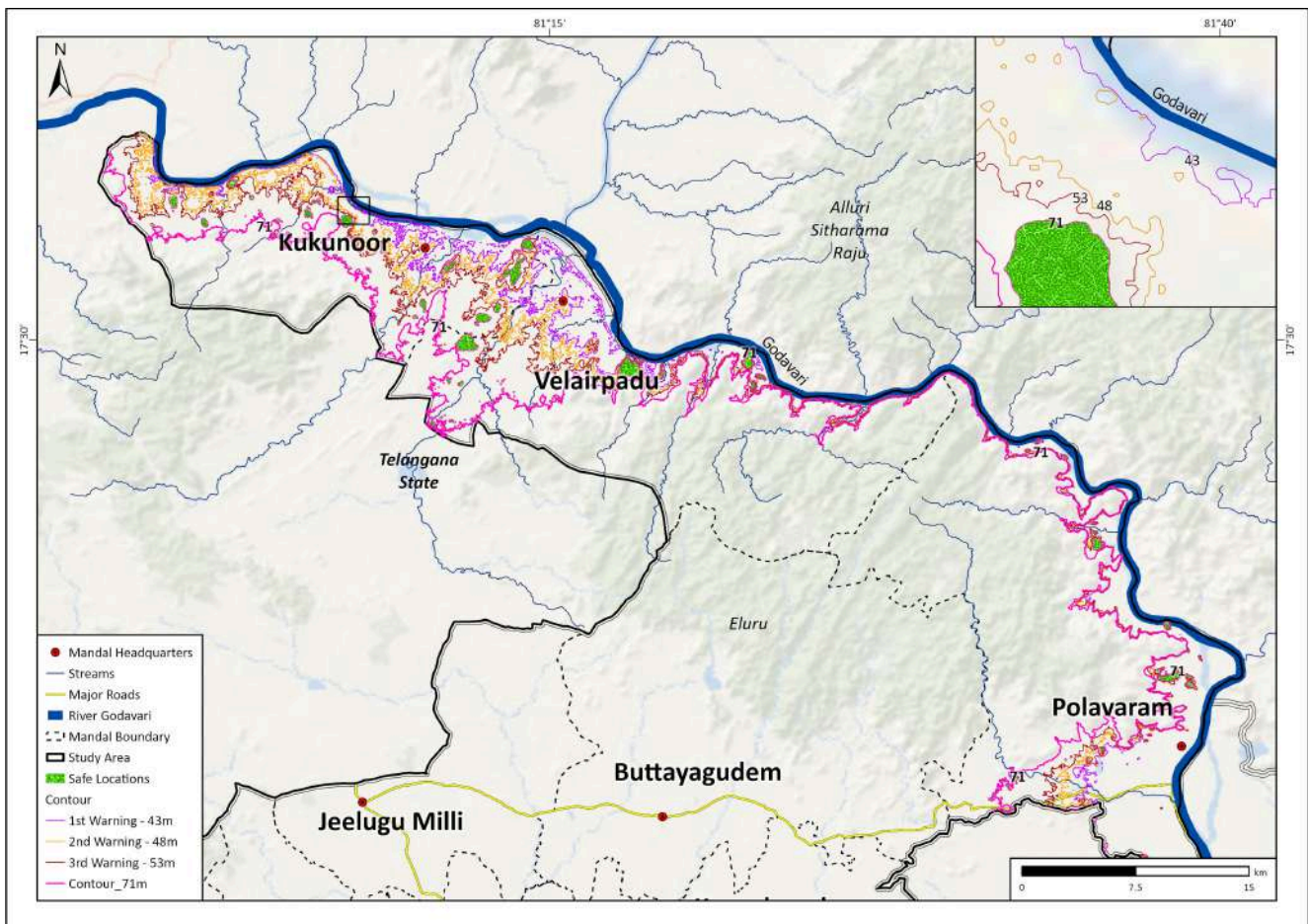


Figure 16 : Higher Elevation Areas Identified As Safe Locations.

The Northern part of Eluru District that includes Kukunoor, Velairpadu, and Polavaram, close to the catchment of River Godavari is prone to frequent flooding. The map in Figure 16, shows the high elevation points and can be considered as safe locations during a flooding event. These elevations were extracted using the Shuttle Radar Topography Mission Digital Elevation Model (SRTM-DEM), which provides accurate terrain height information. To ensure comprehensive flood risk assessment, the map also incorporates reference contours showing the 1st, 2nd, and 3rd flood level warnings as provided by the Velairpadu Mandal Tehsil Office, Eluru District.

These contour lines represent successive flood warning levels at 43 meters, 48 meters, and 53 meters, respectively, highlighting the flood-prone zones in the region. The combination of high-resolution elevation data with official flood warning levels facilitates effective identification of safe zones, essential for disaster management and planning in Velairpadu Mandal, Eluru District.

4.1.2. Cyclone Prone Mandals

In Eluru district, areas such as Denduluru, Bhimadolu, Peddapadu, Kalidindi, Mudinepalle, Mandavalli, Kaikalur, and others are identified as highly prone to cyclones as shown in *Figure 17*, based on the data available from APSDMA. Due to low-lying nature of the areas, these deltaic zones frequently experience high wind speeds, heavy rainfall, and waterlogging during the cyclonic activity in the region

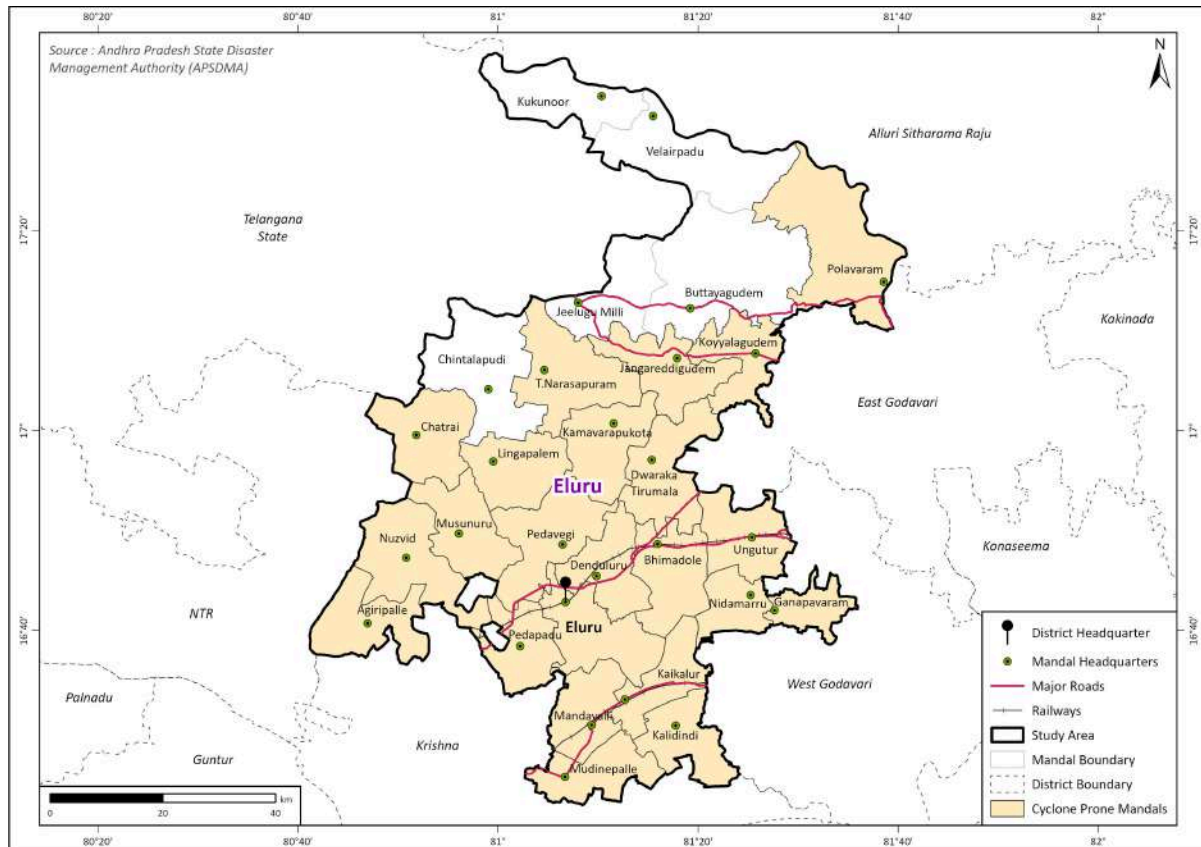


Figure 17 : Map showing Cyclone Prone Mandals of Eluru district

4.1.3. Flood Prone Mandals

The map in *Figure 18*, developed using data from the APSDMA and GIS-based analysis, highlights flood-prone mandals in the Eluru district of Andhra Pradesh. It is observable that the areas along major River Godavari and low-lying regions are naturally susceptible to flooding due to their topography. Mandals like Kukunoor, Polavaram, Velairpadu are vulnerable to flooding from the Godavari River due to extreme weather events. *Figure 19*, depicts the river Godavari and its tributaries in the Eluru and surrounding region due to which additional water from multiple streams and tributaries, including Pala Vagu, Kinnerasani, Chaprampalli Vagu, Jalatarru Kalva, and Murligandi Kalva.

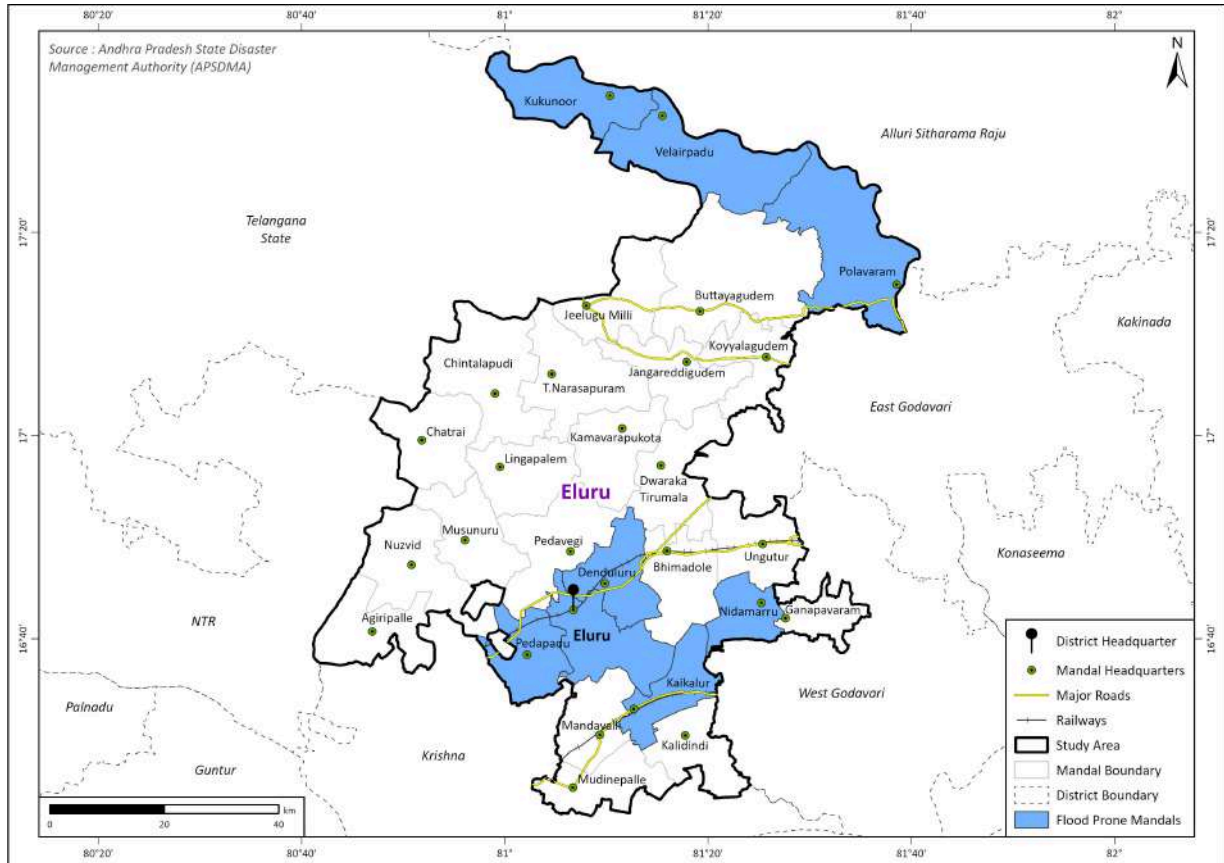


Figure 18 : Map showing Flood Prone Mandal's in Eluru District

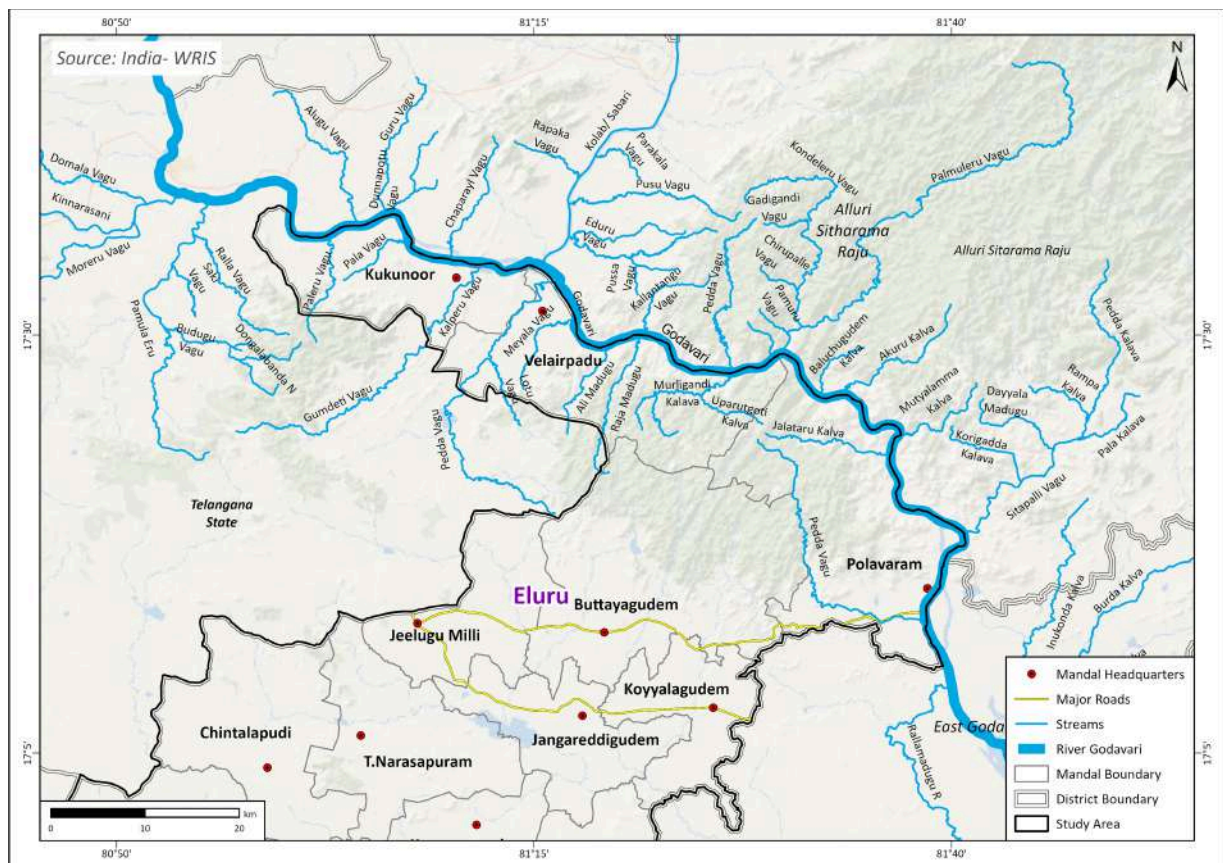


Figure 19 : Map of Godavari Streams along Eluru District.

4.2. Vulnerabilities of Eluru District

Their economies depend heavily on agriculture, with limited livelihood alternatives and low literacy levels may hinder awareness and response to disaster. Though, during the field visit the local communities exhibited high level of indigenous knowledge. Given the lack of ground observational systems for early warning the local administration often depends on the knowhow of local communities for flood management. Local communities have well marked water level points that help them gauge the level of flooding and inform the local administration.

4.2.1. Field Visit Observations: Highly Vulnerable Mandals to flooding

During the field work it was concluded from the discussion with local administration that there are two areas prone to flooding i.e. the tehsils around Kolleru Lake and the tehsils neighbouring River Godavari flood Plains as shown in *Figure 19*. which depicts the river Godavari and its tributaries in the Eluru and surrounding region due to which additional water from multiple streams and tributaries.



Figure 20 : Godavari river at Velairpadu Mandal, Eluru District.

The Kukunoor, Velairpadu and Polavaram are geographically isolated and are the communities are likely to get displaced and rehabilitated due to Polavaram Project. It was noted that Koida, Katkuru, Thatkurugommu, Narlavaram, Rudeamkota, and Tirumalapuram gram panchayats are highly vulnerable to flooding due to their proximity to seasonal streams and low-lying regions as shown in *Figure 20*. The Jangareddigudem mandal, while slightly inland, remains at risk because of its proximity to hilly terrain, which increases the likelihood of flash floods and landslides, posing a serious threat to the safety of its residents.



Figure 21 : Meeting With Deputy Tehsildar Mr. Ibrahim of Kaikalur Mandal, Eluru District.

In contrast, the communities around the Lake Kolleru as shown in *Figure 22* had economic and social levels with major income coming from fisheries. As the communities were cut off during the rainy season due to flooding of lake, they had limited livelihoods and access to overall municipal services. During the meeting with the Tehsildar, he highlighted his role in coordinating relief efforts, particularly through the Public Distribution System, where food and essential supplies are distributed and reported to the district collector. His primary concern was ensuring timely support reaches affected communities despite these structural limitations. The local administration was found to be informed and had measures in place for responding to disaster (Tehsildar Office, Kaikaluru during field visit as shown in *Figure 21*).



Figure 22 : Community Engagement at Pandirepalligudem Village, Kaikaluru Mandal, Eluru District.

4.2.1.1. Flood impact and frequency in Tehsils Kukunoor, Velairpadu and Polavaram

Flooding is a recurrent and impacts are severe in the tehsils of Kukunoor, Velairpadu, and Polavaram. The floods in 2022 the water levels increased incrementally within short span of time – up to 7 feet inundating areas in Tehsils, particularly Kukunoor, Velairpadu, and Polavaram, creating major challenges for evacuation and emergency management. Some of the key challenges faced during the floods, 2022 were:

- **Maintaining communication with district headquarters before, during, and after floods**

Mobile connectivity often becomes unreliable or completely unavailable, in these tehsils. This communication breakdown severely hampers the ability of authorities to coordinate rescue and relief operations effectively. In such situations, satellite phones become crucial, where mobile signals are absent.

- **Damage to Livelihoods**

While inundation of the agricultural fields leads to crop loss, the deposition of sand and silt on farmlands which renders them unfit for cultivation until they are thoroughly cleaned. This impacts the livelihoods of farmers and delays the resumption of agricultural activities.

- **Lack of health infrastructure**

In 2022 floods compromised the healthcare infrastructure; the Primary Health Centre (PHC) was submerged, disrupting essential medical services for the local population. The PHC is key to preventing post-flood healthcare, which may involve management of diseases like typhoid, snakebite, etc. The movement of healthcare professionals was also hindered due to flood. In case of medical emergencies, patients need to travel 70 km to reach Bhadrachalam or another major medical facility.



Figure 23 : Stakeholder Engagement at Velairpadu Mandal, Eluru District.

A relocation plan has been proposed for communities in the affected areas. Displaced residents from flood-prone zones such as Darbhagudem, Doramamidi, Buttayagudem, Rachannagudem, Rowthugudem, Mulagalampalli, and Swarnavarigudem will be resettled in designated safer locations. Permanent land has been allocated to ensure these communities are relocated to secure areas, providing them with long-term protection from the devastating impact of floods (Communicated During Stakeholder Engagement with Tehsildar D.V. Satyanarayana) as shown in *Figure 23*.



4.3 Vulnerability Analysis of Eluru

The high-vulnerability mandals of Eluru District, shown in *Figure 24*, were identified by analyzing physical, socio-economic, and environmental vulnerabilities. Data for this assessment was derived from the Census 2011, District Handbook, and field studies (Data, 2011). The classification criteria are as follows: if a mandal exhibits vulnerability in more than two dimensions, it is categorized as highly vulnerable; if vulnerable in more than one dimension, as moderately vulnerable; and if vulnerable in only one dimension, as low vulnerability (Wiwandari Handayani, 2017; Anamika Barua, 2018–19).

The indicators used for this analysis are listed in *Table 3*.

Table 3 : Indicators used for classifying vulnerability in mandals of Eluru District..

Dimension	Indicator	Interpretation of High / Low Values	Data Source
Social	Literacy rate	Low literacy → High vulnerability	Census 2011
Economic	Marginal workers	Low literacy → High vulnerability	Census 2011
	Agricultural laborers	High % → High vulnerability	
	Industry workers	High % → High vulnerability	
	Non-workers	Low % → High vulnerability (low livelihood diversity)	
Physical	Kutchha houses	High % → High vulnerability	Census 2011
	Semi-kuchcha houses	High % → High vulnerability	
	Pucca road approach	Low % villages with pucca roads → High vulnerability	
	Medical facilities	Low % villages with pucca roads → High vulnerability	
Environmental	Forest cover	Low cover → High vulnerability	Sentinel 2
	River proximity	Presence / closeness → Vulnerability	India - WRIS
	Coastal proximity	Presence / closeness → Vulnerability	India - WRIS
	Large water body proximity	Presence / closeness → Vulnerability	India - WRIS

Through this analysis shown in *Table 4* below, Mandavali and Kaikalur have been identified as highly vulnerable areas as they are reflecting vulnerabilities in three indicators, while Musunuru, Polavaram, and Velairpadu are exhibiting vulnerabilities in two indicators. While the rest are showing vulnerability in one indicator only. The result of this analysis is visually reflected in the Map provided in *Figure 24*.

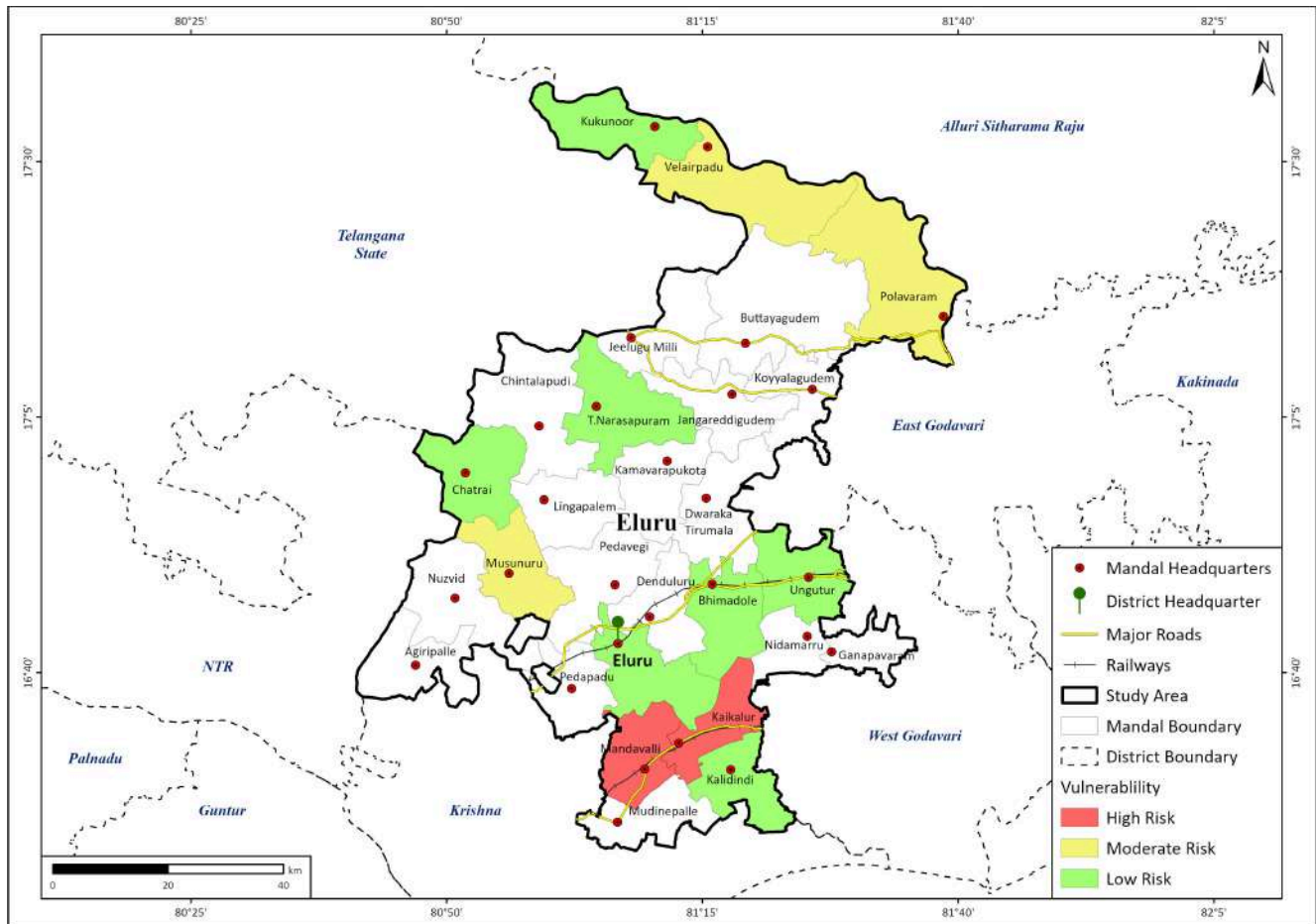


Figure 24 : Vulnerabilities of Eluru

Table 4 : Socio-Economic Vulnerability Assessment of Eluru District..

Economic	Social	Physical	Environmental
Eluru	Velairpadu	Kalidindi	Polavaram
Kaikalur	Kukunoor	Ungutur	Velairpadu
Musunuru	Chatrai	Mandavalli	Mandavalli
Mandavalli	T.Narasapuram	Bhimadole	Kaikalur
Polavaram	Musunuru	Kaikalur	



Environmental Vulnerability: It is considered as the susceptibility of areas to natural disasters like floods and cyclones, influenced by factors such as proximity to water bodies and land cover. Geospatial analysis, including distance to water bodies and percentage-based assessments, has been used to identify these vulnerable mandals (Sentinel-2, ESA), (WRIS, 2024).

The *Table 4*, above reflects the different vulnerabilities exhibited by the mandals based on the different indicators considered for analysis. The table colour represents the risk level shown in Figure 24. The indicators selected for the analysis include:

1. Social Literacy

- a. Low literacy levels increase vulnerability as people have limited access to information, awareness, and opportunities to build resilience.

2. Economic – Livelihood Factors

- a. A high proportion of **marginal workers** indicates instability in income and higher vulnerability.
- b. A large share of **agricultural labourers** reflects dependence on climate-sensitive livelihoods, leading to high vulnerability.
- c. A **low percentage of industry workers** shows limited livelihood diversity, making communities more vulnerable.
- d. A high number of **non-workers** signals weak economic security and thus greater vulnerability.

3. Physical – Housing and Infrastructure.

- a. A high proportion of **kutcha** or **semi-kutcha** houses indicates poor housing quality and higher exposure to hazards.
- b. **Low road connectivity** (few villages with pucca roads) hampers mobility and disaster response, increasing vulnerability.
- c. **Limited medical facilities** reflect weak health infrastructure, adding to vulnerability.

4. Environmental – Natural Conditions

- a. **Low forest cover** reduces ecological protection, increasing disaster risk.
- b. **Proximity to rivers, coasts, or large water bodies** exposes communities to floods, cyclones, and other water-related hazards, thereby heightening vulnerability.

Vijayawada Floods, 2024 and Impact on Eluru District

The Vijayawada floods in 2024 as shown in *Figure 25*, triggered by heavy rainfall had a significant impact on Eluru District, impacting the Budameru Rivulet and the Kolleru Lake catchment area. While Vijayawada experienced severe flooding, the floodwaters from the Budameru eventually pushed into Krishna district, and then impacted Eluru district, inundating villages and submerging roads. Floodwaters from the Budameru shown in *Figure 26*, which originates in NTR district and flows into Kolleru Lake in Eluru, caused widespread inundation in the lake's catchment area. The Eluru-Kaikaluru road was completely submerged, making it difficult for people to access the affected areas. The Budameru rivulet breached its bund, and the water levels rose significantly, disrupting normal life and causing damage to homes and other infrastructure. In some areas, communication was disrupted as phones and inverters stopped working due to power outages caused by submerged poles.

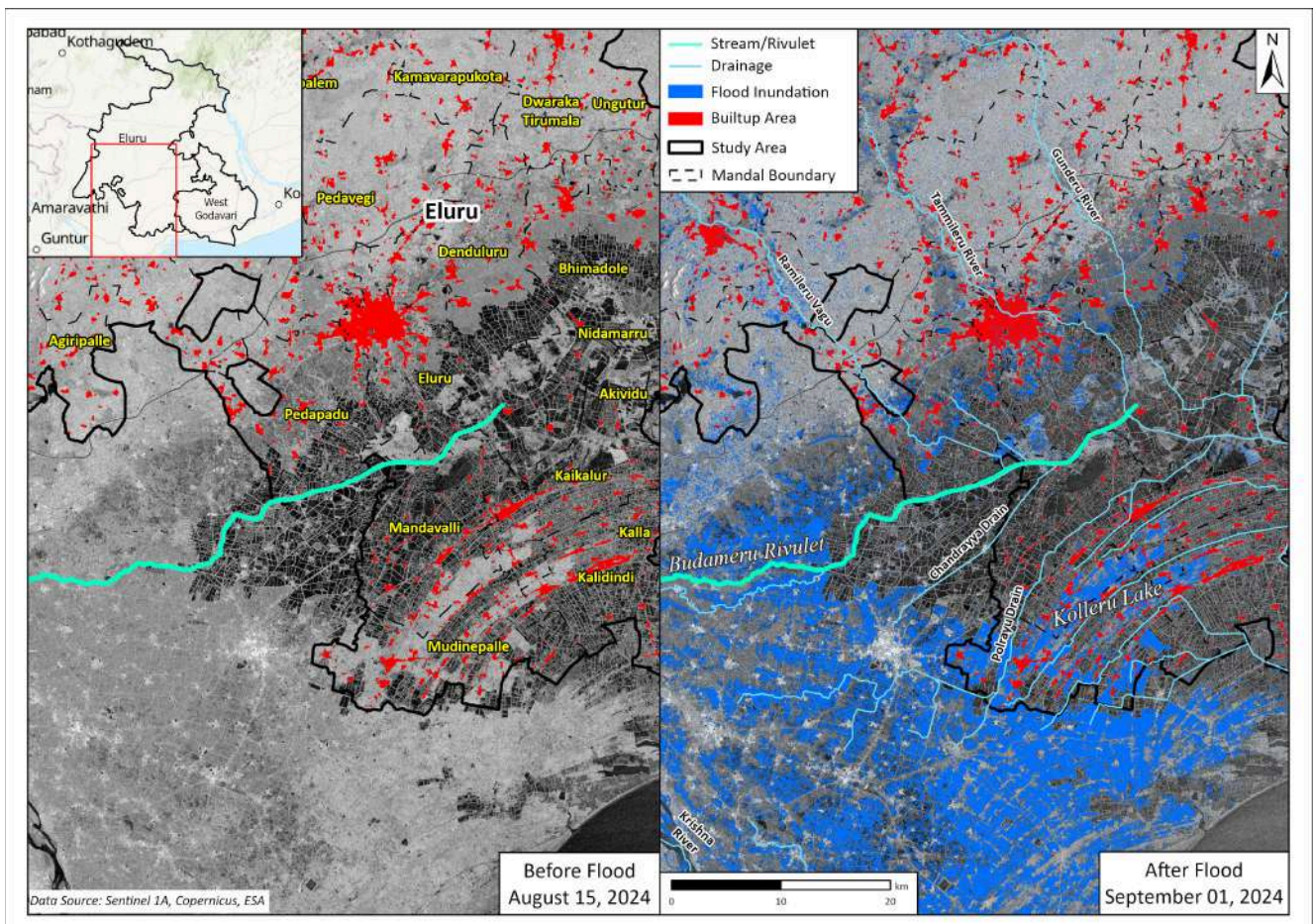


Figure 25 : The Vijayawada floods in 2024.



Figure 26: Budameru Channel, Near Sreeparru Village, Eluru Mandal, Eluru District

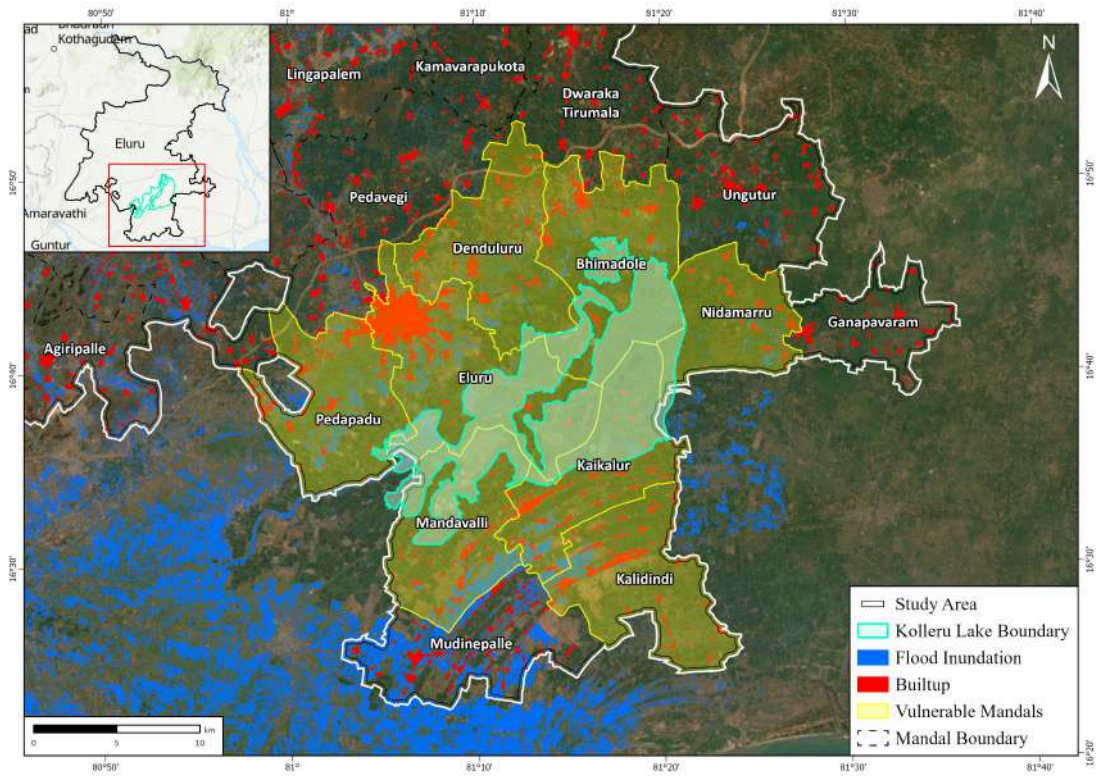


Figure 27: Kolleru Lake and vulnerable mandals

Wetlands like Lake Kolleru shown in *Figure 27* and *Figure 29* are known for their role in flood protection. We carried out a land use change mapping for Lake Kolleru from 2000 – 2024 shown in *Figure 28*. An analysis of land-use changes in Kolleru Lake since 2000 reveals dynamic shifts influenced by both human interventions and ecological responses. In 2000, aquaculture dominated the lake with fishponds occupying 29.7% of the area, while paddy fields, marshy land, and weed-infested zones each held substantial shares.

The 2008 post-restoration landscape, following "Operation Kolleru," marked a significant reversal, with marshy land expanding to nearly 60% and fishponds decreasing to 15.5%, indicating temporary ecological recovery. However, by 2018, fishponds had resurged to 27.7%, suggesting a gradual deintensification of aquaculture activity. As of 2024, while a slight reduction in aquaculture area has been noted compared to 2018, concerns remain regarding unregulated encroachments. These trends highlight the critical need for sustained monitoring and enforcement to protect the ecological balance of this vital freshwater wetland.

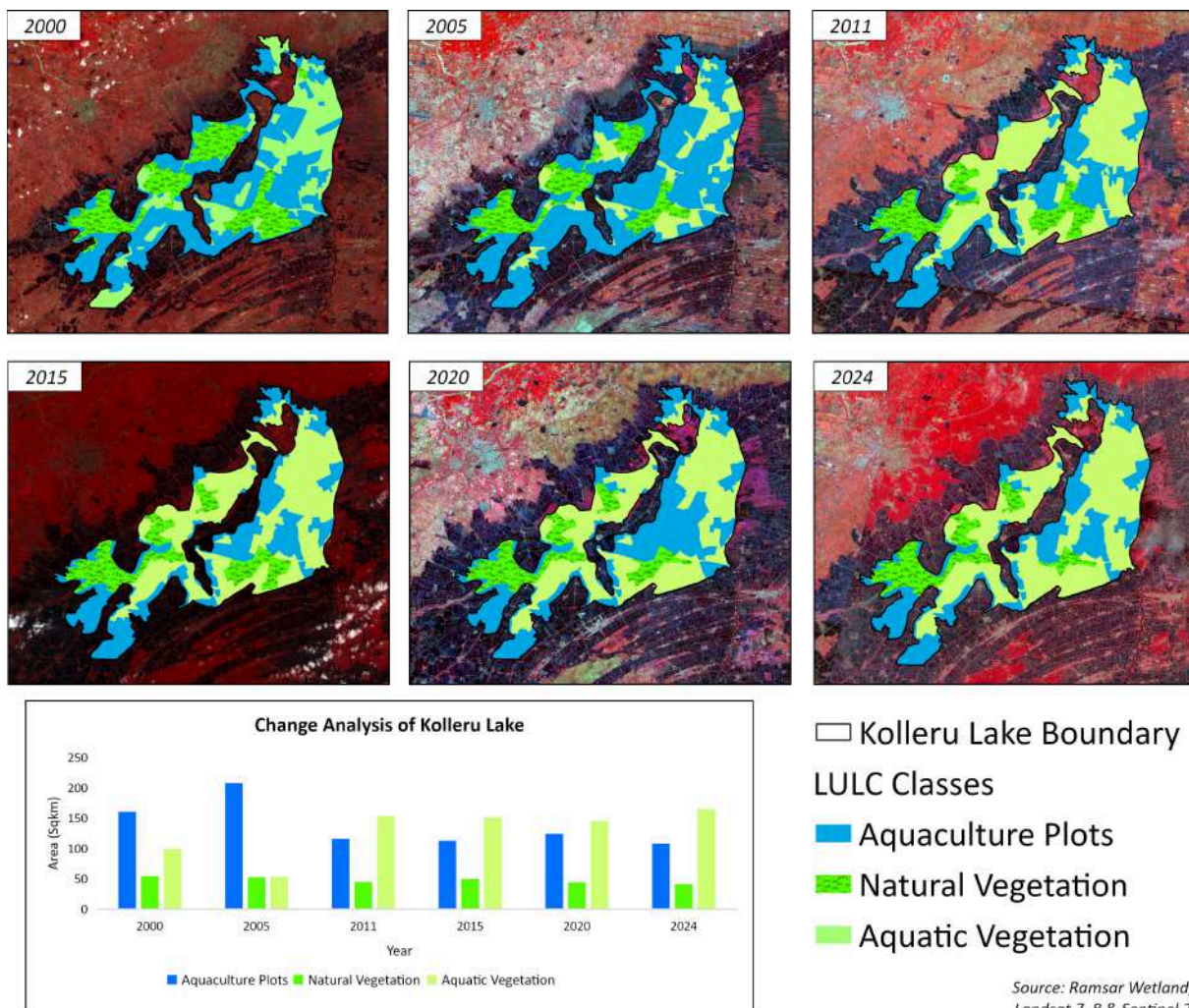


Figure 28: Kolleru Lake Change Analysis: 2000–2024 (5-Year Intervals).



Figure 29: Kolleru lake near Gudivakalanka Village, Eluru Mandal, Eluru District

4.3.1. Socio-Economic Vulnerabilities of Eluru

Socio-economic vulnerability is crucial for understanding the overall vulnerabilities as shown in Figure 30, of Allapadu village in Kaikaluru Mandal, Eluru District as it directly influences how communities respond to and recover from disasters. In district like Eluru, where livelihoods often depend on agriculture and small-scale industries, economic disruptions can significantly impact resilience. Assessing socio-economic vulnerability helps identify the most at-risk populations, guiding targeted interventions for effective disaster preparedness, risk reduction, and recovery planning.



Figure 30 : Interaction with Women at Allapadu village, Kaikaluru Mandal, Eluru District.

4.3.1.1. Cultivators and Agricultural labourers

The map in *Figure 31*, highlights the distribution of cultivators in Eluru District, revealing significant vulnerabilities tied to their reliance on agriculture. High cultivator density areas (4,000–6,000) are concentrated in agricultural hubs like Chintalapudi, Pedavegi, Jangareddigudem, Nuzvid, Eluru, Koyyalagudem, Ungutur and Dwaraka Tirumala. Flood-prone inland areas also suffer from waterlogging, delaying planting seasons and causing crop failures. Resource constraints, such as limited access to irrigation, technology, and markets, further reduce the resilience of cultivators in less developed regions.

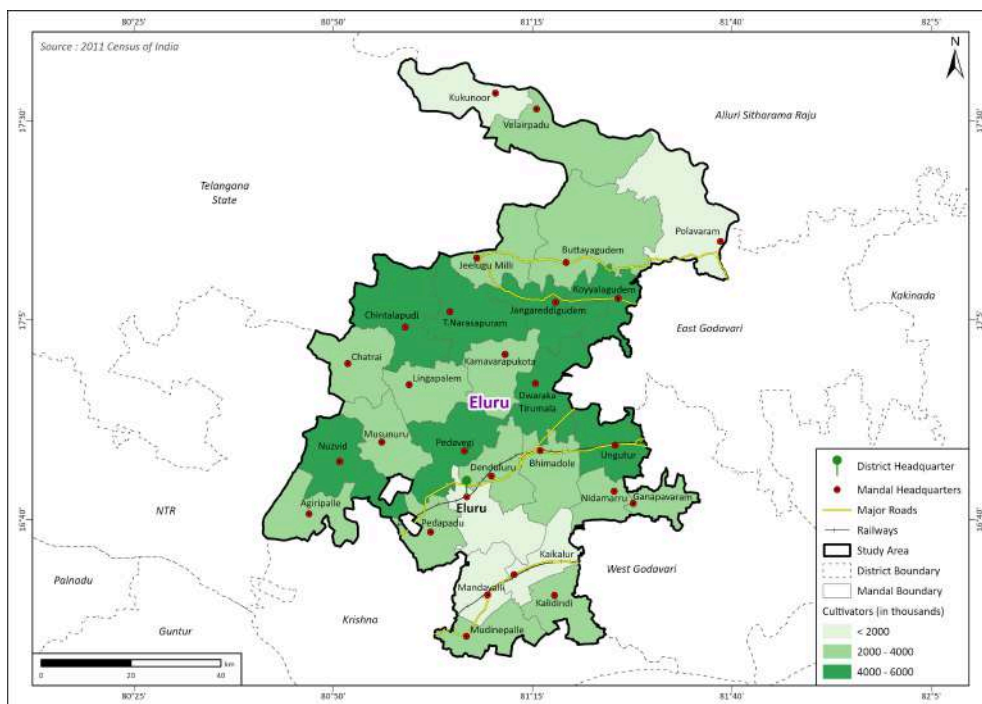


Figure 31: Cultivators Distribution in Eluru

The map in *Figure 32*, highlights the distribution of agricultural labourers in Eluru district, showing densities ranging from <10,000 to 30,000–40,000 (in thousands). Agricultural labourers are particularly vulnerable due to their dependence on low-paying, seasonal jobs and susceptibility to climate variability. Their low financial resilience and lack of alternative income options make recovery from such events challenging. Musunuru, T. Narsapuram, Polavaram, and Buttayagudem are the mandals with highest number of agricultural labourers as a share of respective mandal population.

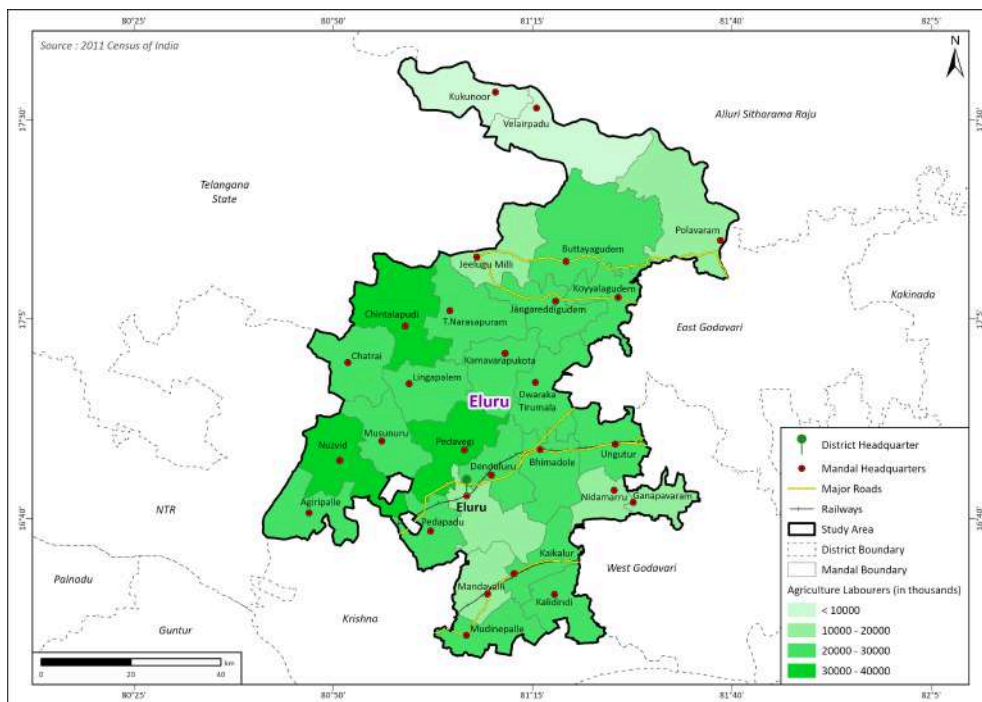


Figure 32 : Agricultural labourers Distribution in Eluru

4.3.1.2. Physical Infrastructure Vulnerabilities

Physical vulnerability, including critical infrastructure, built-up areas, and highly vulnerable mandals of Eluru District, is essential for vulnerability analysis as it highlights the exposure of key assets and populations to potential hazards. Critical infrastructure such as hospitals, schools, roads, and power facilities are extracted from google earth pro and APSDMA which are vital for emergency response and community functioning during disasters. Built-up areas with dense populations increase the risk of damage and casualties, especially in flood-prone or cyclone-affected regions. Identifying highly vulnerable mandals as shown in *Table 5* helps prioritize areas needing strengthened infrastructure, EWS, and disaster preparedness measures to minimize impacts and ensure faster recovery.

Also, mandals Nidamarru, Kaikaluru, Pedaparu, Dendaluru and Eluru are highly flood-prone, likely experiencing frequent waterlogging and overflow of water from Kolleru Lake into low lying regions during monsoon seasons or extreme weather events.

In Figure 33, the map depicts the critical infrastructure of Eluru. The infrastructure is heavily concentrated around the central region, particularly near Eluru town, which serves as a hub for hospitals, police stations, and government buildings. Schools are evenly distributed across the district, enhancing community preparedness and providing shelters during emergencies. Fire stations are sparse but located in key zones for disaster response.

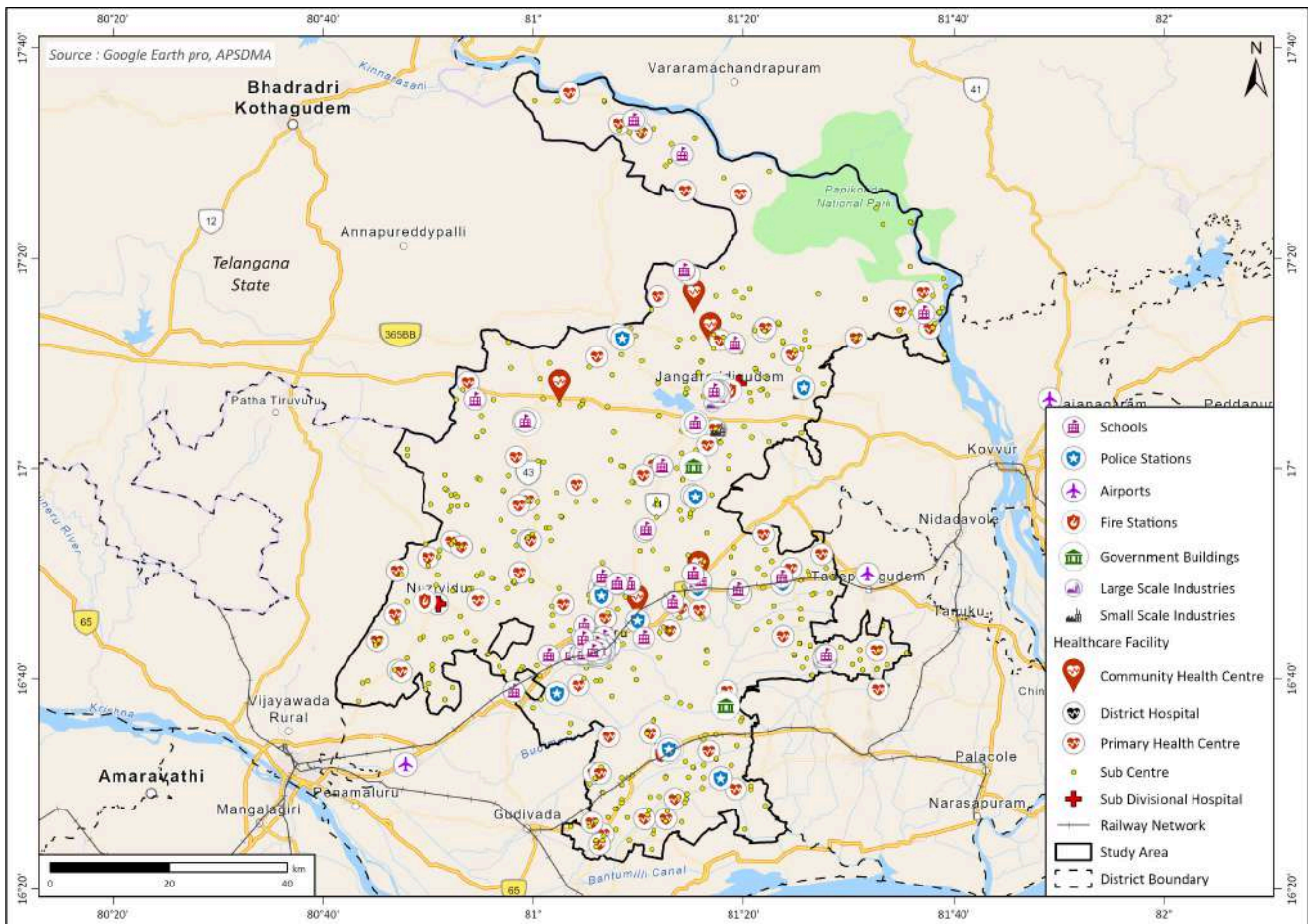


Figure 33 : Critical Infrastructure in Eluru

In Figure 33, the map depicts the critical infrastructure of Eluru. The infrastructure is heavily concentrated around the central region, particularly near Eluru town, which serves as a hub for hospitals, police stations, and government buildings. Schools are evenly distributed across the district, enhancing community preparedness and providing shelters during emergencies. Fire stations are sparse but located in key zones for disaster response.



Table 5 : Socio-Economic and Physical Vulnerability of Eluru District.

Section	Key Focus	High-Risk Areas	Key Vulnerabilities
Main & Marginal Workers	Main Workers: Urban/industrial zones Marginal Workers: Low-paying seasonal jobs	Eluru, Kaikalur, Kalidindi	Vulnerable due to economic reliance, poor social protection
Cultivators & Agri Labourers	Cultivators: Agri hubs Labourers: Seasonal low-income jobs	Cultivators: Chintalapudi, Eluru, Nuzvid, etc. Labourers: Musunuru, T. Narsapuram, Polavaram, Buttayagudem	Flooding & waterlogging disrupt agriculture; labourers have low recovery capacity
Industry Workers	Industrial employment density	Ungutur (high) Mandavalli, Musunuru (low)	Shows weak livelihood diversification
Population Density	Density from < 1L to 4L	Eluru (urban, >3L) Nuzvid, Jangareddigudem (semi-urban)	Urban areas at high risk during disasters
Literacy	Literacy impact on resilience	Low: Valairpadu, Kukunoor, Chatrai, T. Narsapuram	Low literacy delays preparedness & recovery
Physical Infrastructure	Built-up areas, critical infra exposure	High built-up + poor infra = high vulnerability	Need for infra strengthening & EWS



4.3.2. Risk Profile of Eluru

Risk profile of Eluru shown in *Figure 34*, was developed based on the comparative analysis of the mandals by considering the vulnerabilities and hazards of the mandals (Wiwandari Handayani, 2017) (Anamika Barua, 2018-19). Through this analysis mandals like Polavaram, T Narsapuram, Kaikaluru, Kalididindi and Mandavali are classified under high risk areas. The region suffered extensive damage from the 2024 Budameru floods, as floodwaters from the Budameru, Tammileru, and Ramileru Rivulet inundated numerous settlements surrounding Kolleru Lake in the Eluru and West Godavari districts.

- **Mandavalli Mandal:** Kovvadalanka, Nandigamalanka, Penumakalanka, Manuguru Lanka, and Pedagadi.
- **Kalididindi Mandal:** Sunnampudi, Bankupeta
- **Kaikaluru Mandal:** Panchakalamarri and Kothada
- **Eluru Rural Mandal:** Pedayaganamilli, Kalakarru, and Komatilanka
- **Pedapadu Mandal:** Rallapallivari Palem, Sakala Kothapalli, Koniki, and Gogunta

Velairpadu and **Polavaram** located within 5 km of major water bodies, Velairpadu and Polavaram are highly vulnerable to flooding, especially during heavy rains or cyclones (Using geospatial analysis we have got these mandals as high vulnerable). Their risk is confirmed through geospatial analysis of proximity to water bodies.

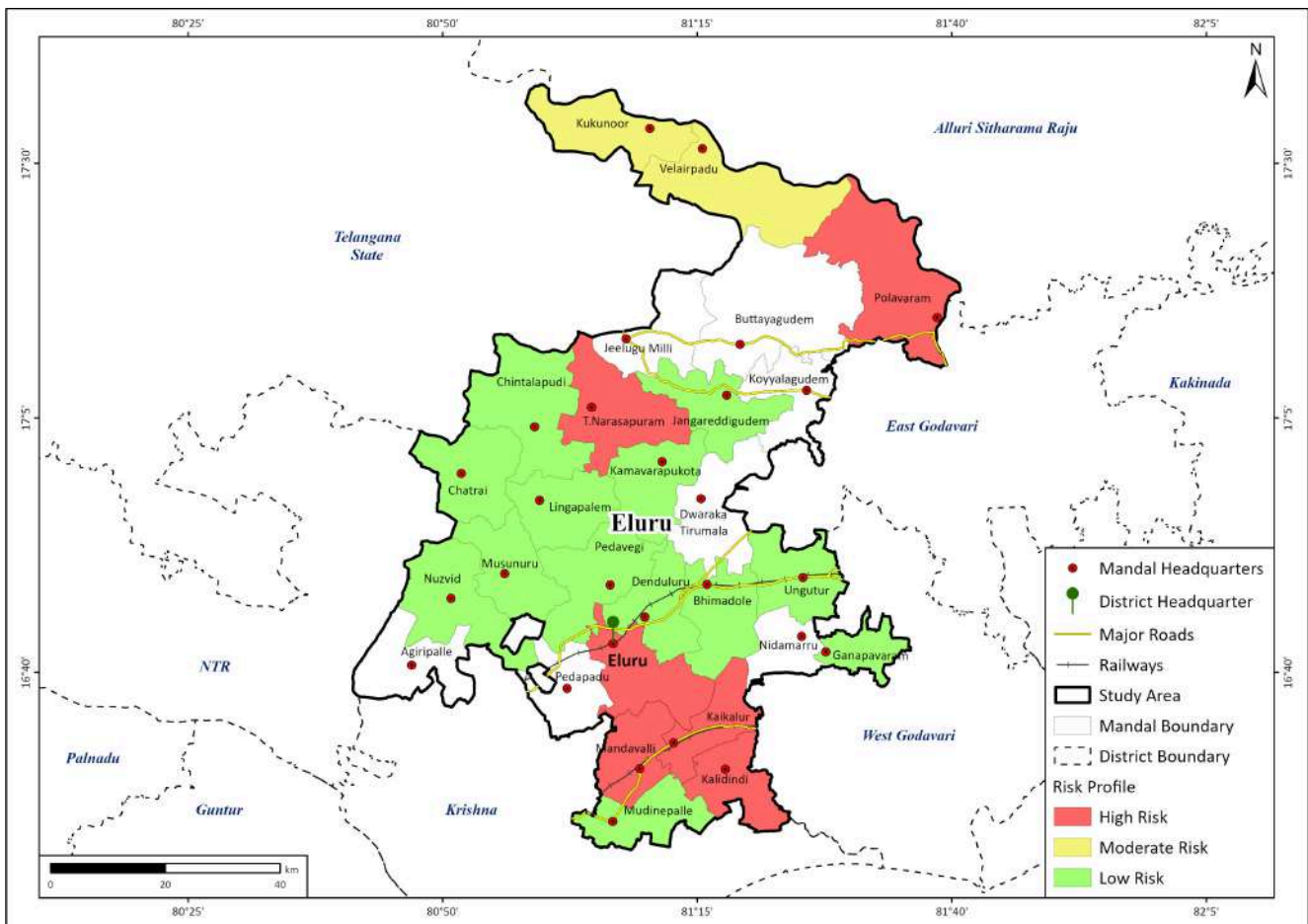


Figure 34 : Risk Profile of Eluru

Elevated water levels also created a flooding threat for communities such as Thokalapalli (Nidamaru Mandal), Agadala Lanka, Pothunuru (Denduluru Mandal), Agadala Lanka, and Chettanppadu (Bhimadolu Mandal). These events underscore the area's susceptibility to flooding and the urgent need for improved infrastructure and flood control strategies to mitigate future threats.

Chapter 5

**Multi-Hazard and
Vulnerability Analysis of
District
West Godavari**

Multi-Hazard and Vulnerability Analysis of District West Godavari

Disaster risk reduction relies heavily on understanding local hazard patterns and vulnerabilities. A clear assessment of risks not only saves lives but also strengthens community resilience and long-term development. In regions such as West Godavari, as per our field observation, we have found these indicators as relevant in understanding local vulnerabilities across Eluru District. These indicators include **social**, **economic**, **physical**, and **environmental** where literacy rate, marginal and agricultural workers, industry and non-workers, kutcha and semi-kutcha housing, road and medical access, forest cover, and proximity to rivers, coasts, and large water bodies. The hazard data was obtained from the APSDMA website (Authority, 2022), covering floods, droughts, cyclones, heatwaves, and storm surges. These maps were georeferenced and digitized using ArcGIS Pro, enabling each hazard type to be analysed individually to identify the most exposed mandals.

Simultaneously, vulnerability was assessed using Census 2011 (Data, 2011), Sentinel 1 (Sentinel-1, ESA), Sentinel-2 (Sentinel-2, ESA), and India WRIS data (WRIS, 2024), interpreting high or low values of the aforementioned indicators to classify mandals. A mandal was categorized as highly vulnerable if it showed weakness in more than two dimensions, moderate in more than one, and low in one dimension (Wiwandari Handayani, 2017)(Anamika Barua, 2018-19). This comprehensive hazard and vulnerability assessment has identified **Mogalthur**, **Undi**, and **Akividu** as high-risk zones in the district. These mandals are particularly exposed due to their coastal location, which makes them highly susceptible to cyclones, storm surges, and coastal flooding.

5.1. Hazard Analysis of West Godavari

The mandal of Mogalthur is classified as High Hazard Zone and Kalla, Bhimavaram, Narasapuram, Palacole, Poduru, and Achanta as Moderate Hazard Zones indicates a significantly elevated risk of natural disasters. This implies a high susceptibility to a combination of hazards, including floods, cyclones, and potentially landslides. High hazard zones are the mandals that are prone to multiple hazards considered like cyclones, floods, heatwaves etc. While moderate hazard zones are susceptible to more than two hazards, and low hazard zones are areas which are susceptible to two or less hazards.

5.1.1. Multi-Hazard Prone Mandals of West Godavari

The Multi-Hazard Map in *Figure 35*, developed using data from the APSDMA and GIS-based analysis, categorizes each mandal based on its susceptibility to natural disasters. While West Godavari district is classified as a Moderate Hazard Zone in Andhra Pradesh (APSDMA, 2016), indicating a risk of floods, cyclones, and other natural hazards such as heatwaves, storm surge, etc. The mandal of Mogalthur is classified as High Hazard Zone and Kalla, Bhimavaram, Narasapuram, Palacole, Poduru, and Achanta as Moderate Hazard Zones indicates a significantly elevated risk of natural disasters. This implies a high susceptibility to a combination of hazards, including floods, cyclones, and potentially landslides.

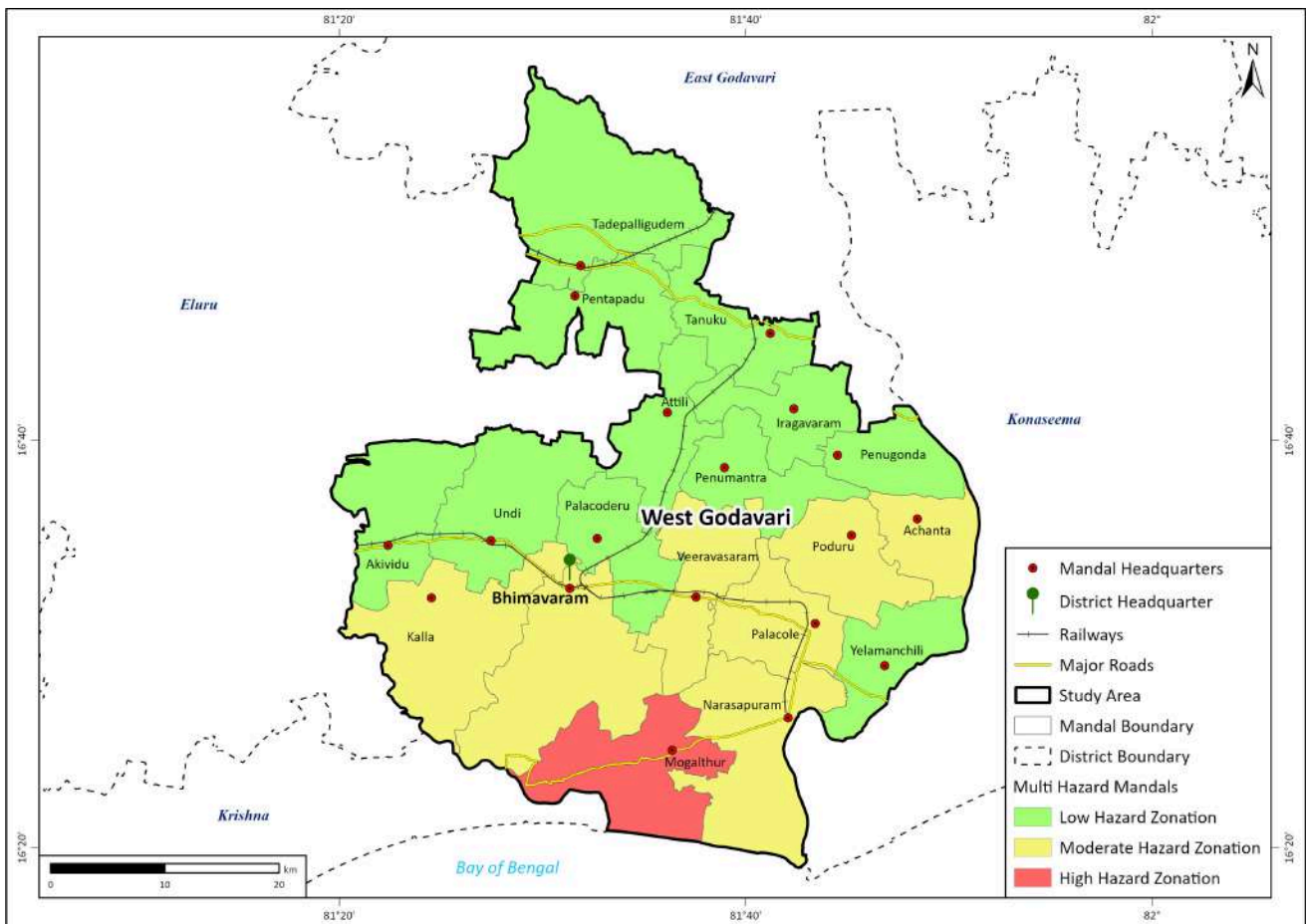


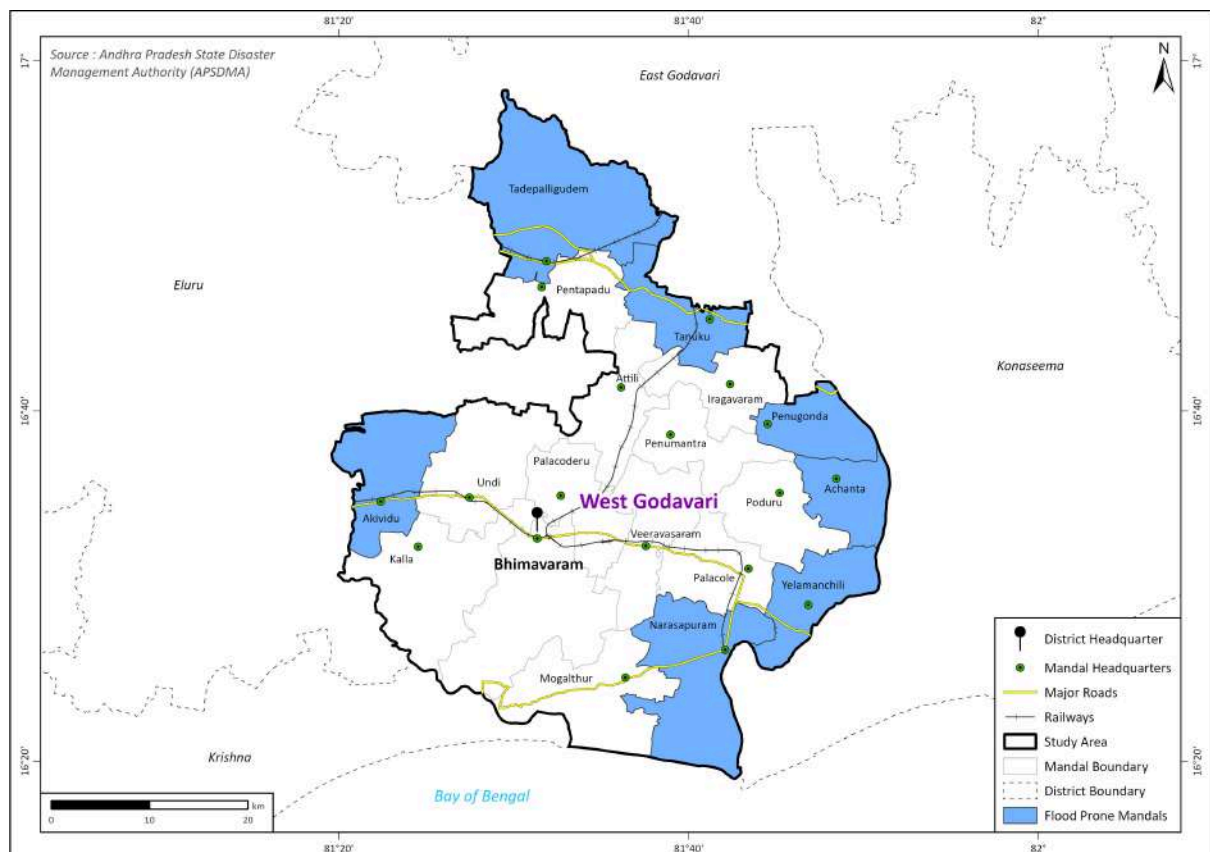
Figure 35: Map showing Multi-Hazard Prone Mandals of West Godavari

5.1.2. Cyclone Prone Mandals

As per data available from APSDMA in the West Godavari district all mandals are identified as cyclone-prone mandals in the West Godavari district of Andhra Pradesh, which are highly susceptible to cyclonic activity. Mandals like Kalla, Bhimavaram, Mogalturu, Narasapur, Palacole, Palacoderu, Undi, and Akividu, Palacole, Poduru face similar threats. The coastal and riverine nature of settlement in the district makes multiple mandals prone to cyclones and their impact on the lives, livelihoods, infrastructure like roads, electricity networks, and communication systems, leading to prolonged recovery times. The loss of income due to agricultural and commercial disruption creates long-term socio-economic challenges, making it difficult for affected populations to regain stability.

5.1.3. Flood Prone Mandals

The map in *Figure 36*, highlights flood-prone mandals developed based on the data available from APSDMA In the West Godavari district, it is observable that areas like Tadepalligudem, Tanuku, Penugonda, Akividu, Achanta, Yelemanchili, and Narsapuram are susceptible to flooding due to proximity to the river Godavari. Also, the low-lying nature of the region makes these areas naturally susceptible to flooding due to their topography, which are identified as highly flood-prone. These areas experience frequent waterlogging and overflow during monsoon seasons or extreme rainfall events.



5.1.4. Storm Surge Prone Mandals in West Godavari

Andhra Pradesh coast frequently experiences storm surges during the monsoon and cyclone seasons, particularly between June and November. The map in *Figure 37*, developed based on the data available from APSDMA Highlights susceptibility of the West Godavari district to storm surges. Regions like Kalla, Bhimavaram, Veeravasaram, Mogalturu, Narasapuram, Palacole, and Poduru in the West Godavari area are categorized as high-risk zones due to their low-lying topography and exposure to coastal storm surges.

The impact includes loss of life, damage to infrastructure, disruption of agriculture, and saline intrusion into freshwater resources. Historical cyclones like *Hudhud* (2014) and *Phailin* (2013) have demonstrated the devastating consequences of storm surges.

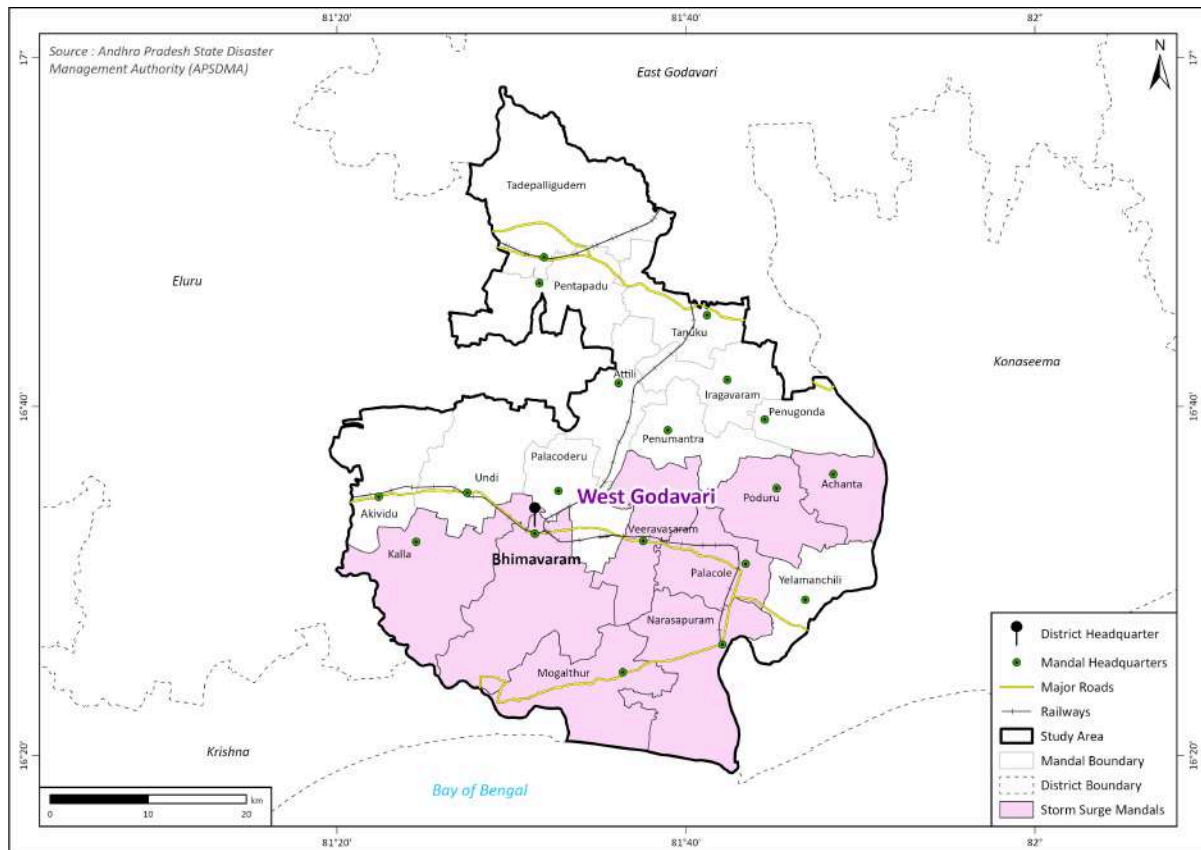


Figure 37: Storm Surge Prone Mandals of West Godavari

5.2. Vulnerabilities of West Godavari

West Godavari district has several vulnerable mandals facing socio-economic and disaster-related challenges. Coastal mandals like Mogalthur and Narsapuram, and other mandals like Bhimavaram, Palacole, Poduru, and Achanta face Moderate Hazard, which indicates a significantly elevated risk of natural disasters like cyclones and flooding. These regions also suffer from limited healthcare and emergency response facilities, while their economies are reliant on agricultural and industrial labour, prolonging disaster recovery. Palacole and Tanuku, with their industrial zones, are prone to flooding and hazardous material spills, posing threats to nearby communities. Emergency response mechanisms in these regions are insufficient to address such hazards. Tadepalligudem and Bhimavaram, major urban centres, are experiencing rapid built-up area growth, leading to overburdened infrastructure.

During a recent field visit to vulnerable areas like Mogalthuru, Narsapuram, and Kalla, and a few villages, Perupalem Mullaparu Village, Kodavari Meraka, Mullaru, Mullaparu, Guntapaka Palem in West Godavari, several key concerns came to light—from flood risks and poor canal maintenance to livelihood challenges and cyclone impacts. Local communities shared their experiences, and gaps in infrastructure and disaster preparedness were evident.



Figure 38 Stakeholder Meeting with District Magistrate, West Godavari District.

These insights highlight the need for timely action and support to build resilience in the most affected mandals (As shared by Smt. C. Naga Rani, IAS, Collector and District Magistrate, West Godavari District shown in Figure 38).