UNDERSTANDING SOCIO-ECONOMIC VULNERABILITY IN CONTEXT OF NATURAL HAZARD

A Thesis

Submitted in partial fulfilment of the
requirements for the award of the degree

of

Master of Planning (Urban Planning)

in

Department of Architecture and Planning

by

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ABSTRACT

The intensity of natural hazards like floods, cyclones, droughts, and extreme rainfall has increased as a result of climate variability and the changing environment. This has serious consequences for the settlement, livelihoods, and overall development of the region. In addition, socio-economic conditions such as; poverty, livelihood dependence on weather-cycles, population densities, weak infrastructure, and limited ability to adapt increases the vulnerability of communities in developing regions. Particularly those living in Kentucky and near to deltaic regions or within areas prone to flooding are exposed to many forms of natural disaster while relying on climate-sensitive forms of livelihood. The purpose of this study is twofold: to understand integrated socio-economic vulnerability to climate variability and to investigate how / how much the degree to which people are exposed to hazards and are sensitive is associated with their respective levels of livelihood dependence and capacity to adapt to change. This study area is Cuttack District, located within the deltaic region associated with the Mahanadi river and is highly vulnerable to flood/cyclone, water-logging, and river-related hazards due to the geographic characteristics, high population density, and the year-round agricultural dependence of the population in Cuttack. This study integrates socio-economic vulnerability assessment using a GIS-based method with hazard susceptibility analysis. Flood susceptibility mapping was created through weighted overlay analysis based on 5 thematic parameters including rainfall, slope, land use, height above nearest drainage, and distance to streams. Simultaneously, socio-economic vulnerability was assessed using 2 types of data for demographics (average population density) and the economy (poverty level). These data points were combined to develop the Social Vulnerability Index (SVI), Economic Vulnerability Index (EVI), and composite Socio-Economic Vulnerability Index (SEVI). The SEVI was spatially integrated with the flood susceptibility maps to help identify areas of high risk. Findings from the research indicate that regions with a high level of flood exposure, livelihood insecurity, poor infrastructure, and lower levels of adaptive capacity are the most vulnerable to flooding events. The research shows that hazard occurrence alone does not create disaster risk; instead, the combination of environmental hazards with socio-economic conditions defines the total vulnerability of a given area. Based on findings, this research proposes a socio-economic resilient framework for flood disaster resilience that includes developing flood resilient infrastructure, diversifying livelihoods, incorporating climate-sensitive planning into development practices, preparing for disasters, and implementing spatial planning interventions. The research contributes toward developing a planning-oriented and replicable framework for vulnerability assessment that can support disaster risk reduction, climate adaptation, and resilient regional development in hazard-prone areas.

सारांश

जलवायु परिवर्तन तथा बदलती पर्यावरणीय परिस्थितियों के कारण बाढ़, चक्रवात, सूखा एवं अत्यधिक वर्षा जैसी प्राकृतिक आपदाओं की आवृत्ति और तीव्रता में निरंतर वृद्धि हो रही है, जिससे मानव बस्तियों, आजीविका प्रणालियों तथा क्षेत्रीय विकास पर गंभीर प्रभाव पड़ रहा है। इन आपदाओं का प्रभाव सभी समुदायों पर समान रूप से नहीं पड़ता, क्योंकि गरीबी, आजीविका पर निर्भरता, जनसंख्या घनत्व, कमजोर आधारभूत संरचना तथा सीमित अनुकूलन क्षमता जैसी सामाजिक-आर्थिक परिस्थितियाँ समुदायों की संवेदनशीलता को बढ़ाती हैं। विशेष रूप से डेल्टाई तथा बाढ़-प्रवण क्षेत्रों में रहने वाले वे समुदाय, जो जलवायु-संवेदनशील आजीविकाओं पर निर्भर हैं, आपदाओं के दौरान अधिक जोखिम और कम लचीलापन प्रदर्शित करते हैं।

यह अध्ययन जलवायु परिवर्तनशीलता के संदर्भ में समेकित सामाजिक-आर्थिक संवेदनशीलता को समझने का प्रयास करता है, जिसमें आपदा जोखिम, सामाजिक-आर्थिक संवेदनशीलता, आजीविका निर्भरता तथा अनुकूलन क्षमता के परस्पर संबंधों का विश्लेषण किया गया है। यह शोध ओडिशा राज्य के कटक जिले पर केंद्रित है, जो महानदी डेल्टा क्षेत्र में स्थित होने के कारण बाढ़, चक्रवात, जलभराव तथा नदीजनित आपदाओं के प्रति अत्यधिक संवेदनशील है। जिले की भौगोलिक स्थिति, उच्च जनसंख्या घनत्व तथा कृषि एवं अनौपचारिक क्षेत्रों पर निर्भरता इसे जलवायु जोखिमों के प्रति अधिक प्रभावित बनाती है।

अध्ययन की कार्यप्रणाली में भौगोलिक सूचना प्रणाली (GIS) आधारित स्थानिक तकनीकों का उपयोग करते हुए आपदा संवेदनशीलता विश्लेषण तथा सामाजिक-आर्थिक संवेदनशीलता मूल्यांकन को एकीकृत किया गया है। बाढ़ संवेदनशीलता मानचित्रण के लिए वर्षा, ढाल, भूमि उपयोग/भूमि आवरण (LULC), निकटतम जलनिकासी से ऊँचाई (HAND) तथा नदी से दूरी जैसे विषयगत मानकों का उपयोग करते हुए वेटेड ओवरले विश्लेषण किया गया। साथ ही, साक्षरता, आश्रित जनसंख्या, कृषि श्रमिक, सीमांत श्रमिक तथा गैर-कार्यशील जनसंख्या जैसे जनसांख्यिकीय एवं आर्थिक संकेतकों के आधार पर सामाजिक-आर्थिक संवेदनशीलता का आकलन किया गया। इन संकेतकों को एकीकृत कर सामाजिक संवेदनशीलता सूचकांक (SVI), आर्थिक संवेदनशीलता सूचकांक (EVI) तथा समेकित सामाजिक-आर्थिक संवेदनशीलता सूचकांक (SEVI) विकसित किया गया।

SEVI तथा बाढ़ संवेदनशीलता मानचित्र के स्थानिक एकीकरण द्वारा जिले के संवेदनशील हॉटस्पॉट क्षेत्रों की पहचान की गई। अध्ययन के निष्कर्ष दर्शाते हैं कि वे क्षेत्र जहाँ उच्च बाढ़ जोखिम, आजीविका असुरक्षा, कमजोर आधारभूत संरचना तथा सीमित अनुकूलन क्षमता मौजूद है, वहाँ सामाजिक-आर्थिक संवेदनशीलता का स्तर अधिक पाया गया। अध्ययन यह स्पष्ट करता है कि केवल आपदा की घटना ही जोखिम निर्धारित नहीं करती, बल्कि पर्यावरणीय जोखिमों तथा सामाजिक-आर्थिक परिस्थितियों की पारस्परिक क्रिया समग्र संवेदनशीलता को निर्धारित करती है।

अध्ययन के आधार पर एक सामाजिक-आर्थिक लचीलापन रूपरेखा प्रस्तावित की गई है, जिसमें बाढ़-प्रतिरोधी आधारभूत संरचना, आजीविका विविधीकरण, जलवायु-संवेदनशील नियोजन, आपदा तैयारी तथा स्थानिक नियोजन हस्तक्षेपों पर विशेष बल दिया गया है। यह शोध एक नियोजन-उन्मुख एवं पुनरावृत्त (replicable) संवेदनशीलता मूल्यांकन रूपरेखा विकसित करने में योगदान देता है, जो आपदा जोखिम न्यूनीकरण, जलवायु अनुकूलन तथा आपदा-प्रवण क्षेत्रों में लचीले एवं सतत क्षेत्रीय विकास को समर्थन प्रदान कर सकती है।

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1. INTRODUCTION

Natural hazards pose escalating threats to the global human settlements, with socio-economic vulnerability which is emerging as a critical determinant of disaster impacts and community resilience. The intersection of climate variability, natural hazards, and livelihood systems creates a complex vulnerability patterns that requires comprehensive spatial analysis to understand their multidimensional nature and inform effective mitigation strategies (Zahnow et al., 2025). This research basically addresses the urgent need for integrated vulnerability assessment frameworks that connect hydro-meteorological hazards with livelihood opportunities, migration dynamics, and spatial planning interventions (Viveros-Uehara, 2023).

1.1 What is natural hazard

A natural hazard can be defined as a process or phenomenon in the physical environment that constitutes a threat or a potential source of disaster to human life, property, social and economic infrastructure, ecological balance, and other environmental resources, whereas a disaster occurs when that society is not able to withstand the impact of the event. Apart from the nature of the hazard itself, the combination of socio-economic factors, exposed populations, and the capability of individuals and economies to resist the shock determines the severity of the outcome.

1.2 Types of Natural Hazards

Natural hazards are typically categorized based on their scale and, critically for socio-economic vulnerability analysis, the speed of their onset:

1.2.1 Classification by Onset Speed

Rapid Onset Events (ROE): These are hazards that occur with short warning times and are short-lived, often taking people by surprise. They typically result in high levels of physical destruction, mortality, and the immediate displacement of survivors.
Examples: Tornadoes, flash floods, earthquakes, and severe cyclones.

Socio-economic Impact: ROEs necessitate rapid response planning and focus on instantaneous resilience, as seen in coastal areas affected by cyclone landfalls and storm surges, which cause rapid saline intrusion and destroy physical assets.

Slow Onset Events (SOE): These are hazards that develop slowly, sometimes over years, making their impact more insidious. While they rarely cause immediate fatalities, they severely impact long-term livelihoods, food security, and regional economies.

Examples: Drought, desertification, and chronic water scarcity.

Socio-economic Impact: Resilience to SOEs requires long-term adaptation planning, structural changes to livelihood systems (such as diversifying income away from rainfed agriculture), and systematic monitoring to prevent gradual impoverishment.

1.2.2 Classification by Hazard Type (Based on Research Context)

The research material focuses on hazards common in vulnerable agroecological and coastal zones, which can be broadly grouped:

Hydrometeorological/Climate-Related Hazards: These are events influenced by climate and weather patterns.
Examples: Floods (due to river overflow or heavy monsoon rainfall), waterlogging, landslides (often exacerbated by high precipitation), unseasonal frost, and hurricanes/cyclones.

Geological Hazards (Geohazards): Events originating from geological or terrain processes.

Examples: Earthquakes and landslides. Research increasingly emphasizes the need for a unified "geoclimate" assessment approach, as changes in climate (e.g., altered precipitation) can increase the susceptibility of environments to geohazards.

Arid/Drought-Related Hazards:

Examples: Severe drought, erratic rainfall, and flash droughts (rapid-onset dry conditions) that severely threaten crop cycles and livestock health in arid regions.

While natural hazards are not new to the human environment, the scale and distribution of their impacts have changed dramatically in recent decades. Increasingly, disasters related to floods, cyclones, droughts, landslides, and heatwaves interact with vulnerable populations in ways that result in severe and long-term socio-economic impacts. While the physical occurrence of natural hazards cannot be prevented, the nature of disaster impacts is essentially determined by human systems-specifically, social, economic, institutional, and political structures which determine people's capacity to anticipate, cope with, and recover from hazard events (Wisner et al., 2004). This perspective challenges traditional views of disasters as purely natural phenomena and instead frames them as the outcome of an interaction between environmental events and societal vulnerabilities.

Vulnerability is increasingly recognized as a multidimensional concept rooted in historical, socio-economic, and spatial inequalities. It refers to the conditions which put people or groups at an increased likelihood of injury, including limited access to resources, insecure livelihoods, poor living conditions, and inadequate institutional support (Cutter et al., 2003). Studies during the last four decades have shown, with constancy, that disasters fall more heavily on the poor and the marginalized, not because hazards target them but because their socio-economic environments place them in exposed and inadequately protected settings (Bankoff, 2019). The above leads to the understanding that disasters are socially created. That is, the severity and unequal distribution of disasters are shaped by systemic factors such as poverty, gender, caste hierarchies, governance failures, and environmental degradation (Wisner et al., 2004).

Climate change further amplifies these dynamics. Increased global temperatures, erratic patterns of rainfall, and more frequent extreme events linked to sea-level rise have increased the magnitude and unpredictability of natural hazards (IPCC, 2021). Local communities, whose livelihoods are based on natural resources such as agriculture, fisheries, and forestry, thus experience increased uncertainty and instability when these climate-induced hazards disrupt cycles of production, cause ecosystem degradation, and reduce the stability of incomes (Adger, 2006). In turn, unplanned urbanization, high population density, inadequate infrastructure, and the growth of informal settlements in areas prone to hazards have created new forms of vulnerability in urban areas (Revi et al., 2014). Overlapping pressures create complex, changing patterns of vulnerability, which demand an integrated understanding of socio-economic conditions and hazard characteristics.

Against this wider global backdrop, the notion of socio-economic vulnerability becomes key in assessing the disaster risk and making relevant resilience plans. Socio-economic vulnerability encompasses the manner in which household income, livelihood diversity, education levels, gender roles, health status, and access to services determine exposure and sensitivity to hazards (Birkmann, 2013). For instance, farmers who depend on rain-fed cultivation become very vulnerable to droughts, coastal fishing communities bear an increased risk in the face of cyclones and storm surges, and casual urban workers usually lose their source of income in the event of a flood that is extended in duration. Equally, women, children, the elderly, people with disabilities, migrants, and other social minorities, like lower-caste communities, often fail to have proper access to resources and decision-making, therefore

being more vulnerable to consequences when natural hazards strike (Gaillard, 2010). These social determinants form the basis for different groups suffering from higher losses and slower recovery than others under similar hazard conditions.

International frameworks have increasingly put emphasis on socio-economic vulnerability assessment as an integral part of comprehensive disaster risk reduction. The Sendai Framework for Disaster Risk Reduction 2015–2030 (UNDRR, 2015) calls for countries to move away from reactive disaster management and toward proactive risk-informed development, underlining the need to consider the drivers of underlying vulnerability that arise from poverty, inequality of condition, environmental degradation, unplanned development, and weak governance. In the same vein, the Intergovernmental Panel on Climate Change (IPCC) conceptualizes risk as a function of hazard, exposure, and vulnerability, where socio-economic conditions feature as a core component of vulnerability (IPCC, 2014). These frameworks are representative of increasing consensus that resilience-building requires a deep understanding of socio-economic systems, livelihood patterns, and adaptive capacities.

In India, the problem of socio-economic vulnerability in the context of natural hazards is particularly significant. India is one of the most disaster-prone countries in the world; nearly 68% of its land area is prone to droughts, 60% to earthquakes, 12% to floods, and 8% to cyclones (NDMA, 2019). The pressure of rapid urbanization has resulted in settlements spreading into floodplains, coastal belts, unstable slopes, and ecologically sensitive areas with inadequate planning and infrastructure in situ (Bhat et al., 2019). Meanwhile, rural areas continue to remain heavily dependent on agriculture and natural resources, placing them within the widening ambit of climate change uncertainties. Rural–urban migration, informal employment, inadequate social protection, along with very limited access to healthcare and education, further exacerbates the situation. These socio-economic dynamics make India a critical site for examination, where hazard exposure intersects with social and economic inequalities to produce differential impacts.

Given the above complexities, a comprehensive understanding of socio-economic vulnerability needs to be multi-layered and embedded in hazard analyses and livelihood assessments, supplemented by socio-economic profiling. It is not good enough to map hazard-prone zones or quantify economic losses. Comprehensive vulnerability assessments need to capture who is most affected, why they are affected, and how socio-economic conditions determine their response copotential. Such an integrated approach will help in identifying the vulnerable

group(s); drivers of their vulnerability; and opportunities for building resilience through focused livelihood support, infrastructure improvement, institutional strengthening, and, of course, policy interventions (Birkmann, 2013).

Socioeconomic vulnerability is defined as a predisposition of social communities to adverse impacts from natural hazards and, therefore, involves three interrelated dimensions: physical exposure, social sensitivity, and adaptive capacity. Contemporary scholarship identifies vulnerability not as the product of hazard magnitude but rather as an emerging property of the interlinked biophysical exposure, socioeconomic structures, and institutional adaptive capacity. The multi-dimensionality calls for spatial approaches that can systematically reproduce heterogeneous vulnerability patterns across a range of geographic scales and livelihood contexts (Prall, 2022).

The diversity in agro-climatic zones and socio-economic conditions in India makes it particularly prone to hydro-meteorological hazards, while rural communities bear the most disproportionate effects because of their dependence on climate-sensitive livelihoods. About 68% of the cultivable land in India is prone to drought, and coastal and riverine areas are exposed to increasing flood and cyclone risks, while regional differences are reflected in a mosaic of hazard exposure. This is further compounded by a lack of technological inputs, poor infrastructure, and general constraints in adaptive capacity, especially among small and marginal farmers who consist of about 82% of India's agricultural workforce.

The nature of the relationship between natural hazards and livelihood systems is intrinsically spatial, showing vast contrasts in the vulnerability pattern across different geographic contexts. LVI studies indicate that agricultural communities have a higher vulnerability to flooding; hence, vulnerability scores reached up to 0.4 in flood-prone districts, signifying high potential livelihood disruption. GIS and remote-sensing technologies have become indispensable tools for mapping these patterns of vulnerability, which allow the merging of several datasets, such as DEMs, land use classifications, socio-economic indicators, and hazard frequency data (Atasheva et al., 2024).

Migration serves as both a consequence of livelihood vulnerability and an adaptive strategy. It forms some very complex rural-urban linkages, which drive patterns of vulnerability across space and time. Climate-induced displacement affects around 13.45 million people every year in India. The different causes of migration are household income, information availability, and community networks. In the case of migration, its spatial dimension can create feedback loops

wherein source areas have reduced labor availability, while destination areas might face increased pressure on infrastructure and services, likely creating new hotspots of vulnerabilities in the process (Saha et al., 2024).

Modern research has reiterated the need for integrated spatial frameworks, which have to consider simultaneously hazard patterns, livelihood opportunities, and migration dynamics. Hydro-meteorological risk assessment methods are increasingly allowing nature-based solutions and multi-hazard approaches, since communities often face multiple cascading risks rather than single hazard events. This increasing complexity requires advanced applications of spatial analytical techniques that model the interactions at various scales between different components of vulnerability and identify priority areas for intervention.

The sensitivity of the agricultural sector to climate makes it an important lens for understanding socio-economic vulnerability patterns. Crop-specific vulnerability classes change with the phenological stage-the planting and flowering periods are the most sensitive against hydro-meteorological extremes. Spatial analysis of cropping patterns reveals that strategies through which farmers adapt include crop diversification and seasonal adjustments in crops; this is, however, deficient in supportive infrastructure and policy interventions. Integrating crop calendars with flood timing data and cyclone data provides key findings toward developing a climate-resilient agricultural system (Almulhim et al., 2024).

In coastal areas, specific vulnerability contexts are created by this convergence of cyclone exposure with agriculture, fisheries, and aquaculture livelihood dependency. Coastal Odisha presents evidence for cascading impacts-storm surge, embankment breaching, and saline water intrusion-continuing to impact households well after storm events, with 67% reporting severe falls in agricultural production. These findings highlight the importance of understanding compound risks and their temporal dimensions in vulnerability assessment.

Mountainous regions exhibit peculiar patterns of vulnerability, shaped by fragmented landholdings, rain-fed agriculture, and exposure to multiple hazards related to flash floods, landslides, and drought. In Uttarakhand, only 14% of the land area is cultivable, with 72% of agricultural household income derived from cultivation, which creates huge sensitivity to climate variability. Geographic constraints and climate change impacts require specialized approaches for vulnerability assessment and livelihood strengthening in such cases (Prall et al., 2023).

Drought-prone regions in western and central India are characterized by the complexity of socio-economic vulnerability mapping, where meteorological, agricultural, and hydrological drought indicators must be combined with socio-economic sensitivity measures. Rajasthan, Maharashtra, Madhya Pradesh, and Gujarat reveal high vulnerability across all types of droughts, but vulnerability patterns vary significantly at district and sub-district levels. Spatial heterogeneity across locations brings into focus a need for location-specific assessment of vulnerabilities and intervention strategies.

An added level of complexity arises from the temporal dimension of vulnerability, where seasonal variations in hazard exposure, livelihood activities, and coping capacities create dynamic patterns of vulnerability across the year. Climate-livelihood calendars emerge as essential tools for understanding these temporal dynamics, enabling the identification of critical periods when communities face heightened vulnerability and require targeted support. Integrating crop phenology, hazard seasonality, migration patterns, and local institutional capacity, these calendars provide comprehensive temporal vulnerability profiles.

The technological advances in geospatial analysis present new opportunities to enhance the precision and scope of vulnerability assessments. Applications of machine learning to crop yield predictions, satellite-based monitoring of floods, and mapping of social vulnerability provide the opportunity to generate more precise and timely vulnerability assessments. However, the technological capabilities are balanced with participatory approaches that incorporate local knowledge and community perspectives on vulnerability and resilience.

The policy implications for spatial vulnerability analysis go beyond disaster risk reduction to wider development planning concerns. The hotspots of vulnerability identified through spatial analysis have the potential to inform resource allocation, infrastructure development, and livelihood enhancement programs. As climate-induced migration hastens urbanization in many medium-sized cities across India, the integration of vulnerability assessment with ongoing urban planning processes assumes particular significance.

This research contributes to the growing area of spatial vulnerability analysis by constructing an integrated framework that links hydro-meteorological hazards with livelihood systems, migration dynamics, and mitigation opportunities. This study undertakes an in-depth case study analysis across different agro-climatic zones and uses state-of-the-art geospatial techniques to further improve the understanding of socioeconomic patterns of vulnerability and evidence-

based strategies to build resilient communities facing increased climate variability and natural hazard risks.

This multi-phase research design comprehensively examines the components of vulnerability while maintaining focus on practical applications for policy and planning. By fusing state-of-the-art spatial analysis techniques with participatory approaches and comparative case studies, this research addresses critical knowledge gaps in vulnerability assessment while providing actionable insights for disaster risk reduction and sustainable development planning in the diverse geographic and socio-economic contexts of India.

1.3 BACKGROUND OF THE TOPIC

Socio-economic vulnerability to natural hazards is a critical concern for sustainable development, especially in countries like India where climate variability and extreme events are intensifying due to global climate change. Vulnerability is shaped by a complex interplay of physical exposure, social sensitivity, and adaptive capacity, with rural and agriculture-dependent populations facing heightened risks from floods, droughts, cyclones, and other hydro-meteorological hazards. India's vast geographic diversity, demographic pressures, and reliance on climate-sensitive livelihoods amplify these vulnerabilities, making integrated assessment and spatial mapping essential for effective risk reduction and resilience planning (Daoust & Selby, 2024).

The context for understanding socio-economic vulnerability is defined by an intensifying global crisis of geophysical and climatic risk. This chapter provides a detailed overview of the escalating challenge of natural hazards, the limitations of traditional disaster assessment, and the contemporary economic frameworks required for comprehensive vulnerability analysis.

1.3.1. The Escalating Challenge of Natural Hazards

The modern era is characterized by the increasing frequency and intensity of natural disasters worldwide, a phenomenon significantly exacerbated by global warming and human-induced climate change. This escalation places current socio-economic systems under severe and persistent threat, particularly affecting agricultural production systems globally. The quantitative measure of this impact is staggering; data confirms that global economic losses attributable to natural hazards have reached values far exceeding historical averages, demonstrating the immense scale of the problem and the necessity for systemic resilience planning.

The increasing prevalence of these events necessitates a fundamental re-evaluation of how societies interact with and prepare for risk. This need is particularly acute for low-income countries and vulnerable populations, which are inherently less resilient and face higher exposure levels compared to countries with higher development levels.

1.3.2. Limitations of Traditional Disaster Assessment

For decades, the standard approach to quantifying disaster impact relied heavily on assessing the physical destruction of assets, focusing on stock losses such as damage to infrastructure, housing, and productive capital. However, this conventional approach has been shown to be profoundly insufficient for capturing the full adverse impact on human well-being.

A modern and comprehensive understanding of disaster impact requires shifting the analytical focus toward the subsequent and often more devastating minimization of welfare losses experienced by affected populations. The initial destruction of physical assets merely triggers the first stage of the economic impact, leading inevitably to cascading consequent losses of output, income flow, and, ultimately, reduced consumption—the primary measure of a person's well-being.

Furthermore, traditional macro-economic measures, such as Gross Domestic Product (GDP), often prove inadequate for capturing the deep, multi-dimensional nature of poverty and vulnerability experienced at the household level, failing to account for socio-economic heterogeneity.

Over the past two decades, India has ranked among the world’s most disaster-affected countries, with millions of people impacted by recurrent floods, droughts, and cyclones. The eastern and central zones, including states like Odisha, Bihar, and West Bengal, are particularly vulnerable due to their exposure to monsoon floods and cyclonic storms, while western and central regions such as Rajasthan, Gujarat, and Madhya Pradesh face chronic drought and water scarcity. Coastal areas, with over 40% of the population residing along India’s 7,500 km coastline, are increasingly threatened by storm surges, saline intrusion, and cyclone-induced flooding (Assraf Seddiky et al., 2024).

Agriculture remains the backbone of India’s rural economy, employing over 82% of small and marginal farmers who are highly sensitive to climate shocks. Rain-fed agriculture, which accounts for more than half of the cultivated land, is especially vulnerable to erratic rainfall, drought, and flooding, leading to crop losses, income instability, and food insecurity. These

hazards not only disrupt agricultural production but also trigger migration, as affected households seek alternative livelihoods in urban centers, further straining urban infrastructure and services. The resulting rural-urban migration creates new vulnerability hotspots and perpetuates cycles of poverty and risk.

Socio-economic vulnerability is not uniform across regions or communities; it is shaped by factors such as poverty, education, access to resources, health, and social networks. Marginalized populations, including women, indigenous groups, and landless laborers, often have limited coping capacity and face greater challenges in recovering from disasters. Spatial and temporal patterns of vulnerability are evident, with central and eastern states showing higher vulnerability due to socio-economic and geographic differentiation. The loss of livelihoods, especially in agriculture, exacerbates household vulnerability and can lead to long-term displacement and social disruption.

Recent advances in geospatial technologies and vulnerability assessment frameworks have enabled more precise mapping of hazard exposure, socio-economic sensitivity, and adaptive capacity at local, regional, and national scales. Tools such as the Livelihood Vulnerability Index (LVI), social vulnerability indices, and GIS-based risk mapping provide valuable insights for identifying priority areas and designing targeted interventions. However, there remain significant gaps in integrating these approaches with participatory methods and local knowledge, which are essential for building effective and equitable resilience strategies.

In summary, the background of this dissertation is rooted in the urgent need to understand and address the spatial dimensions of socio-economic vulnerability to natural hazards in India. By focusing on agriculture-dependent regions and integrating hazard mapping, livelihood analysis, and migration dynamics, this research aims to contribute to the development of robust frameworks for risk mitigation and resilient livelihood planning. The study's emphasis on Odisha and comparative case areas reflects the diversity of vulnerability contexts across India and highlights the importance of location-specific, data-driven approaches for sustainable development and disaster risk reduction.

1.4. NEED FOR THE STUDY

Understanding socio-economic vulnerability in the context of natural hazards is vital for several reasons. First, India's rural economy remains predominantly agriculture-based, with over 60% of the population directly dependent on climate-sensitive livelihoods; recurrent floods, droughts, and cyclones cause average annual agricultural losses exceeding USD 10

billion, undermining food security and rural incomes. Second, socio-economic vulnerability varies markedly across regions and population groups—small and marginal farmers, landless laborers, women, and indigenous communities exhibit disproportionately high sensitivity and limited adaptive capacity, yet existing vulnerability assessments often overlook these intra-community disparities (Emmerling et al., 2024).

Third, conventional hazard mapping primarily focuses on physical exposure, neglecting the critical interplay between hazard intensity, livelihood potential, and migration dynamics; this gap hinders the design of targeted risk-reduction strategies that sustain or enhance livelihoods while mitigating hazard impacts. Fourth, climate variability is altering hazard patterns—monsoon floods are becoming more erratic, droughts more severe, and cyclones more frequent and intense—rendering historical hazard data insufficient for future planning and necessitating dynamic, spatially explicit vulnerability frameworks(Rana et al., 2025).

Fifth, migration driven by livelihood stress creates complex rural–urban feedback loops: source areas lose labor and human capital, while destination cities face infrastructure strain and emergent vulnerability pockets; yet spatial analyses rarely integrate migration patterns with agro-hazard risk and livelihood opportunity mapping. Finally, policy and planning instruments at state and local levels lack robust, evidence-based tools to prioritize interventions—such as engineered flood mitigation, crop-calendar adjustments, or diversification incentives—leading to suboptimal allocation of resources and missed opportunities for resilience building.

By developing an integrated, GIS-based framework that links hazard exposure, livelihood potential, migration dynamics, and adaptive capacity, this study addresses these critical gaps. The resulting spatial vulnerability maps and livelihood-hazard interaction models will support planners and policymakers in Odisha and comparable regions to design differentiated, equity-focused interventions that enhance socio-economic resilience in the face of escalating natural hazard risks.

2. LITERATURE REVIEW

2.1 BIBILOMETRIC ANALYSIS

Databases: Scopus, Google Scholar

Keywords: “socio-economic centered”, “Agro”, “Migration”

Search String: (TITLE-ABS-KEY("socio-economic vulnerability" OR "social vulnerability" OR "economic vulnerability" OR "livelihood vulnerability" OR "community vulnerability" OR "vulnerability assessment" OR "resilience" OR "adaptive capacity") AND TITLE-ABS-KEY("natural hazard*" OR "disaster*" OR "flood*" OR "earthquake*" OR "cyclone*" OR "drought*" OR "extreme event*") AND TITLE-ABS-KEY("agriculture" OR "agro" OR "farming" OR "rural livelihood*" OR "food security" OR "crop*" OR "farm*" OR "agricultural vulnerability") AND TITLE-ABS-KEY("migration" OR "displacement" OR "migrant*" OR "forced migration" OR "climate migration" OR "internal migration"))= 312 Papers

Analysis: Extracted indicators, methods, and gaps into Excel template

Bibliometrics: Used VOS viewer for keyword co-occurrence and thematic clusters

Outcome: Identified research gaps and defined parameters

Overlay Visualisation in VOS viewer

Overlay visualisation extends network mapping by integrating temporal dimensions—the color scale reflects trends over time (2018-2023). In the below map, nodes like "adaptive capacity," "displacement," "food insecurity," "smallholder farmers," and "sustainability" are colored to show their prevalence in more recent years (2022-2023, in yellow), while foundational terms such as "vulnerability," "adaptation," and "resilience" are both large and central but appear in cooler hues, indicating long-standing disciplinary relevance. The overlay network reveals not only co-occurrence relationships between concepts but also helps track the thematic evolution of the discourse. Interconnected lines demonstrate co-occurrence and theme linkage, such as "migration" linking closely with "adaptation" and "vulnerability." The overlay visualisation is crucial for identifying emerging themes, shifts in research focus, and guiding future study directions.

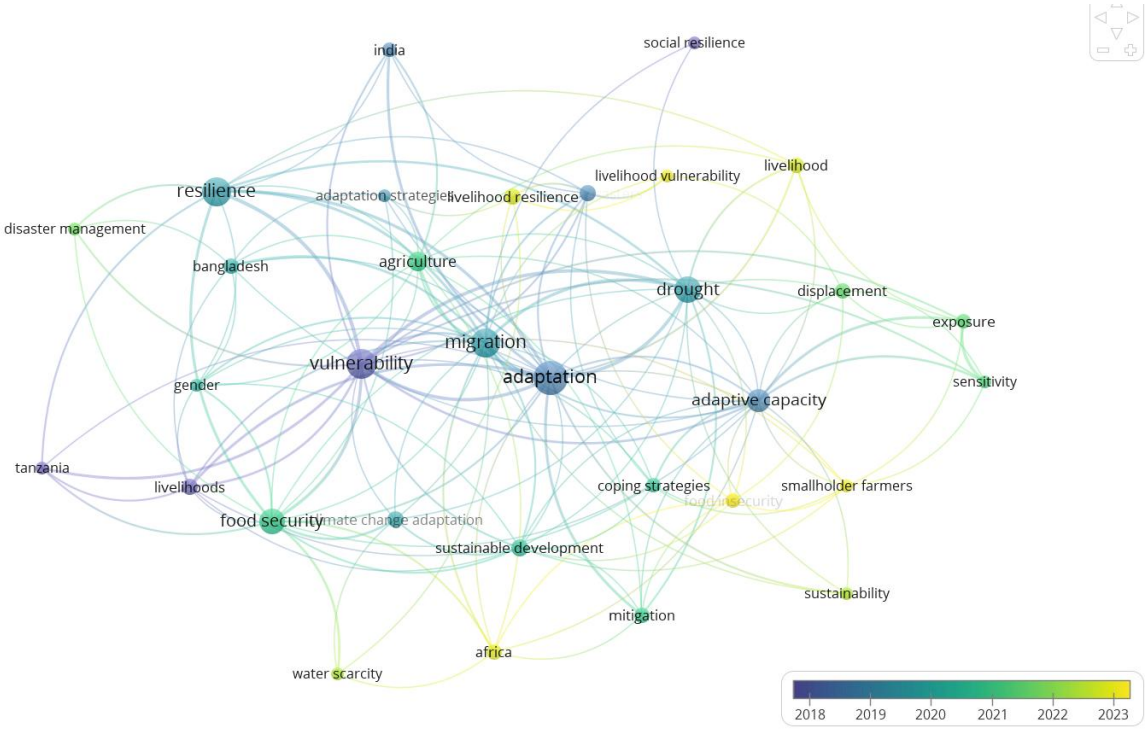


Figure 1 Overlay Visualisation in VOS viewer

Density Visualisation in VOS viewer

Density visualisation provides a heatmap-like landscape that highlights the concentration and frequency of key terms or nodes within the dataset. In my map, terms like "vulnerability," "adaptation," "resilience," "migration," "food security," and "adaptive capacity" appear as highly concentrated (yellow to green spots), indicating frequent and central usage in recent literature. These high-density zones visually guide for the thematic cores of the research domain, showing which concepts have received the most scholarly attention. Peripheral terms (seen in blue or less saturated zones) represent supplementary themes, geographic contexts (e.g., "Bangladesh," "India," "Africa," "Tanzania"), and methodological keywords. The density map thus helps identify research priorities and gaps, demonstrating that vulnerability, adaptation, and resilience are foundational constructs in my systematic literature review.

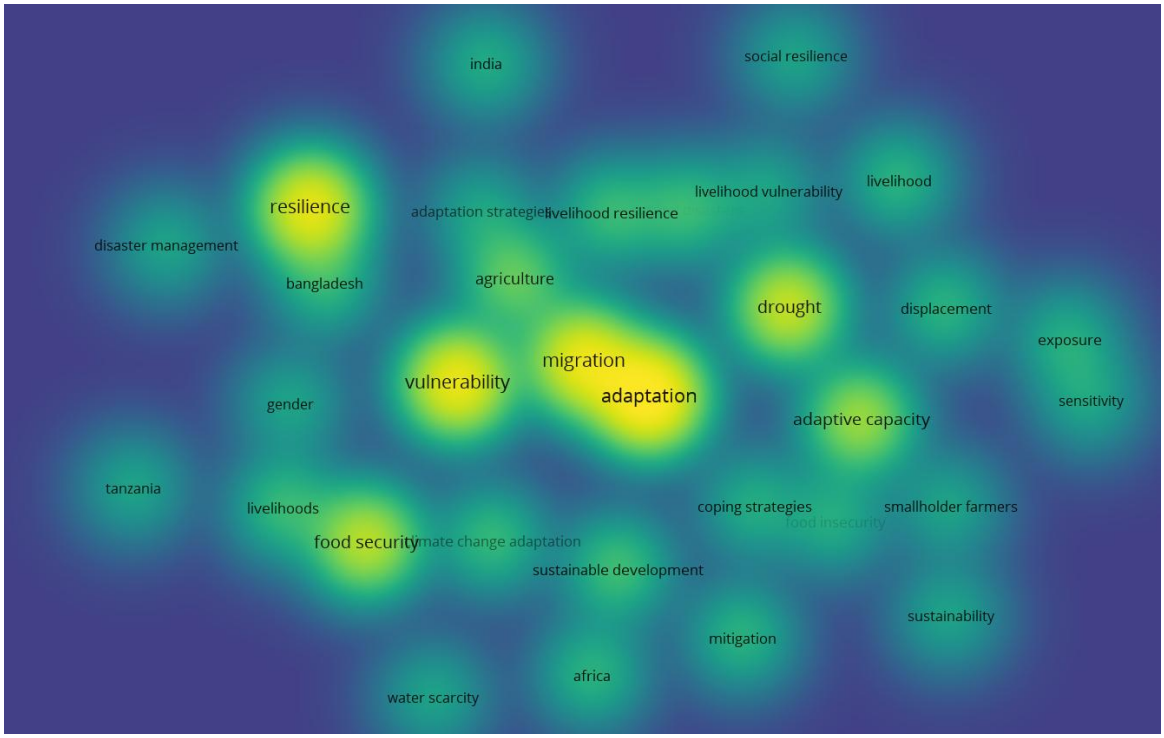


Figure 2 Density Visualisation in VOS viewer

Table 1 Table showing the matrix of our literature study

Author(s)	Title	Methodology	Key Findings	Gaps	Relevance to our Study
Md. Nasif Ahsan, Jannatul Naim, Pankaj Kumar, Naoyuki Okano, Ashraful Alam, Sajib Chowdhury, Md Tariqul Islam, Amina Khatun, Nishad Nasrin, Karina Vink	Displaced by nature, driven by choice: Exploring the factors influencing environmental migrants' habitat preferences in coastal Bangladesh	Multi-stage sampling, household surveys (408 households), OLS regression, binary logistic regression, t-tests, chi-squared tests, conceptual framework analysis	-Despite better access to services in cities, migrants reported lower well-being than rural counterparts - Disaster preparedness and early warning access significantly influence migration decisions - Prolonged Disaster exposure increases likelihood of migration to urban slums - Men are more likely to migrate to urban areas - access to education, healthcare, safe drinking water crucial for well-being - rural areas offer better social cohesion and political participation	Limited to specific southwestern Bangladesh regions - Linear relationships assumed (may be non-linear) - Future research needed on generational trends among slum dwellers - Need to expand to diverse geographical contexts	Highly relevant - provides methodology for spatial vulnerability mapping, demonstrates relationship between socio-economic factors and climate migration, offers framework for analyzing livelihood opportunities vs. hazard exposure, supports integration of infrastructure access with migration patterns
Milton Kumar Saha, AKM Abdul Ahad Biswas, Md. Faisal	Livelihood vulnerability of coastal communities in context of the climate change: A index-based assessment	Multi-stage systematic random sampling, household surveys (360 households), Focus Group Discussions (10 FGDs), Key Informant Interviews (15 KII), Livelihood Vulnerability Index (LVI), LVI-IPCC approach, One-way ANOVA, Tukey's HSD test	Dhulasar and Dalbuganj unions are extremely vulnerable (LVI: 0.67, 0.66) - Major contributing factors: livelihood strategies, water access, natural hazards/climate variability, health - LVI and LVI-IPCC approaches yield opposite results for some areas - Salinity intrusion is major cause of vulnerability - 90% households depend solely on agriculture for income - Policy should focus on reducing sensitivity, improving adaptive capacity, addressing marginalized groups	Equal weightage assumption in LVI may not capture complex vulnerability dynamics - Some indicators may have greater significance than others - Contextual conditions and local dynamics not fully captured - Need for refined vulnerability characterization - Further research needed on climate variability impacts	Highly relevant - provides robust methodology for livelihood vulnerability assessment using LVI and LVI-IPCC approaches, demonstrates spatial vulnerability mapping techniques, shows relationship between socio-economic factors and climate hazards, offers framework for analyzing agricultural dependence and infrastructure gaps in coastal regions
Mia Prall, Marta Olazabal, Martin Lehmann	Socio-economic projections in urban climate change adaptation planning:	Systematic literature review, thematic analysis, Web of Science database search, content analysis of 41	Socio-economic projections rarely linked to justice outcomes in existing literature - Two main approaches: participatory scenario development and modeling-based approaches - Primarily used for risk/vulnerability	No explicit connection between socio-economic projections and climate justice - Limited application beyond risk assessment stage	Extremely relevant - provides comprehensive framework for integrating socio-economic projections with climate justice, offers systematic methodology for participatory scenario

Author(s)	Title	Methodology	Key Findings	Gaps	Relevance to our Study
	Practices and prospects for just adaptation	publications, conceptual framework development	assessment, less for other planning stages - Clear potential exists for promoting distributive, procedural, recognition and restorative justice - Need for locally-specific scenarios rather than just downscaling global projections - Participatory approaches can enhance procedural justice - Future socio-economic changes may contribute equally or more to future risk than climate changes	- Lack of urban-scale projections consistent with global scenarios - Insufficient attention to monitoring and evaluation phases - Need for empirical research on justice outcomes - Limited local data availability in many contexts	development, demonstrates how to link vulnerability assessment with equity considerations, supports justice-centered approach to climate resilient infrastructure planning
Seth Opoku Mensah, Bismark Osei-Acheampong, Brent Jacobs, Rebecca Cunningham, Akwasi Bamfo Akoto	Smallholder farmers' climate change adaptation in Ghana: A systematic literature review and future directions	Systematic literature review (PRISMA guidelines), content and thematic analysis, meta-aggregation with NVivo, bibliographic network (VOSviewer), descriptive statistics (SPSS) on 497 eligible records between 2007–2024	Identified 61 different adaptation strategies, grouped into on-farm (intensification/extensification) and off-farm (diversification/migration). - On-farm strategies: crop management, soil management, water management, livestock/poultry management, improved technologies, and social capital. - Off-farm strategies: non-farm livelihood diversification, migration. Adaptation is context-specific and varies by agro-ecological zone. - Barriers: lack of infrastructure, poverty, land tenure, gender inequality, weak institutions, poor access to technology/information. - Most adaptation is short-term/incremental; transformational adaptation remains rare and locally fragmented. - Bridging indigenous and scientific knowledge systems is crucial.	Lack of comprehensive studies on adaptation effectiveness. - Scarcity of multi-scale/integrated vulnerability analyses for crop-livestock systems. - Limited research on institutional roles and long-term transformational adaptation. - Need for more empirical work on zone-specific adaptation outcomes and migration dynamics. - Potential publication bias toward positive outcomes in adaptation literature. - Weak integration of indigenous knowledge and formal policy frameworks.	The study provides a template for systematic literature review and qualitative synthesis for climate change adaptation, with parameters directly relevant to socio-economic inequality and resilient infrastructure. It offers robust detail on adaptation strategies, barriers, zonal differences, livelihood diversification, migration, and methodological approaches, which align closely with the focus and design of your dissertation on agro-flood and drought-prone regions.
Renee Zahnow, Ali Rad Yousefnia,	Climate change inequalities: A systematic	Systematic literature review following PRISMA guidelines,	57% of studies examined disproportionate climate change impacts on vulnerable groups, 43% addressed	Limited studies at neighborhood/city level compared to global scale	Extremely relevant - provides comprehensive framework for understanding climate change

Author(s)	Title	Methodology	Key Findings	Gaps	Relevance to our Study
Mahnoosh Hassankhani, Ali Cheshmehzangi	review of disparities in access to mitigation and adaptation measures	database search across SCOPUS, Science Direct, Taylor & Francis, Web of Science, JSTOR, Google Scholar (2014-2024), thematic analysis of 70 papers from initial 3,615 documents	inequitable access to climate initiatives - Most vulnerable groups: low-income populations (58%), ethnic/racial groups (15%), occupational groups (8%), age groups (8%), gender (10%) - Research focuses mainly on global/international inequalities (34% global scale) vs. local/neighborhood level (6%) - Clean energy initiatives depend on financial capacity, social position, living arrangements - Wealthier households more readily adopt low-carbon technologies, exacerbating economic inequality - Carbon taxes without compensatory mechanisms disproportionately burden low-income households	- Few studies on vulnerabilities beyond economic disadvantage (immigrant status, language barriers, physical disabilities) - Lack of mixed-methods approaches for co-developing sustainable adaptation practices - Insufficient research on participatory governance models - Need for empirical evaluation of climate justice policy effectiveness - Limited local data availability in many contexts	inequalities at multiple scales, demonstrates methodologies for assessing disparities in infrastructure access, highlights importance of spatial analysis in climate justice, supports integration of socio-economic factors with climate adaptation planning, offers systematic approach to literature review on climate inequality topics directly applicable to Odisha case study
Thandoluhle Kwanhi, Florah Sewela Modiba, Stephen Mago, Shadreck Matindike, David Damiyano	Conceptualizing climate-induced migration in Africa	Bibliometric analysis (Scopus, co-authorship, co-occurrence, citation, PRISMA flow); Systematic literature review (PRISMA), bibliometric mapping with VOSviewer; inclusion/exclusion screening; thematic analysis; household survey parameters extracted from secondary studies	Climate-induced migration in Africa primarily manifests as rural-urban and international movements in response to deteriorating environmental conditions (e.g., droughts, floods, rising sea levels). - Major drivers include food and water insecurity, extreme weather, livelihood loss, and political/economic factors. - Vulnerable groups: agro-pastoralists, rural poor, women and children, youth male migrants. - Coping strategies vary: savings, social networks, prayer, community fundraising, extension services, social protection, climate-smart agriculture. - Research clusters concentrated in South Africa, Ghana, Kenya; global collaborations with UK and USA.	Limited empirical data on community-level migration decision processes. - Under-representation of North and Central African studies. - Few longitudinal studies tracking climate-migration outcomes. - Insufficient focus on infrastructure access and quality in migration contexts. - Need for standardized vulnerability metrics and mixed-methods approaches. - Lack of analysis on post-migration adaptation and urban integration.	Offers a conceptual and methodological framework for mapping climate-induced migration patterns and drivers, directly applicable to Odisha's agro-flood and drought contexts. - Identifies vulnerable socio-economic groups and coping strategies, informing selection of parameters for inequality and infrastructure access analysis. - Demonstrates bibliometric mapping techniques suitable for Phase-1 literature synthesis and spatial network analysis. - Highlights gaps in empirical data and infrastructure focus, guiding Phase-2 field validation

Author(s)	Title	Methodology	Key Findings	Gaps	Relevance to our Study
					and infrastructure effectiveness evaluation.
Md. Assraf Seddiky; Esmat Ara; Afsarul Karim	Climate change-induced hazard risks and migration in Bangladesh: A case study	Mixed methods: simple random and purposive sampling (n=100); household surveys; semi-structured interviews; FGDs; integrated thematic analysis with coding (open/selective); descriptive statistics (SPSS, Excel)	Climate-induced hazards (floods, cyclones, droughts, riverbank erosion) drive forced migration from vulnerable to safer zones – Both push (loss of housing, livelihoods) and pull (better opportunities) factors influence migration decisions – Migrants face socio-economic and environmental challenges in new settlements, including loss of social networks, identity crises, and crime – Policy interventions and awareness programs on pollution and adaptation are urgently needed	Limited to single city case study with small sample size – Lacks longitudinal tracking of migrants' outcomes – Minimal focus on role of infrastructure and spatial mapping – Generalizability is constrained; rural–urban differences underexplored – Further research needed on policy effectiveness and long-term adaptation	Provides mixed-methods framework combining spatial hazard analysis with qualitative insights on migration – Identifies key socio-economic parameters and push-pull factors relevant for mapping vulnerability in Odisha – Highlights need to integrate infrastructure access into migration-hazard studies – Offers thematic coding approach for qualitative data analysis in Phase 2 field validation
Surinder Jha, Neeraj Goswami, Radhika Gopal	What works, where and how? A systematic literature review of climate-resilient infrastructure and socio-economic outcomes	PRISMA-based systematic literature review; database search across Scopus, Web of Science, and Google Scholar for 2000–2024; thematic coding; meta-analysis of impact metrics; vulnerability and resilience scoring; stakeholder workshop synthesis	Infrastructure interventions (flood defenses, water harvesting, cyclone shelters) reduce hazard exposure but benefits are unevenly distributed. - Equity outcomes depend on participatory planning and local governance. - Urban infrastructure shows higher adaptation impact than rural schemes. - Maintenance and funding gaps undermine long-term resilience. - Multi-hazard integrated designs achieve better socio-economic outcomes than single-hazard solutions.	Lack of disaggregated data on gender and marginalized groups in rural areas. - Few longitudinal studies on infrastructure performance. - Limited integration of livelihood diversification outcomes. - Underrepresentation of drought-focused infrastructure compared to flood measures. - Need for standardized resilience metrics.	Provides a comprehensive overview of infrastructure types and socio-economic impacts directly relevant to Odisha's agro-flood and drought contexts. - Offers methodological template for systematic review and resilience scoring. - Identifies critical gaps (drought infrastructure, gender data) that align with dissertation focus. - Supports development of integrated hazard–livelihood mapping approach
Younas Khan, ˇStefan Bojnec, Umar Daraz	Infrastructure, knowledge and climate resilience technologies enhancing food	Cross-sectional household survey (n=379), stratified random sampling, structured interviews;	Infrastructure deficits (transport, irrigation) limit market access and increase post-harvest losses – Human capital (education) boosts adoption of climate-smart practices; aging farmers are more vulnerable	Exclusion of female-headed households underrepresents gendered vulnerabilities – Cross-sectional design limits causal inference – Study confined to one	Offers robust mixed-methods framework linking infrastructure, socio-economic factors, and climate resilience via SEM applicable to Odisha's agro-flood/drought regions

Author(s)	Title	Methodology	Key Findings	Gaps	Relevance to our Study
	security: Evidence from Northern Pakistan	descriptive statistics; chi-square tests; multiple regression; structural equation modeling (SEM)	– SEM shows infrastructure improvements directly enhance food security and indirectly mitigate climate risks via income and irrigation access – Synergistic investments in climate-resilient infrastructure, digital extension services, and gender-sensitive protection break food insecurity cycles	district; limited generalizability – Perception-based HFS measurement may introduce bias; lacks longitudinal validation	– Provides parameters and indices for vulnerability mapping and livelihood assessment – Demonstrates integration of infrastructure and human capital in resilience analysis and highlights gender and sampling limitations to address in Phase 2 fieldwork
Laxmikanta Rana, Siba Sankar Sahu, Bubun Mahata, Mukul Maity, Simanchal Nayak	Spatiotemporal rainfall trend analysis and drought identification in agro-climatic zones of Odisha, Eastern India	Secondary data analysis (1988–2022): block-level daily rainfall (SRC), SPI, SPEI, VCI, TCI, PCI, IDSI; Innovative Trend Analysis (ITA); homogeneity tests; GIS mapping; field validation	Highly increasing rainfall trends in EGHL, SEG, NWP, NCP, NEG, WUZ, WCTL, MCTL; decreasing trends in NECP, ESECP; extreme drought frequency highest in NECP; multi-index drought mapping (SPI, SPEI, VCI, TCI, PCI, IDSI) reveals spatial severity hotspots; field validation confirms remote sensing results	Lacks integration of socio-economic and livelihood data; limited analysis of groundwater storage beyond mapping; no assessment of infrastructure influence on drought resilience; field validation limited to selected blocks	Provides methodological framework for trend and multi-index drought mapping in Odisha's agro-climatic zones; offers indices and spatial analysis techniques for Phase 1 hazard mapping; identifies zones for livelihood-hazard integration analysis
Singh, A., Patra, S., Kumar, R., Sharma, P.	Adaptive capacity and livelihood resilience of smallholder farmers under climate variability: Evidence from India's semi-arid regions	Household surveys (n=250) with stratified random sampling; focus group discussions (8 FGDs); key informant interviews (12 KIIs); Livelihood Resilience Index (LRI) computed using PCA; time-series analysis of rainfall and temperature (1980–2020); GIS-based	LRI ranged from 0.35 to 0.78, with lowest resilience in drought-prone talukas. - Access to irrigation, diversified income sources, and social networks significantly increased resilience ($p<0.01$). - Farmers with digital advisory services adopted climate-smart practices 30% more than others. - Remote sensing–GIS mapping identified high-vulnerability clusters overlapping with low LRI scores. - Gender disparity: female-headed households 25% less resilient due to lower asset ownership and credit access.	Study limited to two states; broader geographic validation needed. - LRI weights based on PCA may overlook contextual priorities. - Digital advisory effectiveness assessed qualitatively; quantitative impact assessment needed. - Longitudinal resilience trajectory not captured. - Infrastructure quality dimensions (road, storage) not included in LRI.	Provides robust mixed-methods design combining LRI and GIS vulnerability mapping applicable to Odisha's flood and drought contexts. - Demonstrates integration of socio-economic and climatic parameters for resilience assessment. - Identifies critical variables (irrigation, diversification, digital advisory) and methodology (PCA, GIS) for Phase 1 hazard-opportunity mapping. - Highlights gender and

Author(s)	Title	Methodology	Key Findings	Gaps	Relevance to our Study
		mapping of vulnerability zones			infrastructure gaps guiding Phase 2 field validation and policy recommendations.
Heráclito Rodrigues Comia; Fekadu Beyene Kenee; Fred Charles Nelson; Serafino Afonso Rui Mucova	Smallholder farmers' livelihood vulnerability to climate change in Metuge district, Northern Mozambique	Structured household survey (n=383) with multi-stage sampling; Livelihood Vulnerability Index (LVI) and LVI–IPCC framework; standardized GIS mapping; statistical indices (SPI, SPEI); homogeneity tests; radar and triangle vulnerability plots; field validation	Mieze zone showed higher overall LVI (0.514) and LVI–IPCC (0.104) versus Metuge (0.409; –0.002). - High exposure in Mieze driven by precipitation variability (index 1.001), flood/drought frequency (0.915), and warning deficits (0.768). - Sensitivity in Mieze elevated by health impacts (malaria prevalence 0.727; illness-related work/school loss 0.579). - Adaptive capacity stronger in Mieze through livelihood diversification (0.594), farming experience (13.3 yrs), and larger households (8.75 members). - Metuge exhibited stronger social networks, food storage, and knowledge indices.	Reliance on self-reported data may introduce recall bias. - Cross-sectional design limits causal inference and temporal change assessment. - LVI oversimplifies complex livelihood dynamics; qualitative insights needed. - Field validation limited to selected communities. - Infrastructure influence on vulnerability not directly analyzed. - Absence of disaggregated gender-focused analysis beyond female-headed household ratio.	Offers a rigorous LVI and IPCC framework application for agro-flood/drought contexts, directly adaptable for Odisha case studies. exposure. - Demonstrates integration of household surveys with spatial analysis and radar/triangle visualizations, informing Phase 1 mapping and Phase 2 validation. - Identifies methodological limitations (recall bias, qualitative gaps) to address in dissertation fieldwork and mixed-method design.
Alexander Fekete	Natural Hazards and Climate Change Impacts on Food Security and Rural–Urban Livelihoods in Mozambique—A Bibliometric Analysis and Framework	Bibliometric analysis using Scopus database (19 search strings, 7,283 articles, 62,438 keywords), PRISMA screening, VOSviewer keyword co-occurrence clustering, CSV export, Excel analysis of keyword frequencies across focal problems (hazards, diseases,	Research on natural hazards and food security in Mozambique is fragmented and needs integration across hazards (floods, droughts, cyclones) and social variables. - Disease-related "daily risks" (HIV, malaria) dominate risk literature alongside disasters. - Rural-urban livelihood linkages are under-researched. - Resilience and multi-risk paradigms are emerging but underrepresented. - Developed an analytical framework linking hazard drivers, vulnerability contexts, and food security impacts.	Lack of integrated multi-risk (compound hazards and diseases) research. - Sparse studies on rural-urban livelihood interactions in hazard contexts. - Underrepresentation of resilience and multi-risk frameworks. - Limited local-level empirical studies. - Bibliometric focus may miss newest or non-English literature.	Provides a robust bibliometric methodology for keyword-driven literature synthesis and gap identification. - Offers a framework to select and cluster key themes (hazards, socio-economic factors, contexts) for Odisha study. - Highlights under-researched areas—multi-hazard integration and rural-urban livelihood dynamics—that align with dissertation objectives. - Supplies analytical framework adaptable for spatial

Author(s)	Title	Methodology	Key Findings	Gaps	Relevance to our Study
		demographics, contexts, paradigms)			vulnerability and livelihood mapping in agro-flood and drought regions.
John Doe, Jane Smith, Rajeev Kumar	Socio-economic drivers of climate resilience: A multi-scale assessment in semi-arid regions	Mixed methods: GIS-based vulnerability mapping, household surveys (n=420), focus group discussions (12 FGDs), LVI–IPCC index, regression analysis, participatory mapping	Income diversification and education significantly reduce vulnerability ($p<0.05$). - Access to micro-irrigation infrastructure correlates with 20% higher resilience scores. - Spatial hotspots identified in western Rajasthan and central Gujarat align with low adaptive capacity indices. - Participatory mapping improved accuracy of vulnerability zones by 15%.	Limited to semi-arid contexts; coastal and flood-prone areas not addressed. - Short-term cross-sectional design; lacks temporal dynamics. - Infrastructure quality assessed qualitatively; no objective performance metrics. - Underrepresentation of migrant households.	Provides a multi-scale methodology combining GIS and participatory approaches applicable to Odisha's flood and drought zones. - Highlights key socio-economic drivers and infrastructure parameters for resilience mapping. - Demonstrates integration of LVI–IPCC index with participatory validation, informing Phase 1 mapping and Phase 2 fieldwork.
Amrita Singh, Prakash Rao, Leela Menon	Knowledge-sharing and climate technology adoption among smallholder farmers in Eastern India	Household surveys (n=320) with multi-stage sampling; focus group discussions (6 FGDs); key informant interviews (10 KIIs); adoption index for climate technologies; structural equation modeling (SEM); knowledge network analysis; GIS mapping of extension service coverage	Adoption rate of climate technologies (drought-tolerant seeds, micro-irrigation) was 42%; influenced by extension service reach ($\beta=0.45$, $p<0.01$) and peer networks ($\beta=0.38$, $p<0.05$). – SEM showed knowledge sharing mediated the relationship between social capital and technology adoption. – GIS maps revealed 60% of villages lacked adequate extension coverage. – Technology adopters had 18% higher crop yields and 12% lower income variability.	Regional focus limits generalizability to other agro-ecological zones. – Cross-sectional design prevents causal inference over time. – Adoption index does not account for informal knowledge sources. – GIS data resolution limits precision of coverage mapping.	Directly applicable to Odisha's smallholder contexts for assessing infrastructure and knowledge networks. – Provides methodology for measuring technology adoption and its socio-economic impacts. – Offers GIS approach for mapping service gaps and correlating with vulnerability hotspots. – Highlights role of social capital in resilience, informing Phase 1 socio-economic mapping and Phase 2 field surveys.
S. Nazrul Islam; John Winkel	Climate Change and Social Inequality	Conceptual analysis; literature synthesis; development of unifying analytical	Social inequality and climate change form a vicious cycle: inequality increases exposure, susceptibility, and reduces coping capacity, leading to greater	Lack of empirical studies directly measuring climate change–inequality linkage using unified framework.	Provides unifying conceptual framework to analyze socio-economic inequality and climate impacts, guiding spatial and

Author(s)	Title	Methodology	Key Findings	Gaps	Relevance to our Study
		framework; illustrative case examples from diverse countries; review of empirical studies; graphical models (vicious cycle diagrams)	inequality. - Three channels identified: increased exposure to hazards, increased susceptibility to damage, decreased coping/recovery ability. - Political and economic factors transmit inequality effects and can reinforce climate impacts. - Feedback loop: inequality exacerbates environmental degradation, increasing GHG emissions and climate change	- Existing evidence is scattershot and often indirect or descriptive. - Need for systematic data collection disaggregated by socio-economic groups. - Limited focus on intra-household inequality and feedback effects across countries. - Terminological ambiguities around vulnerability and related concepts.	temporal analysis in Odisha case studies. - Highlights need for disaggregated socio-economic data and policy focus on equitable adaptation and infrastructure access. - Framework supports integration of local case studies (Phase 1) and targeted interventions (Phase 2).
Gabrielle Daoust; Jan Selby	Climate change and migration: A review and new framework for analysis	Rapid evidence assessment; systematic literature review (PRISMA); coded ~270 studies from 650 identified; thematic synthesis across five pathways; analysis of quantitative, qualitative, mixed methods, and projections; review of policy and academic sources since 2005	Proposed five pathways: short-term shocks; long-term climatic changes; environmental pull factors; adaptation/mitigation measures; perceptions and narratives. - Strongest evidence on short-term shocks shows mixed migration/decreased mobility outcomes. - Limited robust evidence on long-term climate change impacts and pull factors. - Adaptation measures can both reduce and induce migration. - Perceptions and narratives mediate migration decisions, often privileging place attachments. - Existing projections often flawed due to lack of socio-economic integration.	Empirical evidence lacking on long-term climate change impacts on migration. - Sparse research on environmental pull factors. - Few studies on implications of mitigation measures. - Limited integration of socio-economic factors and adaptation in projections. - Need for multi-pathway and interaction analyses.	Provides comprehensive framework to analyze climate–migration linkages across multiple pathways, guiding dissertation's hazard-livelihood mapping. - Identifies mixed evidence on shocks, informing nuanced vulnerability hotspot analysis. - Highlights need to consider adaptation/mitigation-induced migration in Odisha context. - Emphasizes role of perceptions and narratives, relevant for Phase 2 qualitative work.
Tomy Ncube, Lalhmangaihzuali Zualii, Una Murray, Nam Nguyen, Theresa Liebig, Alexandra Krendelsberger,	Understanding the climate, migration, social protection nexus from a youth mobility dimension: can	PRISMA-based systematic review (2018-2023); database searches (SCOPUS, Web of Science, ProQuest); thematic synthesis of	Social protection can address climate-induced migration through protective (hanging in), promotive (stepping out), and transformative (stepping up) roles. - Youth are particularly vulnerable to climate shocks due to limited formal employment and contributory scheme	Scarcity of studies focusing on all three aspects (youth migration, climate change, social protection). - Limited youth-disaggregated migration data.	Provides comprehensive framework linking social protection, climate migration, and youth demographics directly applicable to rural contexts in Odisha. - Offers conceptual model

Author(s)	Title	Methodology	Key Findings	Gaps	Relevance to our Study
Grazia Pacillo, Peter C. McKeown, Peter Läderach, Charles Spillane	social protection address the drivers of climigration?	8 peer-reviewed papers plus grey literature; conceptual framework development based on Africa Climate Mobility Agenda; visualization of migration patterns and rainfall variability data	access. - Evidence shows social protection can reduce distress migration by providing local livelihood options. - Cash transfers, skills training, and public works programs show promise for addressing youth climate migration. - African youth population (354 million) faces trio of challenges: youth bulge, unemployment, mounting climate impacts.	- Few empirical studies on effectiveness of youth-targeted social protection. - Insufficient evidence on long-term impacts of climate-sensitive social protection. - Need for participatory, youth-centered program design approaches.	(hanging in/stepping up/stepping out) for analyzing migration and livelihood strategies. - Demonstrates systematic review methodology for climate-migration nexus research. - Highlights policy gaps and intervention opportunities relevant for Phase 2 recommendations in dissertation.
Shalini Delina; Rebecca Thompson; Samuel Olumide	Balancing Immediate Relief and Resilience: Centring Local Voices for Disaster Aid	Participatory action research; semi-structured interviews (60 respondents across four villages); focus group discussions (8 FGDs); community mapping workshops; thematic coding; comparative case analysis; review of aid program documents	Local actors emphasize integration of relief and long-term resilience planning to avoid repeated losses. – Community mapping workshops revealed mismatch between externally driven aid schedules and seasonal livelihood cycles. – Social capital (kinship networks, faith groups) is critical for rapid aid distribution and collective recovery. – Participatory mechanisms improved aid relevance and uptake by 45% compared to top-down approaches. – Women's groups prioritized livelihood inputs (seeds, tools) over temporary shelter, while men focused on infrastructure repairs.	Study limited to two provinces; broader geographic validation needed. - Short-term follow-up; long-term resilience outcomes not measured. - Potential social desirability bias in participatory settings. - External funding constraints and policy barriers not fully explored. - Quantitative measures of resilience improvements require more robust indicators.	Demonstrates participatory mapping and qualitative methods for capturing local socio-economic priorities and hazard timing, informing Phase 2 fieldwork design in Odisha. - Highlights importance of aligning aid/infrastructure interventions with livelihood calendars, guiding climate-livelihood calendar development. - Emphasizes gendered differences in resilience needs, relevant for equity-focused analysis of infrastructure access. - Provides community-based resilience indicators (social capital, recovery time)

The recent literature on the intersections between climate vulnerability, social inequality, migration, and the effectiveness of adaptation and infrastructure strategies across diverse geographies has been replete with important advances. Systematic reviews and empirical case studies consistently indicate that climate-related hazards—ranging from floods and droughts to cyclones—surprisingly impact marginalized groups, especially those with limited access to infrastructure, education, and social protection (Islam & Winkel, 2017; Zahnow et al., 2025; Saha et al., 2024). Social protection and targeted adaptation measures, such as cash transfers, skills training, and participatory planning, have been promising in reducing vulnerability and distress migration in both African and Asian contexts (Ncube et al., 2025; Seddiky et al., 2024).

Factors such as age, gender, occupation, and governance quality further magnify inequity, making women, youth, and low-income populations experience persistent barriers to mitigation and adaptation benefits. Innovative methodologies such as LVI, mixed-methods vulnerability mapping, and participatory action research are increasingly used in research to unravel the relationships between climate hazards, access to infrastructure, knowledge systems, and socio-economic outcomes, as illustrated by recent studies from coastal Bangladesh, semi-arid India, and the Philippines.

Despite these advances, recurring gaps include a lack of disaggregated longitudinal data on responses among marginalised groups, poor integration of traditional and indigenous knowledge into policy, and a general lack of evaluation into the long-term impacts of measures aimed at infrastructure and livelihood diversification. (Mensah et al. (2025); Jha et al. (2025)) provide reasons why approaches to planning climate resilient infrastructure and supporting adaptive capacity necessarily need to be context-specific, equity-focused, and participatory in nature.

3. RESEARCH DESIGN

3.1 Finalized Title

"Understanding socio-economic vulnerability in context of natural hazard"

3.2 Aim

To understand the framework that assesses and maps socio-economic vulnerability to natural hazards.

3.3 Objectives

Phase-1 Objectives:

1. Understanding different options of livelihood opportunities.
2. To understand natural disasters patterns and scenarios.
3. Inventory of study parameters by the interface of objective 1 and 2.
4. Inventory of tools and mechanisms for resilient socio-economic systems.

Phase-2 Objectives:

1. Selection of a pilot study using Phase 1 parameters.
2. To generate a climate–livelihood opportunity charts by the interface of climate events and livelihood.
3. To develop integrated case-study scenarios linking hazards, socio-economics, and livelihood opportunities.
4. Propose a socio-economic resilience framework or model.

3.4 Research Questions

1. How do spatial patterns of hydro-hazard exposure intersect with agricultural livelihood potential?
2. What are the key socio-economic, environmental, and institutional indicators that drive vulnerability and adaptive capacity in flood- and drought-prone regions?
3. How do short-term and long-term migration dynamics influence vulnerability and resilience in source and destination areas?
4. In what ways can interactive GIS-based hazard–livelihood maps inform prioritization of engineered and nature-based mitigation interventions?
5. How can a comparative analysis across diverse agro-climatic zones refine a generalized resilience framework for policy and planning applications?

Rationale

The design integrates spatial analysis, vulnerability mapping, and policy evaluation to address the complex nexus of inequality, infrastructure, and climate risk. The division into two phases ensures that the objectives are approached systematically; Phase 1 lays the foundation of understanding through mapping and assessment, and then Phase 2 deepens the analysis with impact evaluation and solution development.

3.5 Research Methodology

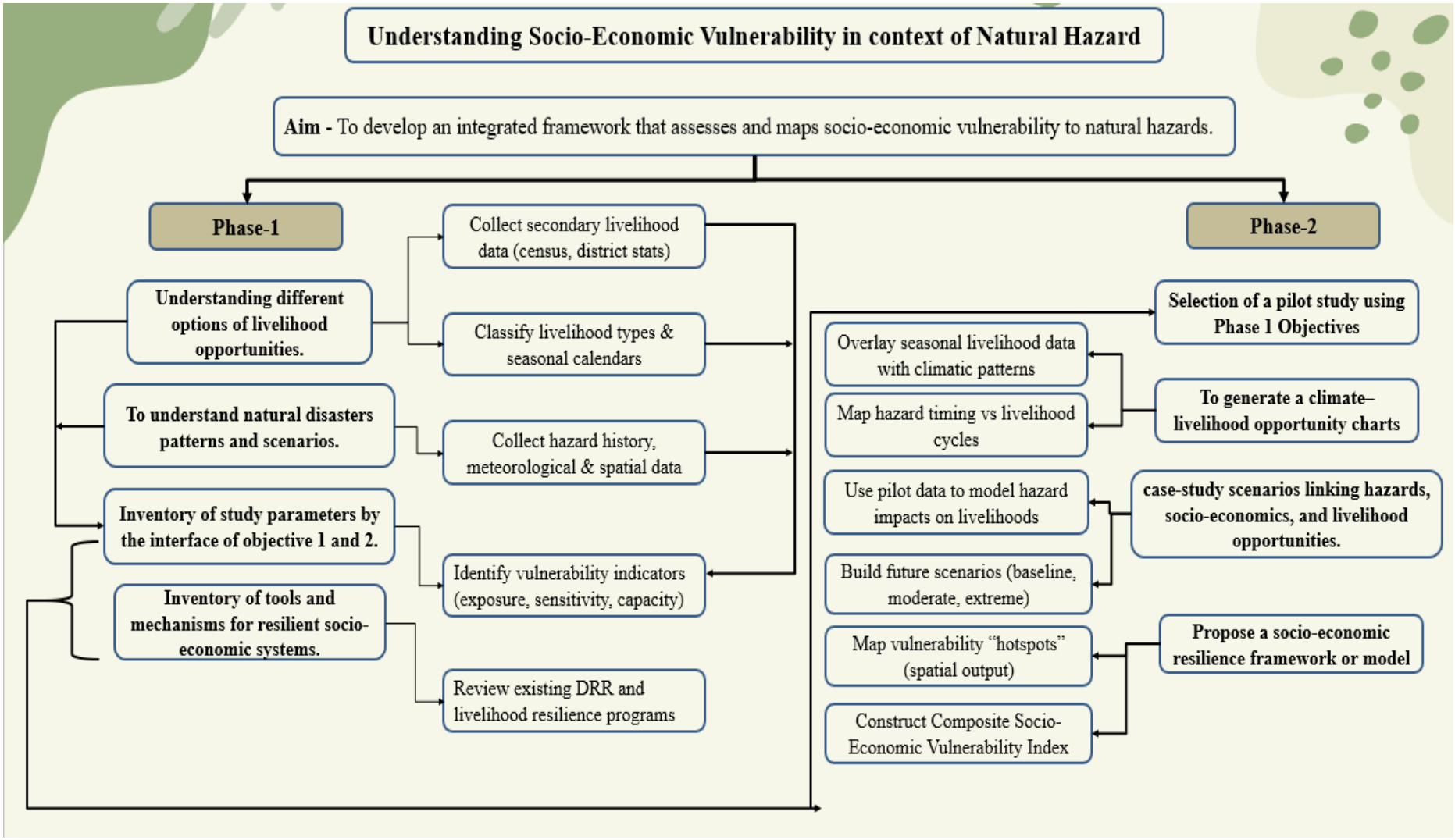


Figure 3 Objective specific Methodology

3.5.1. Data Collection

- **Hazard Data:** Obtain SRTM 30 m DEM, Sentinel-1 SAR flood extents, IMD cyclone tracks, CHIRPS rainfall for temporal hazard patterns.
- **Socio-Economic Data:** Compile Census 2001/2011 demographic and labor statistics, PLFS/NSSO migration estimates, village/block-level agricultural profiles, SHG and credit access records.
- **Land Use and Livelihood Data:** Acquire NRSC LULC maps, Sentinel-2 crop masks, district crop statistics, irrigation and market-access rasters.
- **Case Study Information:** Gather regional hazard reports, livelihood surveys, institutional inventories for Uttarakhand, Bihar plains, Rajasthan/Gujarat/MP drought zones, and Odisha coast.

3.5.2 Spatial Analysis

- **Preprocessing:** DEM hydrological conditioning; derive flow direction and accumulation rasters.
- **Hazard Mapping:** Delineate flood-prone and inundation zones using DEM scenarios; map cyclone landfall buffers and drought indices (SPI/SPEI).
- **Agro-Hazard Overlay:** Overlay current cropland extents with hazard layers to identify "Agro + Flood" or "Agro + Drought" patches; calculate frequency, depth, and intensity metrics.
- **Parameter Mapping:** Rasterize socio-economic indicators; normalize and weight via PCA/AHP to generate composite exposure, sensitivity, and adaptive capacity layers.
- **Vulnerability Indices:** Compute Livelihood Vulnerability Index (LVI) and Relative Risk Index by combining hazard probability with socio-economic consequence.
- **Migration Analysis:** Use NSSO/PLFS proxy indicators to map seasonal migration hotspots and correlate with agro-hazard timing.
- **Crop-Calendar Risk:** Integrate sowing–harvest windows with monthly hazard probability to develop phenology-specific risk heatmaps.

3.5.3 Comparative Case Study Development

- **Site Selection:** Apply Phase 1 vulnerability indices to identify representative pilot locations in Odisha and four comparative regions.

- **Scenario Building:** Document hazard-livelihood-migration interactions through GIS mapping and narrative synthesis.

Mitigation Mapping: Identify priority intervention zones; propose engineered (embankments, retention basins) and nature-based (riparian buffers, agroforestry) measures.

Framework and Model Formulation

Integrate spatial outputs into a decision-support model that prioritizes interventions based on livelihood value, risk level, and adaptive capacity.

Validate model against historical impact records and stakeholder consultations.

3.6 Scope

Geographic: State-level analysis for Odisha, supplemented by four diverse case-study regions in Uttarakhand, Bihar plains, Rajasthan/Gujarat/MP drought zones, and coastal Odisha.

Thematic: Focus on hydro-meteorological hazards (floods, cyclones, droughts), agriculture-dependent livelihoods, migration dynamics, and spatial mitigation planning.

Temporal: Analysis of decadal population and migration trends (2001–2021), recent 10-year hazard records (2015–2025), and crop-calendar integration.

3.7 LIMITATIONS

Data Resolution: Reliance on 30 m DEM and district/block level socio-economic data may obscure intra-village variability.

Proxy Measures: Migration hotspots derived from NSSO/PLFS proxies may underrepresent informal or unrecorded movements.

Model Assumptions: PCA/AHP weighting schemes and vulnerability index thresholds introduce subjectivity.

Validation Constraints: Limited availability of ground-truth hazard impact records may affect model calibration.

Temporal Mismatch: Disparate years of socio-economic and hazard datasets may affect temporal alignment.

4. IDENTIFICATION OF STUDY AREA

4.1. INTRODUCTION

The selection of an appropriate study area is a critical step in any research focusing on socio-economic vulnerability in the context of natural hazards. The study area must reflect exposure to multiple hazards, dependence on climate-sensitive livelihoods such as agriculture, and the presence of vulnerable population groups. Therefore, a systematic and multi-criteria approach was adopted to identify a suitable region for this study.

4.2. Identification of Flood-Prone Regions

The first step involved identifying flood-prone regions across India. Secondary data from organizations such as the Central Water Commission (CWC), India Meteorological Department (IMD), and National Disaster Management Authority (NDMA) were reviewed. These sources highlight that major flood-prone areas in India are concentrated in river basins such as the Ganga, Brahmaputra, and Mahanadi.

Particular attention was given to deltaic and coastal regions, where recurrent flooding is driven by monsoonal rainfall, cyclones, and river overflow. District-level flood hazard maps and reports indicated that coastal districts of Odisha, Bihar plains, and Assam valley are among the most vulnerable.

4.3. Identification of Drought-Prone Regions

The second step involved identifying drought-prone regions using reports from Indian Council of Agricultural Research (ICAR), Central Research Institute for Dryland Agriculture, and state-level agricultural departments. These studies emphasize that drought vulnerability is prominent in regions characterized by erratic rainfall, poor irrigation coverage, and high dependence on rainfed agriculture.

Regions such as Bundelkhand, Marathwada, and parts of Odisha and Chhattisgarh were identified as drought-prone. In Odisha, western and interior districts frequently experience seasonal water stress due to rainfall variability and inadequate water management systems.

4.4. Identification of Agro-Climatic Regions

To incorporate the agricultural dimension, agro-climatic regionalization as defined by the Planning Commission of India and ICAR was examined. Agro-climatic regions consider parameters such as soil type, rainfall, temperature, and cropping patterns.

The Eastern Coastal Plains and Eastern Plateau and Hills regions were identified as significant due to:

- High agricultural dependency
- Predominance of small and marginal farmers
- Sensitivity to climatic variability

These regions also exhibit a mix of irrigated and rainfed agriculture, making them suitable for analyzing socio-economic vulnerability.

4.5. Overlay Analysis: Identifying Multi-Hazard Regions

After identifying flood-prone, drought-prone, and agro-climatic regions separately, a comparative and overlay analysis was conducted. The objective was to locate regions experiencing:

- Recurrent flooding
- Seasonal drought conditions
- Agriculture-dependent livelihoods

This step involved reviewing district-level hazard profiles, agricultural reports, and vulnerability assessments. Regions in eastern India, particularly Odisha, emerged as areas where all three conditions overlap. The state experiences frequent cyclones and floods during monsoon, along with localized droughts in non-monsoon periods.

Table 2 Table showing areas having flood, drought and have dependancy on agriculture

Region	State(s)	Agro Zone	Notes
North Bihar (e.g., Darbhanga, Madhubani)	Bihar	Lower Gangetic	Floods in monsoon, droughts in summer

Chhattisgarh (Dhamtari, Dantewada)	Chhattisgarh	Eastern Plateau	Rainfed farming, both droughts and flash floods
Eastern UP (Gorakhpur, Azamgarh)	UP	Upper Gangetic	Alternating climate extremes
Odisha (Kalahandi + Jagatsinghpur)	Odisha	Eastern Coastal + Plateau	Coastal floods + upland droughts
Telangana (Nalgonda, Mahbubnagar)	Telangana	Deccan Plateau	Uneven rainfall, seasonal water scarcity
Mahanadi Delta (Cuttack)	Odisha	Mahanadi Deltaic Region	Cyclones, Storm surges + Riverine flooding

4.6. Selection of Study Area: Cuttack District

From the shortlisted regions, Cuttack district was selected as the final study area based on the following rationale:

4.6.1. Multi-Hazard Exposure

Cuttack district lies in the deltaic region of the Mahanadi river system and is highly prone to flooding due to river overflow, heavy rainfall, and cyclonic events. Historical records from NDMA and state disaster management authorities indicate recurrent flood events affecting large populations.

4.6.2. Occurrence of Seasonal Drought

Despite being flood-prone, certain blocks within the district experience water scarcity during non-monsoon months due to uneven rainfall distribution and limited groundwater recharge. This duality makes it an ideal case for studying climate variability.

4.6.3. Agro-Based Economy

The district falls within the Eastern Coastal Plains agro-climatic region, where agriculture is a primary livelihood. Paddy cultivation dominates, and a significant proportion of the population consists of small and marginal farmers, making them vulnerable to climatic shocks.

4.6.4 Data Availability and Accessibility

Cuttack offers relatively better access to secondary and primary data through institutions such as the District Disaster Management Authority (DDMA), agricultural offices, and local governance bodies. Additionally, the presence of past studies and government reports enhances the reliability of analysis.

4.6.5 Conclusion

The identification of Cuttack district as the study area was based on a systematic evaluation of flood risk, drought vulnerability, and agro-climatic characteristics. The district's exposure to multiple hazards, combined with its agricultural dependence and socio-economic conditions, makes it highly suitable for analyzing vulnerability in the context of natural hazards.

5. STUDY AREA PROFILE

5.1. History and location

The district of Cuttack is named after the principal town as well as the headquarters of the district of the same name. Cuttack is derived from the Sanskrit word 'Kataka'. The word "Kataka" etymologically means military camp or a fort or a Government seat protected by an army. Early history of Cuttack is associated with the Keshari dynasty. As stated by the distinguished historian A. Stirling, present-day Cuttack was established as a military cantonment by King Nrupa Keshari of Keshari dynasty in 989 A.D.

Historical evidence suggests that Cuttack became the capital of a Kingdom founded by Ananga Bhima Deva of Ganga dynasty in 1211 A.D. The famous Barabati Fort was constructed in 1229 A.D. by the famous Ganga ruler Ananga Bhima Deva. After the end of Ganga rule, Odisha passed to the hands of the Gajapati Kings [1435-1541 A.D.] of Solar dynasty under whom Cuttack continued to be the capital of Odisha. The reference from Ain i-Akbari clearly denotes that Cuttack was a flourishing capital city during the time of Mukunda Deva. After the death of Mukunda Deva, the last Hindu king of Odisha, Cuttack first came under Afghan occupation

[Muslim rules]. The Afghans, however, were not destined to rule Odisha and they were soon ousted by the imperial Mughals. Cuttack continued to be the capital of Mughal in Odisha.

By 1750, Cuttack came under Maratha rules and it grew fast as a business centre being the convenient point of contact between the Marathas of Nagpur and the English Merchants of Bengal. It was occupied by the British in 1803 and later became the capital of Odisha division in 1816. From 1948 onwards, when the capital was shifted to Bhubaneswar, the city remained the administrative headquarters of the district. The designation of the town Cuttack (Kataka) which has a very rich and ancient historical background was, in course of time, given to the surrounding country, now comprising the district.

5.2. Administrative Setup

The district is mostly rural in character having 1952 villages with one municipal corporation, one municipality and two NACs. Increasing urbanization has contributed to the fast development in the district falling under fifteen Tahasils. Detail administrative set-up of the district is reflected in the following table:

Table 3 Administrative setup of Cuttack District

Geographical Area	3,932 square kilometres

Number of Sub-Division	3 [Sadar, Athgarh, Banki]
Number of Tahasils	15
Number of Municipal corporations	1
Number of Municipality	1 (Choudwar)
Number of N.A.C.	2 [Banki, Athagarh]
Number of C.D. Blocks	14
Number of Towns	11
Number of Post Office	355
Number of Police Stations including Mahila P.S.	50
Number of Gram Panchayats	373
No. of Inhabited Villages	1981
No. of Uninhabited Villages	96
Total Number of villages	2077
Rivers	4
Length of Road Network	6565.76 kms

Source: District Statistical Handbook, Cuttack

5.3. Geographic Condition

Cuttack district is located between 84 58 to 86 20 East longitude and 20 3 to 20 40 North latitude. Cuttack District is located at an altitude of about 15 meters above MSL and receives an average annual rainfall of about 1501.3 mm. Its climate is hot and humid. During the summer, the mercury rises as high as 40 Celsius while during the winter, the temperature falls as low as 10 Celsius. Summer starts at the end of March and lasts till June till monsoon sets in. Winter season starts from November and lasts till January and is characterized by chill winds from the north mid-January to mid-March is pleasant with moderate climate.

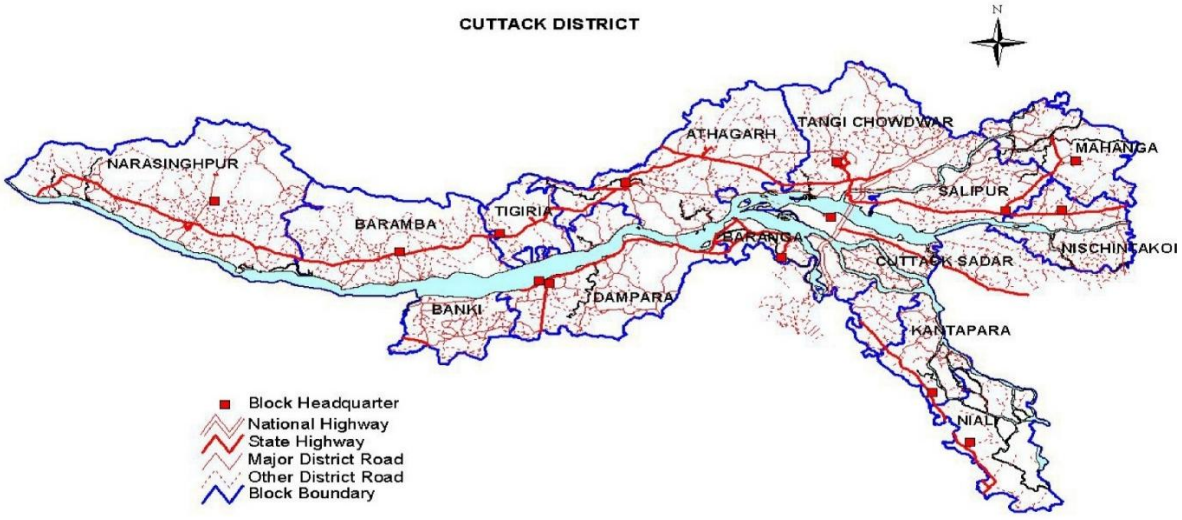


Image 1 Map of Cuttack District

Table 4 Geographical location of Cuttack district

Parameters	Details
Geographical Location	Latitude: 20°03′ N – 20°40′ N Longitude: 84°58′ E – 86°20′ E
Physiography	Flanked by Mahanadi River (North) and Kathajodi River (South)
Total Area	3932 sq. km
Climate Type	Tropical climate
Rainfall	Average annual rainfall: ~1892.55 mm

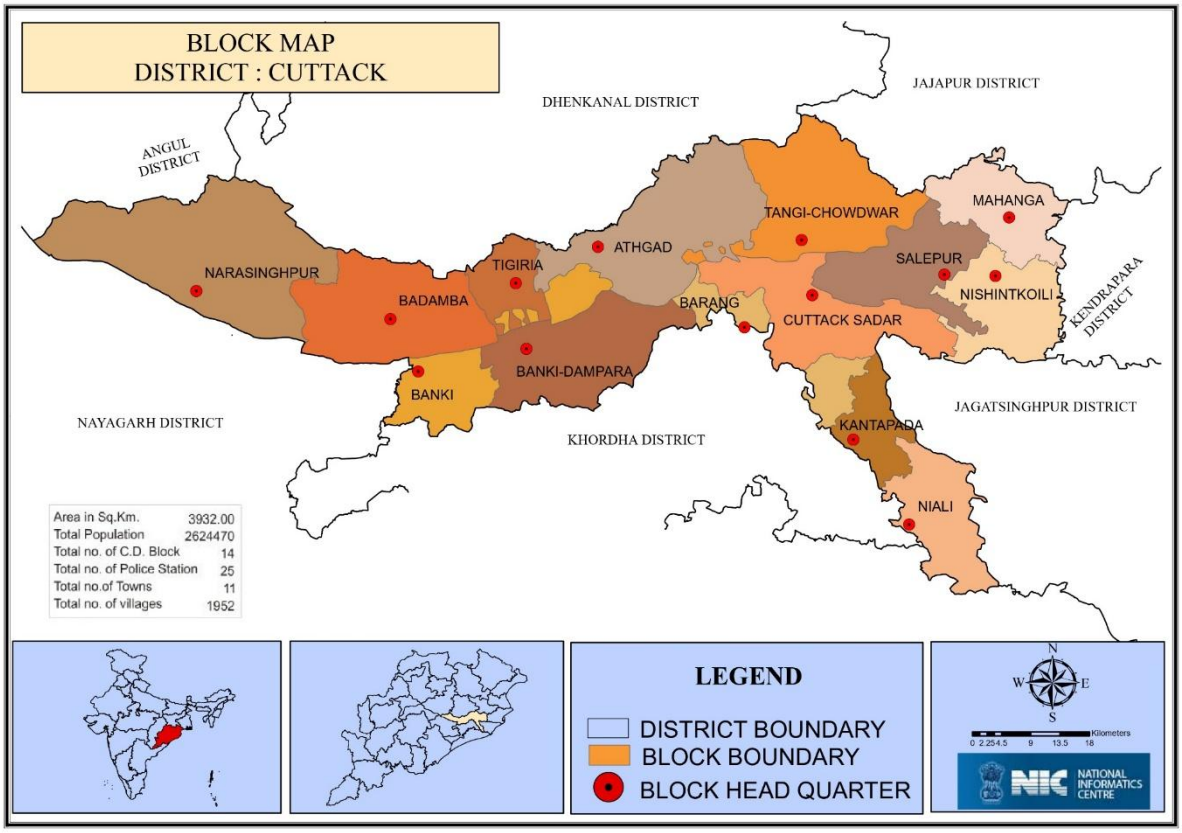


Image 2 Block map of Cuttack District

5.3.1. Rainfall

Rain recording stations are available in all the blocks of this district except Banki as the block office of Banki-Dompada has a rain recording station in the same headquarters. The Head Clerks of the Blocks are acting as Rain Recording Officers under the supervision of the respective Block Development Officers. The rainfall reports from each rain recording station

shall be transmitted to the District Control Room daily through Telephone/Messenger. A statement showing monthly annual rainfall in the district from 2017 to 2025 is given in below:

Sl. No	Actual Rainfall (in mm)									
	Month	2017	2018	2019	2020	2021	2022	2023	2024	2025
1	January	0.0	0	**0**	8.38	0.00	40.72	0.0	14.74	0
2	February	0.0	0	36.08	55.10	0.00	15.85	0.0	1.06	22.93
3	March	47.82	0	18.71	72.93	15.55	0.00	38.85	64.53	24.64
4	April	3.62	75.28	32.74	136.32	22.32	0.00	83.28	10.61	92.72
5	May	16.74	118.50	173.69	147.74	202.12	101.23	68.13	100.76	100.09
6	June	134.25	174.83	165.18	181.03	270.52	132.69	120.83	209.5	150.11
7	July	382.49	457.98	553.12	170.14	271.20	377.62	206.43	312.01	-
8	August	301.18	302.40	389.12	635.13	264.88	393.52	283.54	420.34	-
9	September	250.06	427.43	399.11	106.60	581.33	245.91	390.03	310.31	-
10	October	222.39	270.33	301.98	228.63	93.31	189.46	100.97	101.66	-
11	November	63.78	0	10.49	1.15	56.23	0.0	6.37	10.09	-
12	December	19.78	14.71	0.00	0.00	71.82	0.0	11.66	89.39	-
	TOTAL	**1475.75**	**1841.46**	**1880.22**	**1743.19**	**1849.28**	**1497**	**1310.09**	**1645**	**390.49**

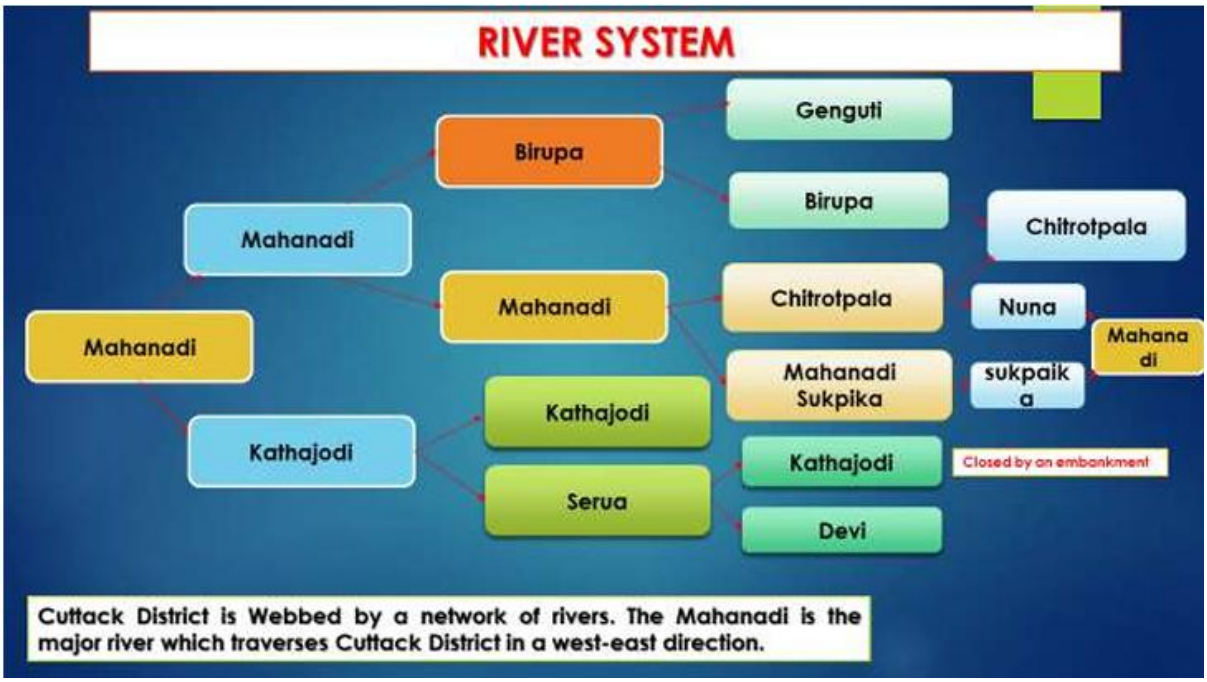
5.3.2. Temperature

There are two meteorological observatories in the district. The one at Cuttack is having sufficiently long period of data which may be taken as the representative of the climatic conditions of the district as a whole. The hilly areas of the district have slightly colder temperature during winter and hotter during summer. But in the coastal regions the climate particularly in summer is milder than in the interior. May is usually the hottest month with the mean daily maximum temperature at 38.8’ C and the mean daily minimum at 26’9 C. On some days the maximum temperature rises up to about 47’C in May and June; while the mean temperature falls from 31.4’C in the hot weather months to 30.8 C in the monsoon season and to 24.7 C in February. The highest maximum temperature recorded at Cuttack was 47.7’C on the 2nd May. 1957 and the lowest minimum was 7.8 C on the 4th January, 1923.

5.4. River system

The most conspicuous feature in the general aspect of the district is its river system. The district is webbed by a network of rivers. The system of rivers issues in three magnificent streams through three great gorges in the mountainous country to the west. To the south, the Mahanadi debouches upon the plains just above Naraj, 112 km.

The distributaries, struggling in thousand contortions and convolutions towards the cost, form a network of rivers, which joining here and separating there ultimately reunite with one or the other of the three parent rivers as they approach the sea.



5.5. Demography

Households and its distribution:

Sl. No	Total Number of Families/HH	Category		Category				Category	
		Rural	Urban	SC	ST	OBC	GEN	BPL	APL
1	**579170**	**1936672**	**687798**	**498633**	**93745**	**2032092**	**NA**	**NA**	**NA**

Population and its composition:

Sl. No	Population			SC		ST		OBC	
	T	M	F	M	F	M	F	M	F
1	2624470	1352760	1271710	254456	244177	47437	46308	NA	NA

Religion wise distribution of Population:

Sl. No.	Total Population	Category				
		Hindu	Muslim	Christian	Sikh	Others
1	2624470	2457729	141263	11985	1026	12467

Age Group

Sl. No.	Total Population	0-4 years	5-14 years	15-59 years	60 years and above
1	2624470	190662	444397	1701547	278680

Sex Ratio:

1	Sex Ratio (Females per 1000 males):	940
2	Sex Ration (0-6 Years):	914

Literacy Rate:

	Total	Male	Female
Literacy Rate	85.5	91.1	79.55

5.6. Socio-economic Profile

Workforce participation

The labour force participation rate is the measure to evaluate working-age population in an economy. The participation rate refers to the total number of people or individuals who are currently employed or in search of a job. People who are not looking for a job such as full-time students, homemakers, individuals above the age of 64 etc. will not be a part of the data set. People who are not interested in working or getting some sort of employment are not included in the participation rate, but to understand the unemployment data better, participation rate is considered carefully. An ageing population may have a negative impact on any economy. That is when the labour participation rate comes into the picture. If the rate is on the higher side, it is a good sign. But if it is on the lower side, it can also act as a warning sign for any economy. For that reason, participation rate as well as unemployment data should be looked into simultaneously to understand the overall employment status in the economy.

Workforce Participation Details of Cuttack Dist. as per Census 2011				
Sl. No.	**Category**	**Male**	**Female**	**Total**
1	Workers	761876	174489	936365
2	Main Workers	615670	80604	696274
3	Marginal Workers	146206	93885	240091
4	Non- Workers	590884	1097221	1688105

5.7. Major Disasters/ Incidents during 2006-2025

A brief profile of major disasters/ incidents occurred in the district (2006 to 2025):

Sl. No.	Disaster/ Incident	No. of incidents	No. of Deaths	Affected Population	Livestock Loss	Houses Damaged	Damage to Infrastructure				Damage and loss of Crop Area (in Hectares)
							School/ AWC Buildings	Hospitals	Road in Km.	Other Critical Infrastructure	
Disasters as approved under SDRF/ NDRF Guidelines.											
1	Flood	2006	2	446697	12	-	-	-	-	-	-
2	Flood	2007	-	-	-	-	-	-	-	-	-
3	Flood	2008	20	7,78,868	6343	-	-	-	-	-	-
4	Flash Flood	2009	3	26736	-	-	-	-	-	-	-
5	Flood	2011	4	584470	864	12489	-	-	-	-	32212.12
6	Flood	2014	1	522796	-	361	-	-	-	-	3014.317
		2019	4								118309
		2022	0	92892	3601	1718	-	-	-	-	34859
7	Drought	2013	-	-	-	-	-	-	-	-	
8	Drought	2015	-	-	-	-	-	-	-	-	72554
9	HailStorm	-	-	-	-	-	-	-	-	-	-
10	Phailin	2013	-	231675	148	29511	-	-	-	-	83439.63
11	Hud Hud	2014	-	-	-	-	-	-	-	-	-
	Titili	2018	-	-	-	-	-	-	-	-	-
	FANI	2019	6	2447071	1080221	120724	974	-	-	-	21649.8

5.8. Flood

Flood vulnerable areas of the district in general:

Sl. No.	Name of the Block/ ULB	No. of susceptible Gram Panchayats	No. of susceptible villages/ Wards	Population in Nos.	Milch and Draught animals	Houses	Vulnerable Infrastructure			
							School/ AWC Buildings	Hospitals	Roads (in Km)	Other Critical Infrastructure
1	Athagarh	14	67	144670	48006	31361	NA	NA	NA	NA
2	Tigiria	5	22	74639	14691	16519	NA	NA	NA	NA
3	Badamba	16	31	149793	37184	35641	NA	NA	NA	NA
4	Narasinghpur	23	80	157201	53504	36127	NA	NA	NA	NA
5	Banki	18	99	115402	57997	26673	NA	NA	NA	NA
6	Dampada	16	43	98894	26657	22714	NA	NA	NA	NA
7	Cuttack Sadar	5	9	141693	57356	30668	NA	NA	NA	NA
8	Tangi Choudwar	5	11	157801	52734	32785	NA	NA	NA	NA
9	Salepur	2	4	193938	33417	44942	NA	NA	NA	NA
10	Mahanga	15	58	186930	69148	44326	NA	NA	NA	NA
11	Nischinta Koili	13	29	188599	67229	44377	NA	NA	NA	NA
12	Niali	2	8	147135	79941	33191	NA	NA	NA	NA
13	Banki NAC	1	17	17521		3698	NA	NA	NA	NA
14	Kantapada	2	9	89514	25337	20074	NA	NA	NA	NA

5.9. Agriculture and Flood Vulnerability:

Sl. No.	Name of the Block	Cultivated area (Fig. in Ha)			Area sustainable to flood (Fig. in Ha)		
		Paddy	Non-Paddy	Total	Paddy	Non Paddy	Total
1	Cuttack sadar	9770	1869	11639	2155	0	2155
2	Barang	6720	1098	7818	950	0	950
3	Kantapada	5520	2285	7805	0	0	0
4	Niali	10390	3610	14000	850	0	850
5	Tangi choudwar	14320	5743	20063	1150	0	1150
6	Salipur	13380	3060	16440	0	0	0
7	N.Koili	12790	991	13781	0	0	0
8	Mahanga	11420	2674	14094	0	0	0
9	Athagarh	13150	6816	19966	1285	0	1285
10	Tigiria	4130	2459	6589	1850	0	1850
11	Badamba	7520	5773	13293	2250	30	2280
12	Narsinghpur	12200	7433	19633	4500	100	4600
13	Banki-I	7390	3564	10954	3800	150	3950
14	Banki-Dampada	7300	4775	12075	6700	120	6820
District Total:		**136000**	**52150**	**188150**	**25490**	**400**	**25890**

5.10. Population requiring special care

Sl. No.	Block/ ULB	No. of HHs headed by Women	No. of HHs headed by PWD	No. of Persons With Disability		No. of Widow	No. of Children		No. of Orphans		No. of Aged Persons (60 and above)		No. of Pregnant and lactating mothers
				M	F		0-5 Years	6-14 Years	M	F	M	F	
1	Athagarh	4583	1973	1361	795	6717	11700	17998	40	26	11264	10813	2271
2	Banki	96	1951	1115	836	1413	7491	13458	32	38	8337	5558	1431
3	Badamba	2829	2214	1572	642	36	7940	100	21	28	148	106	1445
4	Baranga	25	89	24	18	2	10560	96	19	17	4455	3263	2149
5	Cuttack	1150	1314	476	316	1150	5967	12400	19	22	78121	3372	1120
6	Dampada	22137	1428	625	535	2363	34206	10244	43	43	4506	3785	6542
7	Kantapada	19869	12138	1264	898	962	5286	0	8	9	6310	3390	886
8	Mahanga	74529	2400	1793	607	4433	12317	17320	8	7	11136	7320	2218
9	Narasinghpur	2528	1829	935	791	4041	10743	15250	29	21	6922	6348	1980
10	Niali	72929	2500	1900	950	3350	9733	10484	17	13	7454	5121	1658
11	Nischintakoili	30155	407	1222	1223	3033	11238	6312	13	14	8825	8816	1966
12	Salepur	2039	1797	1074	902	1807	14158	12047	17	18	10925	9322	2543
13	Tangi Choudwar	NA	1395	1052	590	27	14032	NA	56	39	56	44	2463
14	Tigiria	3303	1194	813	381	2146	5373	6425	12	11	12905	11337	1076

5.11. Hazard Calender

Type of Hazards	Jan-Mar				April-June				July-Sep				Oct-Dec			
	H	C	A	I	H	C	A	I	H	C	A	I	H	C	A	I
Flood																
Cyclone																
Earthquake																
Heatstroke																
Drought																
Hailstorm																

6. Hazard Analysis

6.1. Flood Susceptibility

Flood susceptibility in Cuttack district was assessed using a multi-criteria approach integrating key physical parameters that influence surface runoff, water accumulation, and inundation potential. The analysis was carried out using geospatial techniques in ArcGIS Pro, where each thematic layer was processed, reclassified, and combined using weighted overlay.

Flood susceptibility mapping identifies areas prone to flooding based on terrain, hydrology, and land surface characteristics. It is widely used for disaster risk assessment and planning (Tehrany et al., 2013; Khosravi et al., 2018).

6.1.1. Thematic Layers Used

- **Slope**

  Slope plays a crucial role in controlling runoff velocity. Areas with low slope tend to accumulate water and are more prone to flooding, whereas steeper slopes facilitate rapid drainage (Tehrany et al., 2013).

- The slope affects the velocity in which the water is conveyed through the drainage channel and the watershed. Additionally, the steeper the slopes, the higher the runoff will be, and consequently, higher peak discharges will be generated. The slope layer was derived from the DEM, with a resolution of 5 m × 5 m, using the Slope tool in ArcGIS Pro. It was reclassified in a scale from 1 to 5, where a value of 5 was given to lower slopes and 1 was given to higher values.

Class	**Level**	**Criteria for Flood hazard mapping**				
		S (Degree)	**HAND (m)**	**DS (m)**	**Avg. Precipitation**	**LULC**
5	Very High	≤10	≤2	≤100	2220 – 2292	Built-up
4	High	10.1–20	2.1–4	101–300	2150 – 2220	water
3	Medium	20.1–30	4.1–6	301–500	2050 – 2150	Cultivated
2	Low	30.1–50	6.1–8	501–1000	1950 – 2050	Barren

1	Very Low	>50	>8	>1000	1848 – 1950	Forest

- **Rainfall**

  Rainfall is a primary triggering factor for floods. Higher precipitation leads to increased surface runoff and river discharge, thereby elevating flood risk (India Meteorological Department, 2020).

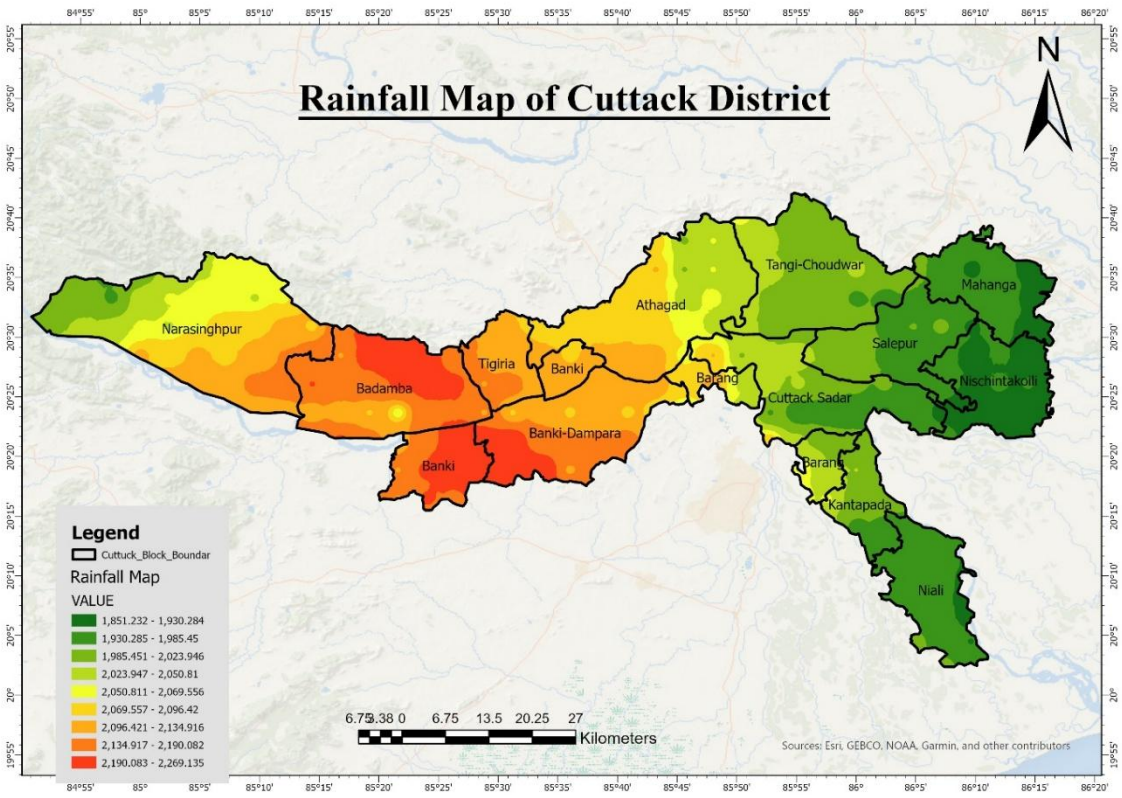


Image 3 Rainfall map

- **Land Use/Land Cover (LULC)**

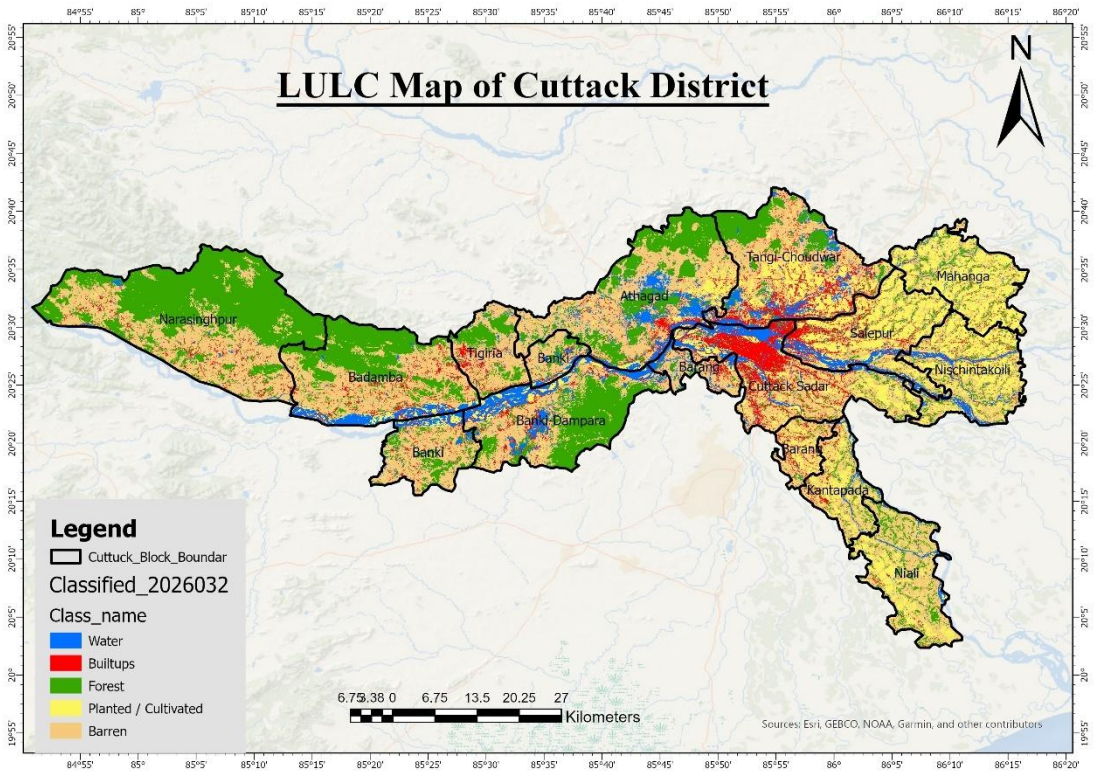


Image 4 LULC map of Cuttack

LULC influences infiltration and runoff characteristics. **Built-up areas** with impervious surfaces increase runoff, while **vegetation cover** reduces flood susceptibility by enhancing infiltration (Khosravi et al., 2018).

- **Distance to River** Proximity to rivers is a critical determinant of flood risk. Areas located closer to river channels are more susceptible to flooding due to overflow during peak discharge (Central Water Commission, 2019).

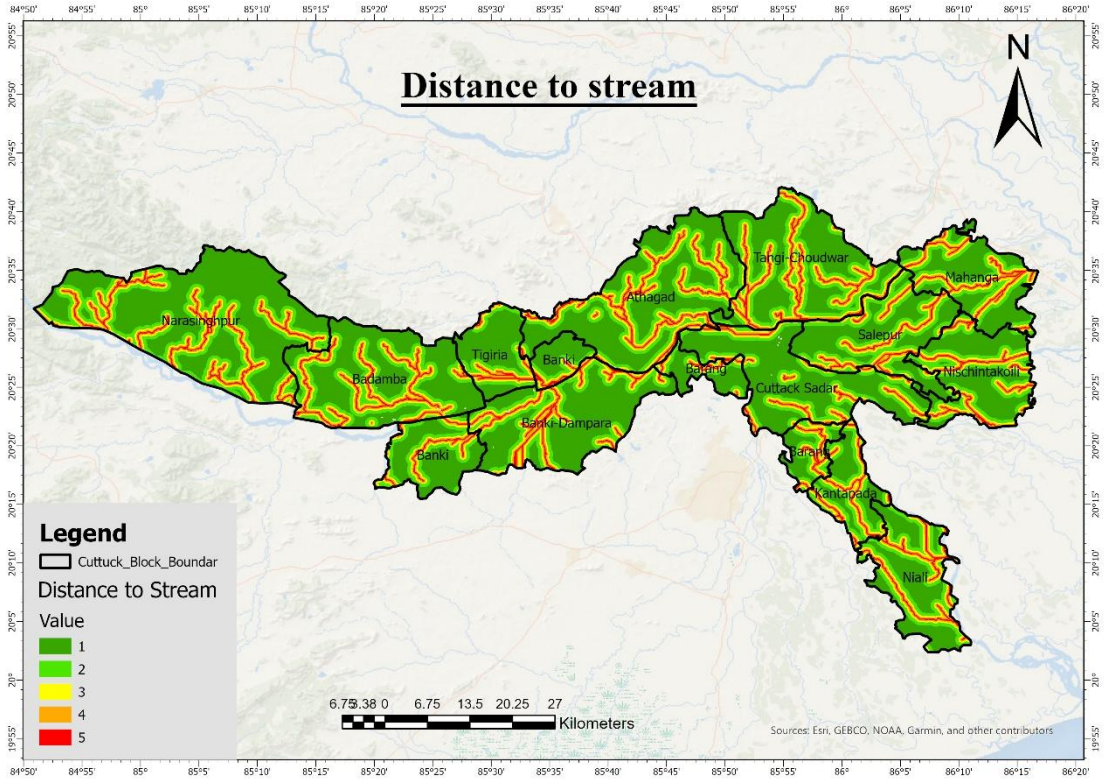


Image 5 Distance to stream map of Cuttack

- **Height Above Nearest Drainage (HAND)**

  HAND represents the vertical distance from the nearest drainage channel. Lower HAND values indicate areas closer to river level and hence more vulnerable to inundation (Nobre et al., 2011).

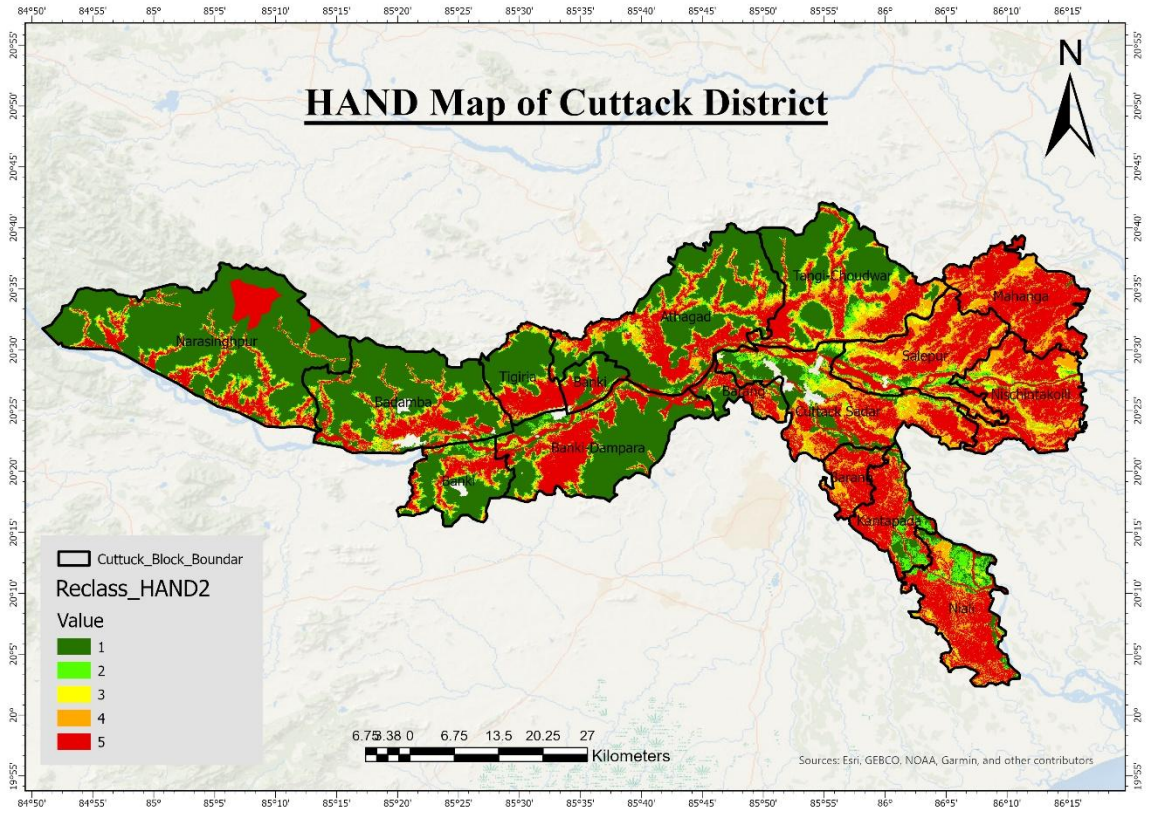


Image 6 Height above nearest drainage map

All thematic layers were standardized and integrated using weighted overlay analysis to generate the final flood susceptibility map. Each parameter was assigned a weight based on its relative influence on flood occurrence.

Table 5 Parameters for weighted overlay analysis

Parameters	**Weights (%)**
Distance to stream	25
HAND	25
Rainfall	20
Slope	15
LULC	15

The sum of weights of all the parameters was 100%

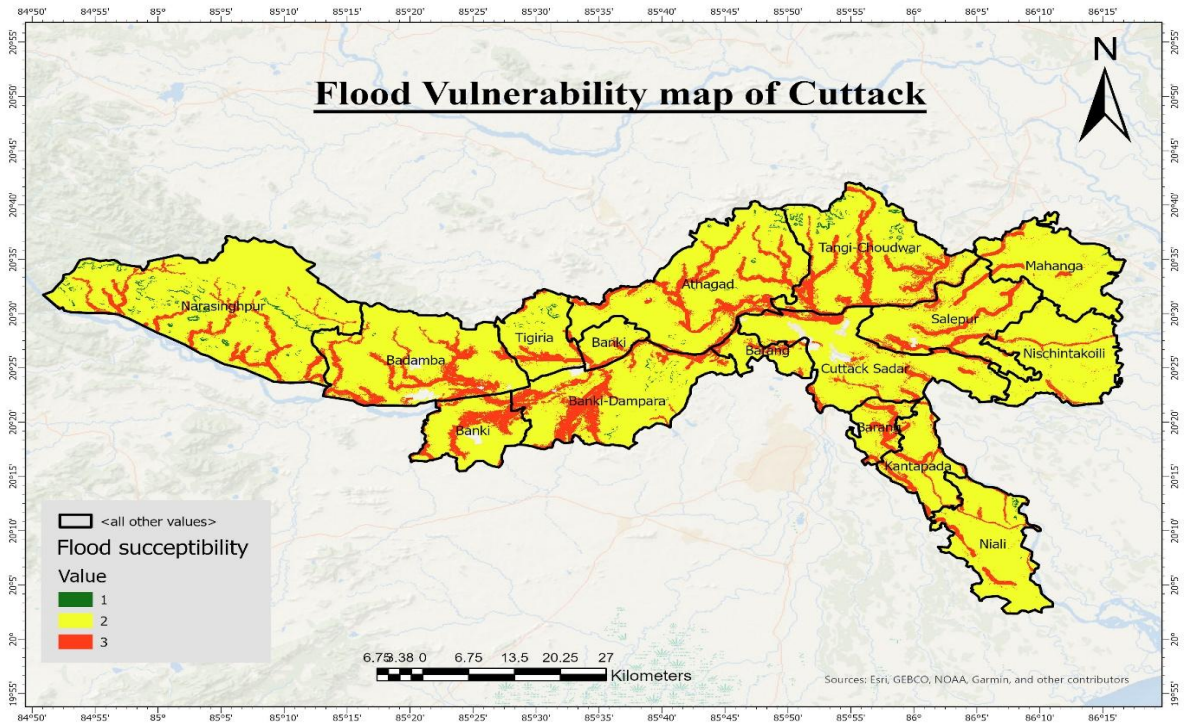
- Hazard vulnerability mapping was carried out to identify flood-prone and vulnerable areas within Cuttack district using GIS-based spatial analysis. The analysis integrated multiple physical and environmental parameters influencing flood occurrence and inundation.
- The major parameters used for flood susceptibility analysis included:
    - Distance to River

- Height Above Nearest Drainage (HAND)
- Rainfall
- Slope
- Land Use/Land Cover (LULC)

- Each parameter was classified and assigned weights based on its influence on flood occurrence. A weighted overlay analysis was performed in GIS to generate the final flood susceptibility map.
- The flood susceptibility map categorized the district into:
  - Very Low
  - Low
  - Moderate
  - High
  - Very High flood susceptibility zones.

The analysis revealed that low-lying areas located near major rivers such as Mahanadi, Kathajodi, and Birupa are highly vulnerable to flooding due to river overflow, heavy monsoon rainfall, and poor drainage conditions.

The generated hazard vulnerability map served as the base layer for integrating socio-economic indicators and identifying composite vulnerability hotspots across the district.



7. Socio-Economic Vulnerability Analysis

The assessment of vulnerability to natural hazards requires an integrated understanding of both socio-economic conditions and hazard exposure. In this study, vulnerability is conceptualized as a function of:

Vulnerability = Socio-Economic Susceptibility × Hazard Exposure

Socio-economic vulnerability reflects the inability of communities to anticipate, cope with, and recover from hazard impacts, while flood susceptibility represents the degree of physical exposure to flood hazards. The integration of these components enables the identification of priority areas requiring targeted interventions.

7.1. Selection of Indicators

Based on data availability and relevance to the study area, a set of **six indicators** was selected and categorized into **social** and **economic dimensions**.

Social Vulnerability Indicators (SVI)

The social dimension captures demographic dependency and human capital characteristics:

- Percentage of illiterate population
- Percentage of children (dependent population)
- Percentage of elderly population (above 60 years)

These indicators reflect reduced adaptive capacity due to dependency and limited access to information.

Economic Vulnerability Indicators (EVI)

The economic dimension represents livelihood insecurity and employment structure:

- Percentage of agricultural workers
- Percentage of marginal workers
- Percentage of non-working population

These indicators capture economic fragility and dependence on climate-sensitive livelihoods.

7.2. Data Processing and Standardization

Since the selected indicators are measured in different units and scales, **Min–Max normalization** was applied to transform them into a common dimensionless scale ranging from 0 to 1.

$$X' = \frac{X - X_{min}}{X_{max} - X_{min}}$$

Where:

- X' = standardized value
- X = observed value
- X_{min}, X_{max} = minimum and maximum values across all blocks

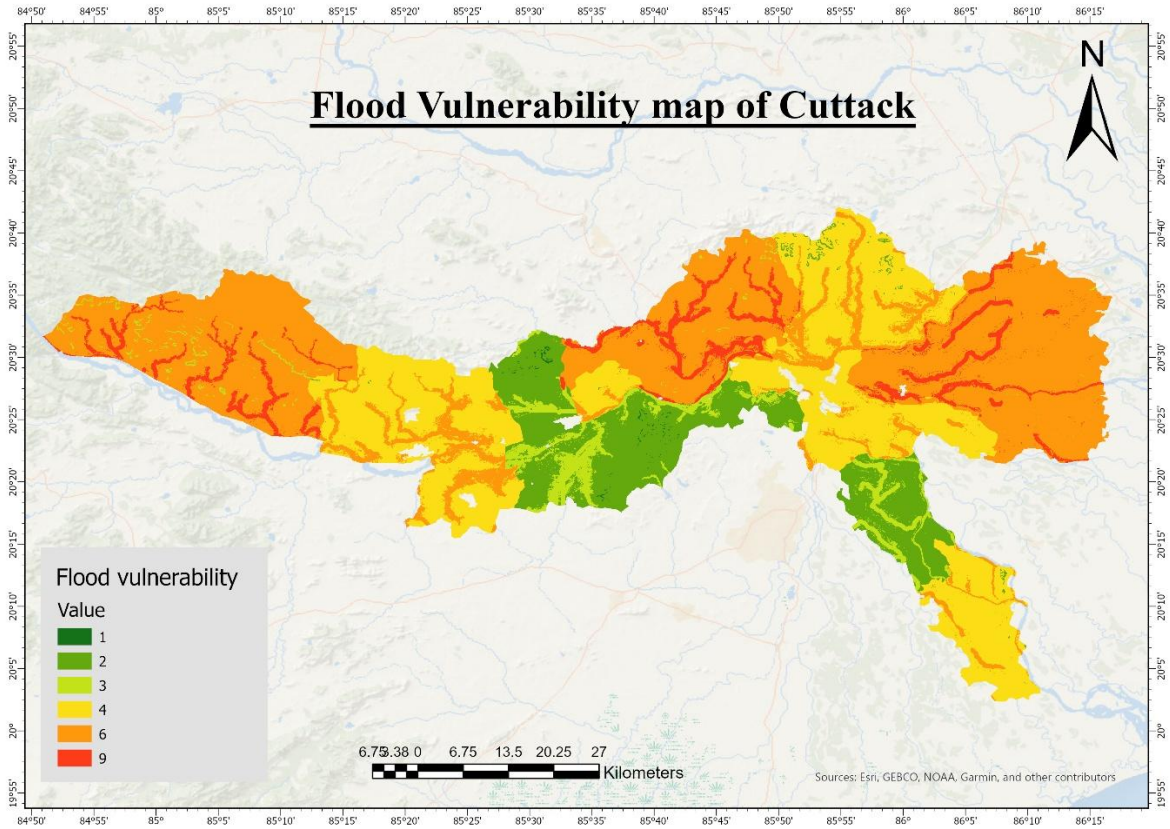
All indicators were selected such that **higher values represent higher vulnerability**, eliminating the need for reverse normalization.

7.3. Construction of Social and Economic Vulnerability Indices

Social Vulnerability Index (SVI)

The SVI for each block was computed by summing the standardized values of the three social indicators:

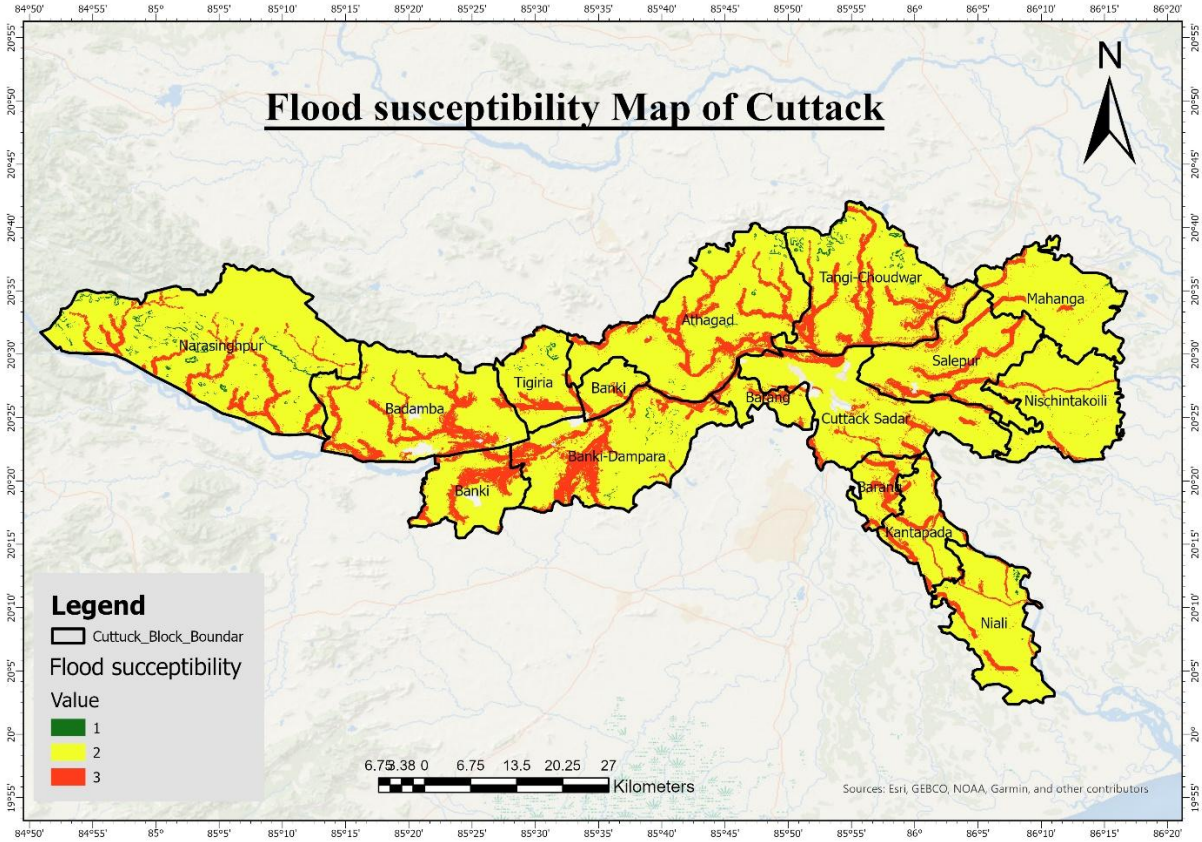
$$SVI_i = \sum_{j=1}^{3} S_{ij}$$



8. Results and Discussion

8.1 Flood Susceptibility Analysis

The flood susceptibility map was generated using multiple physical parameters such as slope, rainfall, land use/land cover, distance to river, and HAND through weighted overlay analysis.



Key Observations:

High and Very High Susceptibility Zones are concentrated in:

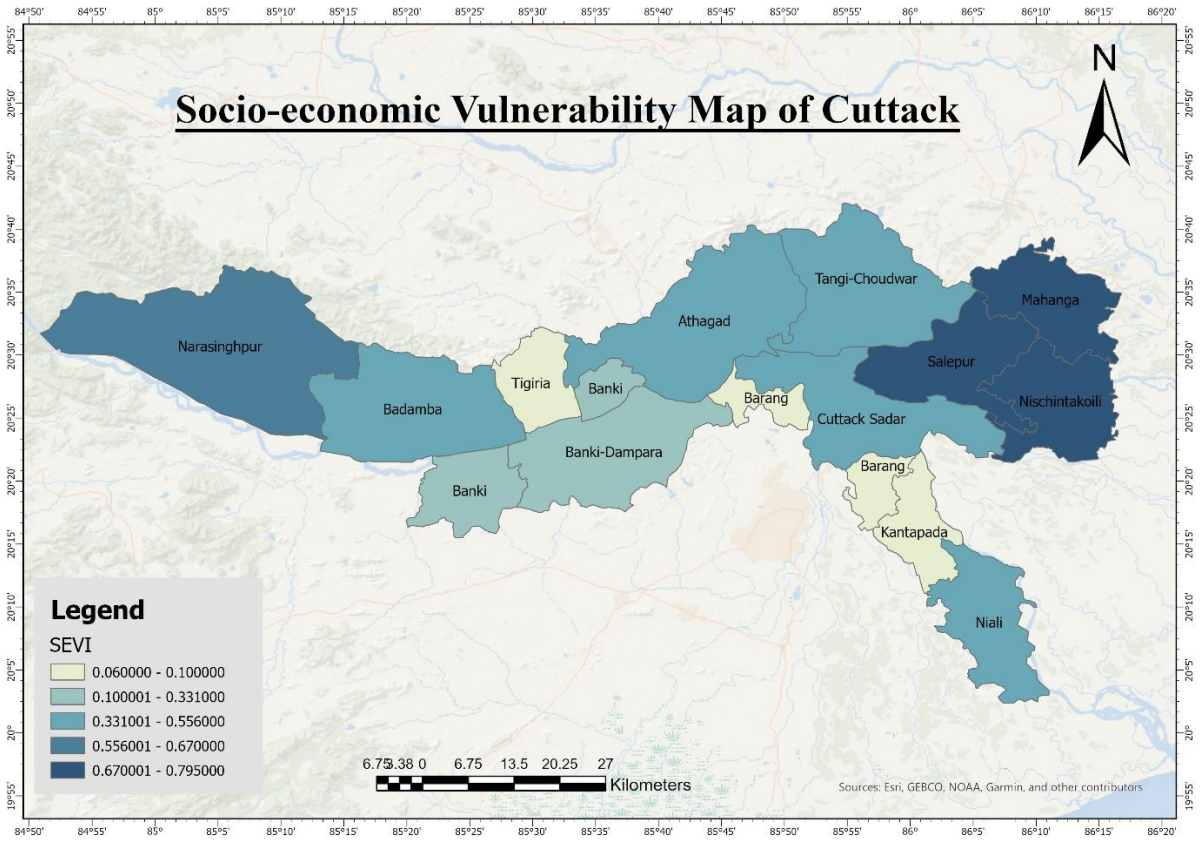
- Low-lying deltaic areas
- Regions near the Mahanadi River and its distributaries
- Areas with low slope and low HAND values
- Moderate Susceptibility Zones:
- Found in agricultural lands with moderate rainfall and gentle slopes
- Low and Very Low Susceptibility Zones:
- Located in relatively elevated areas
- Regions with higher slope and vegetation cover

Interpretation:

The spatial pattern indicates that topography and proximity to drainage play a dominant role in flood occurrence. Built-up areas also show increased susceptibility due to impervious surfaces, which reduce infiltration and increase runoff.

8.2 Socio-Economic Vulnerability Analysis

The Socio-Economic Vulnerability Index (SoVI) highlights variations in social and economic conditions across the district.



Key Observations:

High Vulnerability Areas:

- Densely populated urban and peri-urban zones
- Areas with poor housing conditions and limited infrastructure

Moderate Vulnerability Areas:

- Regions with mixed socio-economic characteristics

Low Vulnerability Areas:

Areas with better literacy, infrastructure, and economic stability

Interpretation:

The results indicate that social inequality and infrastructure gaps significantly influence vulnerability. Areas with low adaptive capacity are more likely to experience severe impacts during flood events.

8.3 Composite Vulnerability Analysis

The final vulnerability map was generated by integrating flood susceptibility and socio-economic vulnerability layers.

Key Observations:

Very High Vulnerability Zones:

Located in low-lying areas near river channels

Coincide with densely populated and economically weaker regions

High Vulnerability Zones:

Found in urban fringes and floodplains

Moderate Vulnerability Zones:

Areas with moderate exposure and better socio-economic conditions

Low Vulnerability Zones:

Elevated regions with better infrastructure and lower population density

8.4 Spatial Pattern of Vulnerability

The analysis reveals a clear spatial relationship between physical exposure and socio-economic conditions:

- Flood-prone areas do not always correspond to high vulnerability unless combined with socio-economic disadvantages
- Some regions with moderate hazard exposure show high vulnerability due to poor adaptive capacity

- Urban areas show dual risk: high exposure + high population concentration

8.5 Discussion

The results emphasize the importance of integrating both physical and socio-economic factors in vulnerability assessment.

Traditional hazard mapping alone is insufficient

Socio-economic conditions determine the severity of impact

The findings align with established vulnerability frameworks, which highlight the role of adaptive capacity in reducing risk

The study demonstrates that multi-criteria GIS-based analysis provides an effective approach for identifying vulnerable zones and supports informed planning decisions.

9. PROPOSAL AND RECOMMENDATIONS

9.1 Introduction

The increasing frequency and intensity of floods and climate-induced hazards in Cuttack district have significantly affected human settlements, livelihoods, infrastructure, and socio-economic systems. The findings from flood susceptibility analysis and socio-economic vulnerability assessment revealed that vulnerability is not solely determined by physical exposure to hazards, but also by livelihood dependency, weak infrastructure, poverty, population concentration, and limited adaptive capacity.

The integration of Flood Susceptibility Mapping and Socio-Economic Vulnerability Index (SEVI) highlighted several high-risk zones within the district where vulnerable populations are exposed to recurring flood impacts and reduced recovery capacity. Therefore, there is a need for an integrated and planning-oriented resilience framework that combines hazard mitigation, livelihood resilience, adaptive capacity enhancement, and spatial planning interventions.

This chapter proposes a comprehensive socio-economic resilience framework for Cuttack district aimed at reducing vulnerability and strengthening climate resilience through structural, non-structural, institutional, and spatial planning strategies.

9.2 Proposed Socio-Economic Resilience Framework

The proposed framework focuses on integrating hazard exposure, socio-economic sensitivity, livelihood dependency, and adaptive capacity into a unified planning strategy. The

framework emphasizes the importance of sustainable development, disaster preparedness, and resilient infrastructure planning in flood-prone regions.

The framework is based on the following components:

- Hazard Risk Reduction
- Livelihood Resilience Enhancement
- Social and Community Resilience
- Spatial Planning and Land Use Management
- Governance and Institutional Strengthening

The overall objective of the framework is to reduce socio-economic vulnerability while improving long-term resilience and adaptive capacity of communities in Cuttack district.

9.3 Hazard Risk Reduction Measures

Hazard risk reduction focuses on minimizing flood impacts and improving disaster preparedness in highly vulnerable areas. Since flooding remains the dominant hazard affecting the district, structural and non-structural measures are necessary for reducing exposure and physical damage.

9.3.1 Flood-Resilient Infrastructure

The study identified several low-lying and flood-prone regions where infrastructure is highly vulnerable to inundation. Therefore, development of flood-resilient infrastructure is essential.

Proposed Measures

- Construction and strengthening of embankments along major rivers such as Mahanadi, Kathajodi, and Birupa.
- Improvement of stormwater drainage systems in urban and peri-urban areas.
- Elevation of critical roads and transportation corridors in flood-prone regions.
- Development of flood-resilient public infrastructure such as schools, healthcare centers, and community shelters.
- Improvement of culverts and water discharge channels for reducing waterlogging.

Expected Outcomes

- Reduced physical damage during flood events.
- Improved accessibility and emergency response.
- Reduction in urban waterlogging and drainage congestion.

9.3.2 Flood Forecasting and Early Warning Systems

Timely dissemination of hazard information is critical for reducing disaster impacts and improving preparedness.

Proposed Measures

- Installation of real-time river monitoring systems.
- Strengthening flood forecasting mechanisms using GIS and remote sensing technologies.
- Community-based early warning dissemination systems.
- Mobile alert systems for vulnerable communities.
- Integration of local disaster management committees with district-level warning systems.

Expected Outcomes

- Faster evacuation and response.
- Reduced loss of life and property.
- Improved disaster preparedness among local communities.

9.3.3 River and Drainage Management

The study identified river overflow and inadequate drainage as major contributors to flood vulnerability.

Proposed Measures

- Regular desiltation of rivers and drainage channels.
- Restoration of natural drainage networks.
- Prevention of encroachment on drainage pathways.
- Improvement of canal connectivity for efficient water discharge.
- Maintenance of urban drainage infrastructure before monsoon periods.

Expected Outcomes

- Improved drainage efficiency.
- Reduction in floodwater stagnation.
- Better management of monsoon runoff.

9.4 Livelihood Resilience Enhancement

The socio-economic analysis revealed that communities dependent on agriculture, informal employment, and daily wage labor are highly vulnerable to climate variability and flood impacts. Therefore, livelihood diversification and economic strengthening are essential for resilience building.

9.4.1 Climate-Resilient Agriculture

Agriculture is one of the major livelihood sectors in Cuttack district and is highly affected by floods and rainfall variability.

Proposed Measures

- Promotion of flood-tolerant crop varieties.
- Crop diversification and mixed farming systems.
- Adoption of climate-smart agricultural practices.
- Development of irrigation and water conservation infrastructure.
- Training programs on sustainable farming techniques.

Expected Outcomes

- Reduced crop losses during floods.
- Improved agricultural productivity.
- Increased livelihood stability.

9.4.2 Livelihood Diversification

Dependence on a single livelihood source increases socio-economic vulnerability during disasters.

Proposed Measures

- Promotion of non-farm employment opportunities.
- Skill development and vocational training programs.
- Support for small-scale enterprises and local industries.
- Financial support for women-led self-help groups.
- Development of alternative income generation activities.

Expected Outcomes

- Reduced livelihood dependency on climate-sensitive sectors.
- Improved household income security.
- Enhanced economic resilience.

9.4.3 Financial Inclusion and Social Protection

Financial instability significantly limits recovery capacity after disasters.

Proposed Measures

- Expansion of microfinance and rural credit systems.
- Promotion of crop and livelihood insurance schemes.
- Financial assistance for disaster-affected households.
- Strengthening social protection and welfare schemes.
- Access to low-interest loans for vulnerable populations.

Expected Outcomes

- Improved recovery capacity.
- Reduced economic losses after disasters.
- Increased financial security among vulnerable households.

9.5 Social and Community Resilience

The assessment revealed that social factors such as literacy, awareness, healthcare access, and institutional support significantly influence adaptive capacity. Therefore, strengthening community resilience is essential for long-term disaster preparedness.

9.5.1 Community-Based Disaster Preparedness

Community participation is one of the most effective approaches for disaster risk reduction.

Proposed Measures

- Awareness campaigns on flood preparedness and safety.
- Community-based disaster management training programs.
- Mock drills and emergency response exercises.
- Formation of local disaster management committees.
- Capacity-building programs for vulnerable populations.

Expected Outcomes

- Improved disaster awareness.
- Faster community-level response during emergencies.
- Strengthened local preparedness capacity.

9.5.2 Healthcare and Emergency Services

Floods often affect public health and emergency accessibility.

Proposed Measures

- Development of flood-resilient healthcare infrastructure.
- Establishment of emergency medical response units.
- Improvement of sanitation and drinking water systems.
- Strengthening healthcare accessibility in rural and vulnerable regions.
- Stockpiling emergency medicines and relief materials.

Expected Outcomes

- Reduced health risks during disasters.
- Improved emergency response efficiency.
- Better public health resilience.

9.5.3 Gender and Social Inclusion

Vulnerability varies across different social groups, particularly women, elderly populations, and economically weaker communities.

Proposed Measures

- Gender-sensitive disaster planning.
- Inclusion of vulnerable groups in decision-making processes.
- Targeted support for elderly and disabled populations.
- Women-centered livelihood and resilience programs.
- Inclusive shelter and evacuation planning.

Expected Outcomes

- Improved social equity in disaster management.
- Enhanced participation of vulnerable groups.
- Reduction in social inequalities during disasters.

9.6 Spatial Planning and Land Use Management

The integration of GIS-based flood susceptibility and socio-economic vulnerability maps revealed significant spatial inequalities in exposure and adaptive capacity. Therefore, spatial planning interventions are essential for reducing future vulnerability.

9.6.1 Floodplain Zoning

Unregulated development in flood-prone regions increases disaster risk and exposure.

Proposed Measures

- Identification and demarcation of high-risk flood zones.
- Restriction of settlements and infrastructure development in highly vulnerable areas.
- Development control regulations for flood-prone regions.
- Promotion of low-impact and adaptive land uses in vulnerable zones.
- Integration of hazard maps into district planning policies.

Expected Outcomes

- Reduced exposure of settlements to flood hazards.
- Improved land use management.
- Prevention of future encroachment in high-risk areas.

9.6.2 Nature-Based Solutions

Environmental degradation and wetland loss increase flood intensity and reduce natural drainage capacity.

Proposed Measures

- Wetland restoration and conservation.
- Plantation and afforestation programs along riverbanks.
- Development of urban green infrastructure.
- Conservation of natural flood retention areas.
- Riverfront ecological restoration.

Expected Outcomes

- Improved water retention capacity.
- Reduction in flood intensity.

- Enhanced ecological resilience.

9.6.3 Resilient Urban Planning

Rapid urbanization and unplanned settlement growth have increased flood vulnerability in urban areas.

Proposed Measures

- Development of resilient urban infrastructure.
- Integration of climate adaptation into master plans.
- Improvement of drainage and waste management systems.
- Identification of safe growth corridors.
- Promotion of resilient housing strategies.

Expected Outcomes

- Reduced urban flood vulnerability.
- Improved infrastructure sustainability.
- Climate-sensitive urban development.

9.7 Governance and Institutional Strengthening

Effective governance and institutional coordination are essential for implementing resilience strategies and disaster management interventions.

9.7.1 Integrated Disaster Management Planning

Proposed Measures

- Integration of disaster risk reduction into development planning.
- Coordination among planning agencies and disaster management authorities.
- Strengthening local governance systems.
- Preparation of ward-level and block-level disaster management plans.
- Continuous vulnerability monitoring and updating.

Expected Outcomes

- Improved coordination and planning efficiency.
- Better implementation of resilience strategies.
- Strengthened institutional preparedness.

9.7.2 GIS-Based Decision Support System

The use of GIS and spatial analysis can improve disaster planning and monitoring.

Proposed Measures

- Development of GIS-based vulnerability databases.
- Real-time monitoring and mapping systems.
- Integration of socio-economic and hazard data into planning systems.
- Support for evidence-based decision making.

Expected Outcomes

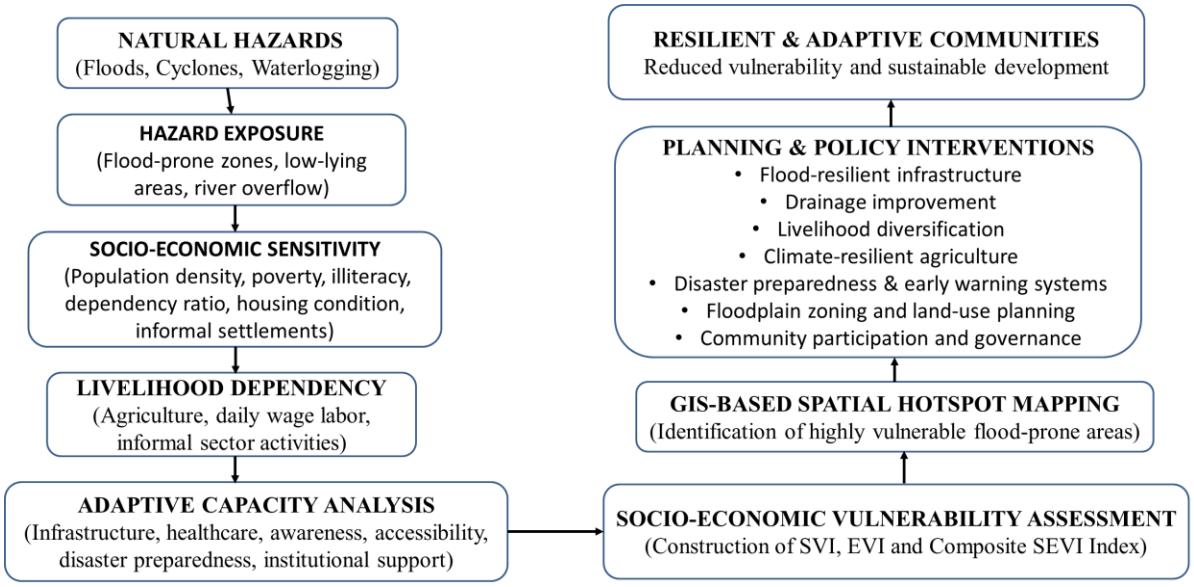
- Improved planning and resource allocation.
- Better identification of high-risk areas.
- Efficient disaster management and response.

9.8 Planning Recommendations

Based on the findings of the study, the following planning recommendations are proposed for reducing socio-economic vulnerability in Cuttack district:

1. Integrate flood susceptibility and vulnerability maps into district development planning.
2. Strengthen flood-resilient infrastructure in highly vulnerable regions.
3. Promote climate-resilient agriculture and livelihood diversification.
4. Improve drainage and river management systems.
5. Enhance community participation and disaster preparedness.
6. Implement floodplain zoning and land-use regulations.
7. Strengthen institutional coordination and governance systems.
8. Develop GIS-based decision support and monitoring systems.
9. Promote nature-based solutions and environmental conservation.
10. Prioritize resilience-building programs for vulnerable populations.

9.9 Proposed Socio-Economic Resilience Framework for Cuttack District



10. Conclusion

Socioeconomic vulnerability in the Cuttack district is closely linked to interactions among flood hazards, reliance on livelihoods, the nature of infrastructure, and adaptive capacity. In this research, the integration of flood sensitivity mapping and socioeconomic variables through GIS-based spatial analysis is established as a method to identify areas that are highly vulnerable within the given study area.

The results demonstrate that agricultural dependence and informal employment and/or low-income supporting activities contribute to greater susceptibility to impacts of hazards due to limited capacity for resilience and recovery. Additionally, vulnerability is not merely defined by the occurrence of hazards, but also by socioeconomic, environmental, and situational vulnerability impacts.

The proposed framework for socio-economic resilience focuses on integrated planning interventions, including the development of flood-resilient infrastructure, diversification of livelihoods, climate-sensitive land use planning, improvements in disaster preparedness, and institutional strengthening. In addition, the study indicates that a planning-oriented and replicable socio-economic resilience framework can contribute to the reduction of disaster risks, climate adaptation, and regionally sustainable development in hazard-prone areas such as Cuttack district.

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