सत्यमेव जयते

SOCIO-ECOLOGICAL RESILIENCE TO CYCLONE VULNERABILITY

A STUDY OF COASTAL ODISHA

National Institute of Disaster Management
Ministry of Home Affairs, Govt. of India

Research case study under the CAP-RES (project funded by DST-GOI)
Jointly with IGNOU, New Delhi

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2025

Resilient India : Disaster free India

National Institute of Disaster Management

(Ministry of Home Affairs, Govt. of India)

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Socio-Ecological Resilience To Cyclone Vulnerability: A Study of Coastal Odisha

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Dr. Akhilesh Gupta
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MESSAGE

The eastern coast of the Indian peninsula is highly vulnerable to extreme weather events and the disasters associated with them. The state of Odisha which covers approximately 480 km of the Indian coastline exhibits a wide range of physical, ecological and socio-economic diversity. However, the state is one of the most disaster-prone and disaster-impacted states in the world. Cyclone has the most devastating effect and has been affecting the lives and livelihoods of millions of people particularly those living along the coast. Therefore, there is a need for a detailed vulnerability assessment at the micro-level to identify the socio-ecological vulnerability as well as planning for enhancing resilience to disasters like cyclones.

I compliment the research team and congratulate NIDM for taking up this study and documenting the key insights. I am sure that this very innovative study will contribute to facilitating an effective planning strategy for cyclone risk reduction.

(Akhilesh Gupta)

nidm
Resilient India - Disaster Free India

राजेन्द्र रत्नू, भा. प्र. से.
कार्यकारी निदेशक

Rajendra Ratnoo, IAS
Executive Director

सत्यमेव जयते

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FOREWORD

Climate change has become a universal phenomenon and its manifestations are in the form of increased intensity, frequency and uncertainty of extreme events and disasters. Thus, it isnot only important to understand the underlying risks and vulnerabilities, but also to take appropriate measures to reduce the vulnerability. India is one of the worst-affected countries by natural disasters. This has been affecting the sustainable development of the country as significant proportions of people are socio-economically deprived. The coast of Odisha has been impacted by three major disastrous cyclones in the past few decades, which has tested the state's resilience to extreme events at many levels. The present study "Socio-Ecological Resilience to Cyclone Vulnerability: A Study of Coastal Odisha" provides a spatio temporal analysis of cyclones in coastal Odisha for the last fifty years and tries to identify a trend and pattern that would help in micro-level planning to reduce the cyclone vulnerability of the coast of Odisha.

I congratulate all the authors and the entire research team for bringing out such a relevant publication. NIDM has undertaken this study as part of the CAP-RES project (funded by DST, GoI). This publication holds immense significance in terms of micro-level planning for reducing the impacts of cyclones on the eastern coast of India. I hope that the publication will be a very good resource material for researchers, academicians, practitioners, scholars, policymakers and students.

(Rajendra Ratnoo)

Dr. Anil Kumar Gupta
Project Director: CAP-RES (DST)
Professor and Head - Environment, Climate and Disaster Risk Management Division

सत्यमेव जयते

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PREFACE

The international developmental agendas are primarily focusing on "Resilience" as a pillar to combat the dual challenges of climate change and disasters, as well as, to achieve holistic and sustainable development. However, socio-ecological resilience will include on only the ability to persist external disturbances, but also to learn, adapt and self-organise within any system. Such can be possible only by reducing the existing vulnerabilities within the system.

India is highly prone to multiple disasters, so it is essential to understand closely the risk factors or disaster vulnerabilities to enhance the capacity to respond to them. In similar terms, this study on "Socio-Ecological Resilience to Cyclone Vulnerability: A Study of Coastal Odisha" tries to analyze the seasonality, trends and patterns of the cyclones of coastal Odisha and constructs a micro-level cyclone disaster vulnerability index and identifies the factors that need to be strengthened for enhancing the socio-ecologic resilience to cyclonic vulnerability.

The study is undertaken in collaboration with IGNOU under the CAP-RES project (funded by DST).

(Anil K Gupta)

ACKNOWLEDGEMENT

The case study on Socio-ecological Resilience to Cyclone Vulnerability – A Study of Coastal Odisha has been supported by the Department of Science and Technology (DST), Government of India, through the Climate Adaptive Planning for Resilience and Sustainability in Multi-Hazard Environment (CAP-RES). A special note of thanks to Dr. Akhilesh Gupta, Secretary SERB and Senior Advisor, DST, GoI for entrusting NIDM with the opportunity to take up and work on the CAP-RES project. The project team is thankful to Shri Rajendra Ratnoo, Executive Director, NIDM for his constant support and encouragement for undertaking the study and ensuring the smooth functioning of the project. The contributions of the expert collaborator Prof. Subhakanta Mohapatra (Professor, Discipline of Geography, School of Sciences, IGNOU, New Delhi) and Mr. Uma Shankar Singh (PhD Scholar, Discipline of Geography, IGNOU, New Delhi) are acknowledged for joining hands with us in undertaking this study which takes into account both technical understanding and policy interventions at the same time. We are also thankful for the support provided by Dr. Nisha Mendiratta, Advisor and Head CCP, DST-GoI and Dr. Susheela Negi, Scientist E, DST-GoI. From CAP-RES team, Ms. Pritha Acharya (Research Associate) coordinated, assisted the study and also designed the report. The project team also extend thanks to Dr. Kundan for review and useful inputs, Shri SK Tiwari (Librarian, NIDM) and the entire publication cell of NIDM including Ms Karanpreet Kaur Sodhi, Jr Consultant (Publication) for helping in printing and publication of this report.

We are grateful to Prof. Nageswar Rao, Vice Chancellor IGNOU for providing all the support in conducting the study and writing the foreword for the report. We also duly acknowledge the support extended by the Director, School of Sciences, Planning Division and Finance Division, IGNOU.
The technical and administrative cooperation extended by the Odisha State Disaster Management Authority (OSDMA), Government of Odisha is highly appreciated without which the completion of this project could not be so smooth. Special thanks to Sh. P. K. Jena Chief Secretary, Government of Odisha for providing suggestions for completing this work. We are also thankful to Dr. Kamal Lochan Mishra and Mrs. Susmita Behera, General Manager OSDMA for their guidance from time to time. A special thanks to Mr. Sutanu Singh, State Project Officer, OSDMA for extending all academic and administrative support and facilitating the project work in all the coastal districts of the state.

We are thankful to all six District Project Officers (DPOs) without their help extensive fieldwork would have not been possible. They are Mr. Sukanta Dash, DPO Puri; Mr. Prabhu Prashad Maharana, DPO Ganjam; Mr. Abani DPO Balasore, Mr. Biswanath Mohanty, DPO Bhadrak; Mr. Ashutosh Mohanty, DPO Jagatsinghpur; and Mr. Ajaya Kumar Mohanty, DPO Kendrapada. We would like to extend special thanks to Dr. Rakesh Thakur and Mr. Sankar Prasad Goudo for the preparation of GIS maps. Thanks are due to Mr. Vasudev and Mr. Saswat Pati for conducting fieldwork in Puri and Ganjam and in Kendrapada and Jagatsingpur respectively. We are thankful to Dr. Manoj Sharma for the statistical analysis. This project would have not been completed without the help of Mr. Anil Kumar for assisting in project implementation.

(Prof. Anil K. Gupta)
Principal Investigator,
CAP-RES

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LIST OF ABBREVIATIONS

ACWC	Advance Cyclone Warning Centre
ADPC	Asian Disaster Preparedness Centre
ANOVA	Analysis of Variance
APL	Above Poverty Line
BPL	Below Poverty Line
CD	Community Development
CV	Coefficient of Variance
DFID	Department for International Development
DSH	District Statistical Handbook
AR5	Fifth Assessment Report
AR	Sixth Assessment Report
FGD	Focus Group Discussion
FSI	Forest Survey of India
GoI	Government of India
GOO	Government of Odisha
GIS	Geographic Information System
HFA	Hyogo Framework for Action
HHs	Households
IADB	Inter-American Development Bank
ICZM	Integrated Coastal Zone Management
IFRC	International Federation of Red Cross and Red Crescent Societies
IMD	India Meteorological Department
IPCC	Inter-governmental Panel on Climate Change
LDI	Livelihood diversification Index
MNREGA	Mahatma Gandhi National Rural Employment Guarantee Act
MSSRF	M S Swaminathan Research Foundation
NGO	Non- Government Organisation
NIDM	National Institute of Disaster Management
OECD	Organisation for Economic Co-operation and Development
OSDMA	Odisha State Disaster Management Authority
PRI	Panchayati Raj Institutions
PSU	Public Sector Undertaking
SC	Schedule Caste
SD	Standard Deviation
SDMA	State Disaster Management Authority
SDMP	State Disaster Management Plan
SEI	Stockholm Environmental Institute

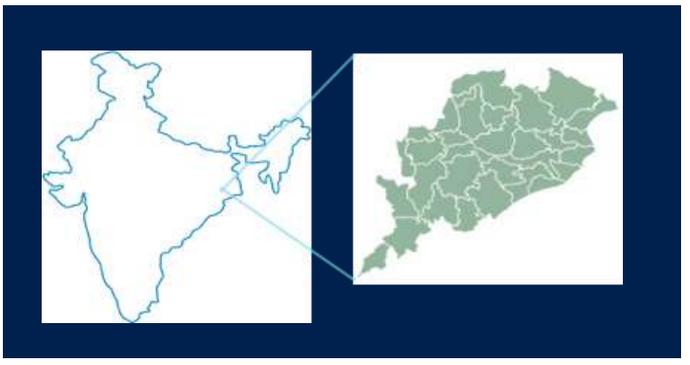
SHGs	Self Help Groups
ST	Schedule Tribe
TAR	Third Assessment Report
UN	United Nations
UNDP	United Nations Development Programme
UNISDR	United Nations International Strategy for Disaster Risk Reduction Secretariat
WB	World Bank
WCDRR	World Conference on Disaster Risk Reduction
WHO	World Health Organisation
WLL	Wireless in Local Loop
WMO	World Meteorological Organisation

ABSTRACT

Odisha has a 480 km long stretch of coastline and is one of the most cyclone-vulnerable regions in India. Coastal Odisha consists of six districts and twenty-two Community Development Blocks. Nearly one-third of the total population of the state lives in these coastal regions. Major urban centres namely Bhubaneswar, Cuttack, Puri, Berhampur, Balasore, Paradeep are also located in this region. Between 1891 and 2018, the state was hit by about 110 cyclones. The impact of these cyclones was mainly confined to these six coastal districts, where the maximum destruction occurred within 100 km from the centre of the cyclones and on either side of the storm track. The worst devastation is dependent upon the time and place of the high tide. Therefore, there is a need for a micro-level vulnerability assessment to identify the socio-ecological vulnerabilities as well as planning for enhancing resilience to cyclone disasters. This would help identify and devise better strategies for providing last-mile adaptive measures.

The study used secondary data from various government records namely India Meteorological Department (IMD), Census of India, Odisha State Disaster Management Authority (OSDMA) and District Statistical Handbook. IMD data was analysed to present trends and patterns of cyclones in Odisha.

Objectives of the Study



To analyze the trend, pattern and seasonality of cyclones in Coastal Odisha;

To construct a micro-level cyclone vulnerability index taking Community Development Blocks as a unit area of analysis;

To identify the factors that need to be strengthened for enhancing socio-ecological resilience to cyclone vulnerability both at the household and community level in coastal Odisha.

Twenty-two indicators were selected representing bio-physical, socio-economic, built-environment, and institutional aspects related to socio-ecological resilience. Socio-ecological resilience to cyclone disaster index was constructed by taking District and Community Development Blocks as a unit area of analysis. The index thus developed presents levels of socio-ecological resilience to cyclone vulnerability.

The study on the assessment of socio-ecological resilience at household and community levels used a structured questionnaire with Focused Group Discussion.

The purposive sampling method was used for identifying sample villages and stratified random sampling method was used to give a representation of different socio-economic strata.

Two hundred six households were selected from twelve villages (two each from the six Coastal Districts) that were affected by severe cyclones that took place in the last ten years (1912-21). Household analysis revealed the barriers to attaining socio-ecological resilience and also highlighted different indicators that need to be strengthened to enhance socio-ecological resilience.

To maximize the benefits from this study, initiatives will be taken to minimize the gap between the science, policy and implementation through the scientific investigation and institutional analysis. To bridge this gap, this study will investigate the technical feasibilities of sustaining and managing socio-ecological resilience in coastal Odisha and implementation with the involvement of the local communities. Involvement of governmental officials, institutions, stakeholders and the local community level is also proposed.

EXECUTIVE SUMMARY FOR POLICY PLANNERS

Antonio Guterres "India is the third worst affected country by natural disasters since 1995." It has also been revealed that many of the natural disasters like cyclones, floods and droughts have been increasing due to the impacts of climate change. This has been affecting the sustainable development of the country as significant proportions of people are socio-economically deprived. Odisha in general and Coastal Odisha in specific is one of the most disaster-prone areas in the world. During the last two decades, this region encountered frequent floods droughts and cyclones several times (OSDMA, 2019) and cyclones, have had the most devastating effect on the lives and livelihoods of the locals living along the coastline.

Detailed analysis of available secondary data, primary survey of households and extensive interactions with diverse stakeholders revealed that significant progress has been made over the last twenty-three years (1999 – 2022). About 10, 000 casualties in 1999 to almost zero casualties in 2021 (Cyclone Yaas) speaks in volumes about the efforts made by the Odisha Government. There is a robust institutional arrangement from the State Headquarter up to the Cyclone Shelter level (at the grassroots), which earned appreciation from the United Nations.

However, there are many areas of concern for making coastal Odisha from a cyclone-vulnerable region to a cyclone-resilient region in the country. The present study provides a spatio-teporal analysis of the cyclone in Coastal Odisha for the last fifty years (1971-2021) so that these trends and patterns would be useful in micro-level planning. This information can further contribute to facilitating an effective planning strategy for cyclones and cyclone-induced flood control. There are many indicators related to bio-physical, socio-economic, built-environment and institutional parameters that need to be strengthened. This is a continuous process in which the state needs to critically analyse measures related to the readiness, responsiveness and revitalization of coastal communities. It would be possible when people's vulnerability is properly assessed and measures are properly executed. Like a robust mechanism for 'Zero Casualty', the state should have a Vision Document for the "resilient Coastal Communities". The Institutional arrangement should be re-oriented which would ensure local people's participation and bring developmental co-benefits.

Based on major findings, the suggestions for policy implications are as follows-

Long-term sectoral plan for climate and hydro-meteorological disaster proofing agriculture, horticulture and fisheries

There is a need for a detailed analysis of sector-specific livelihoods namely agriculture, horticulture and fisheries as these three economic activities are the mainstay of the population surplus in coastal areas. These sectors are also climate-sensitive and there is a need to prepare sectoral plans to make these sectors climate-resilient and provide sustainable livelihoods. Odisha government has been implementing a project in the fishery sector with technical support from the World Fish Programme, Penang, Malaysia. The project is on the verge of completion and will be under the review process. Similarly, plans for the agriculture and horticulture sectors should also be made and implemented.

Development of Block Disaster Management Plan for all the twenty-two coastal Blocks:

Odisha State Disaster Management Authority has already prepared the District Disaster Management Plans (DDMP) and is in the process of preparing the village-level Disaster Management Plans. However, there is a need to prepare Block-Level Disaster Management Plans for all the 22 Coastal Blocks of Odisha. This is the smallest administrative division.

Policy and guidelines for making cyclone resilient infrastructure

The government of Odisha undertakes the construction of roads, buildings, bridges, power, telelines, and other critical infrastructure. If one adds the concept of disaster resilience and mitigation to these projects, the final product could be different. The construction of roads, bridges, buildings and others should feature characteristics of disaster resilience so that they can withstand calamities like floods and cyclones. Coastal erosion has been a serious problem along the Odisha coast. Analysis revealed that 116 coastal stretches in Puri district followed by Kendrapada (69), Jagatshinghpur (43) and Ganjam (33) districts were identified to be highly vulnerable.

Detailed plan for diversification of rural livelihood

The household survey revealed that the majority of the households had a single income source (95.1%) and were climate-sensitive in nature. Cyclone had severe impacts on their livelihood. As the amount of income was meagre, these households did not have much savings to be used at the time of disaster. Therefore, there is a need for diversification of livelihood with an emphasis on climate-proofing these livelihoods. Efforts should be made to explore climate-neutral livelihood opportunities.

SOCIO-ECOLOGICAL RESILIENCE TO CYCLONE VULNERABILITY

A STUDY OF COASTAL ODISHA

INTRODUCTION

The Context

The incidences and vulnerability of natural disasters namely cyclones, floods, droughts, heat waves etc. have been increasing across the globe over the years. According to the World Meteorological Organisation (WMO) Atlas on "Mortality and Economic Losses from Weather, Climate and Water Extremes (1970 - 2019)", there were more than 11000 reported hazards related to these hazards globally. As per the Atlas, there were over 2 million deaths and US$ 3.64 trillion monetary losses (WMO, 2021). However, these disasters have differential impacts. People residing in the developing countries have been most affected. Even within developing countries, the socio-economically marginalised section of the population is most vulnerable. There has been a huge loss of lives and livelihoods in these developing countries. This acts as a deterrent to sustainable development. Therefore, efforts have been made at international, national, as well as community levels to make societies disaster-resilient.

According to Alexander (2013), there has been a change in attitude particularly after the observation of International Decades for Disaster Risk Reduction (1990-2000).

There has been a paradigm shift in disaster management from 'relief' measure' to 'preparedness' action. Therefore, there is a new paradigm which is popularly known as Disaster Risk Reduction (DRR) and Resilience. Now the emphasis has shifted from simple vulnerability assessment to understanding how communities can be made more disaster resilient against multiple disasters.

The Hyogo World Conference on Disaster Reduction held in 2005 was a milestone in endeavouring for the necessity and methods to establish disaster-resilient communities (Birkmann, 2006; Manyena, 2006; Cutter et al., 2008). The Sendai World Conference on Disaster Risk Reduction in 2015 has strengthened this. This was further endorsed by accepting four specific priorities for action which are (i) "understanding disaster risk, (ii) strengthening disaster risk governance to manage disaster risk, (iii) investing in disaster risk reduction for resilience and enhancing disaster preparedness for effective response and (iv) to "Build Back Better" in recovery, rehabilitation and reconstruction" (UNISDR, 2015). India is one of the most natural disaster-prone countries in the world. Many natural disasters like cyclones, floods and droughts have been increasing due to the impacts of climate change, affecting the sustainable development of the country as significant proportions of people are socio-economically deprived.

Odisha in general and Coastal Odisha in specific is one of the most disaster-prone areas in the world. The state has been frequently affected by hydro-meteorological disasters namely cyclones, floods and droughts. During the last two decades, this region encountered floods droughts and cyclones several times (SDMP, 2019). Out of the three, cyclones have the most devastating effect and have been affecting the lives and livelihoods of millions of people particularly those living along the coast. Therefore, the major objective of this case study was to identify measures to make cyclone-resilient coastal communities for achieving sustainable development.

Conceptual Framework

The conceptual framework is a tool that connects to the problems and gives directions for data collection. Therefore, in this section, an attempt has been made to discuss the concepts namely disaster, vulnerability, coping, adaptation and resilience and their linkages and inter-relationships. The below given schematic presentation depicts the complex relationships among these concepts (refer to Fig. 1.1).

Concept of Resilience

The term resilience is derived from the Latin word 'resilio', meaning 'to jump back' (Klein, Nicholls and Thomalla, 2003). The field in which it was originally used is still contested. Some say ecology (Batabyal, 1998), while others say physics (Van der Leeuw & Leygonie, 2000). In the sphere of ecology, it gained importance and was widely used after the publication of Holling's seminal work in 1973, entitled "Resilience and Stability of Ecological Systems" (Blaikie and Brookfield, 1987; Levin, 1998; Adger, 2000; Van der Leeuw & Leygonie, 2000). Most of the literature, however, states that the study of resilience evolved from the disciplines of psychology and psychiatry in the 1940s, and it is mainly accredited

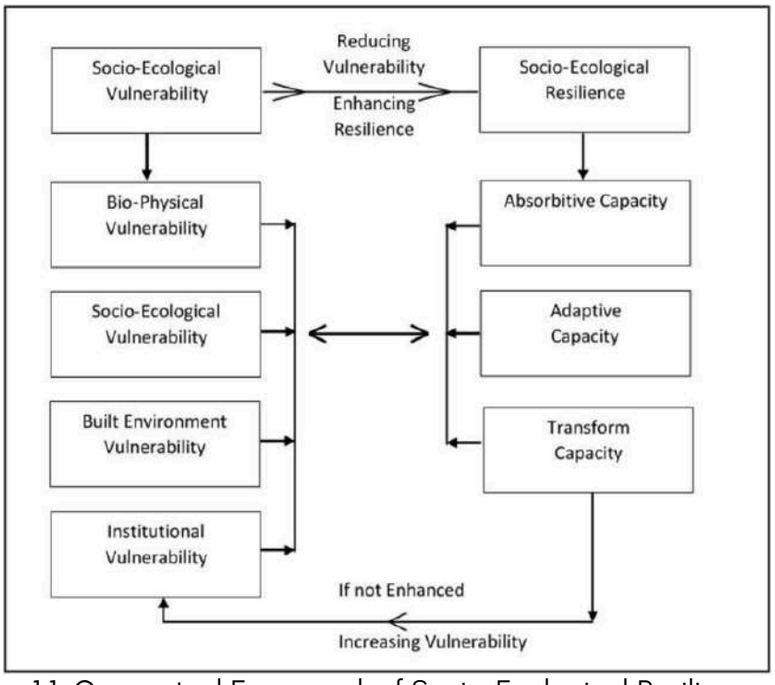


Fig. 1.1: Conceptual Framework of Socio-Ecological Resilience.

to Norman Garmezy, Emmy Werner and Ruth Smith (Waller, 2001). It materialised as a result of efforts to understand the aetiology and development of psychopathology, most particularly in studies of children 'at risk' of psychopathological disorders due to parental mental illness, perinatal problems, inter-parental conflict, poverty or a combination of both (Masten, 1999; Rolf, 1999). The pioneers in the study of resilience were interested in analysing risks and the negative effects of adverse life events on children, such as divorce and traumatic stressors namely abuse, neglect and war.

Today, resilience is being applied in several fields, especially climate change and disaster management. The adoption, on 22 January 2005, of The Hyogo Framework for Action 2005-2015—also known as 'The Hyogo Declaration' by the UNISDR is a positive move. This has further been re-endorsed in the Sendai Framework.

According to Alexander (2013), there has been a change in attitude particularly after the observation of International Decades for Disaster Risk Reduction (1990-2000). On similar terms, the IFRC (2004) also mentions that increased attention will be paid to what affected communities can do for themselves and how best to strengthen them. Yet, if the concept of resilience is to lead to a new way of tackling disasters and providing policy options, there is a need to address the philosophical questions that continue to blur the concept. To enhance resilience, it is necessary to have a good initial understanding of what it is, its determinants (Klein et al., 1998), and how it can be measured, maintained and improved (Klein, Nicholls and Thomalla, 2003). Simultaneously, any planning on enhancing resilience in different contexts including disaster management should have clarity on four questions. Sharifi (2021) outlined the questions as follows:

- Resilience of What?
- Resilience to What?
- Resilience for What?
- Resilience at What stage?

These four key questions have been meticulously addressed through four variables: macro-scale urban form elements and structure, shocks and stresses, resilience characteristics, and resilient stages. (Refer to Fig. 1.2).

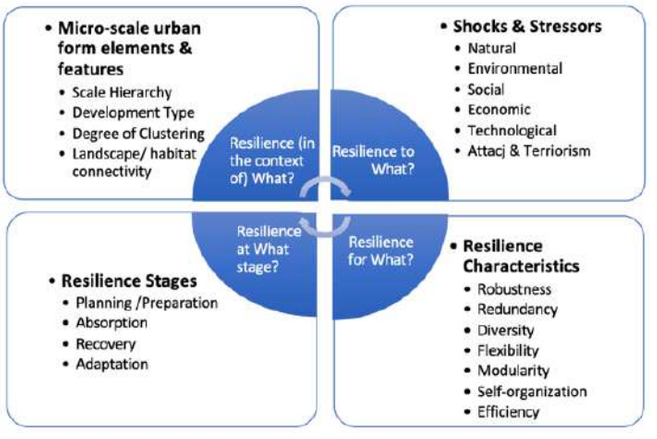


Fig. 1.2: Potential linkages between macro-scale urban form and resilience.
(Source: Sharifi, 2021)

The ecosystem which is the base for survival would be sustainable and resilient if it is integrated with socio-economic aspects of human life. Therefore today the integrated concept of socio-ecological system is more relevant. The figure below depicts the relationship between the social and the ecological systems.

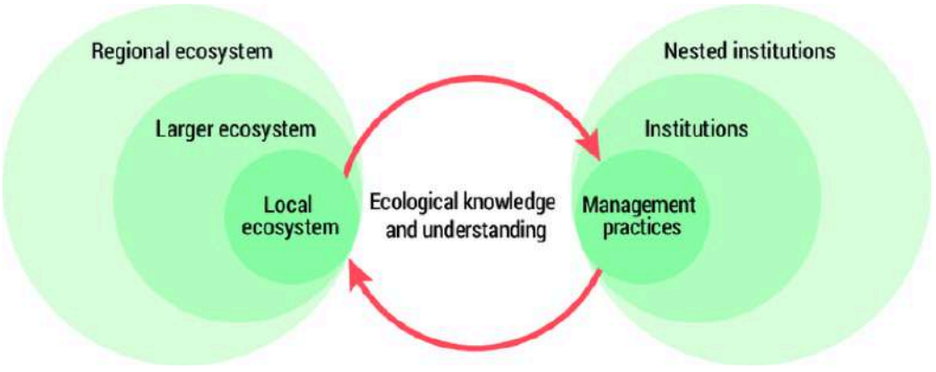


Fig. 1.3: Schematic Presentation of Socio-Ecological System.

The local ecosystems are most pertinent and are addressed through different management practices. To reach from ecosystem to management practices, an understanding of the ecological knowledge must be practised for the understanding of socio-ecological systems (Fig. 1.3).

Elements of Resilience

Resilience can be divided into various systems depending on the purpose and scope of the framework. Below is a suggestive list of systems from which one or more might be part of the various types of resilience formulated in various situations (Sherrieb et al., 2010; Cutter et al., 2010; and Constanza, 2012).

- Physical system (e.g., critical infrastructure, communication systems, etc.)
- Human system (e.g., skills, knowledge, health, education, etc.)
- Social system (e.g., community networks, trust, civic engagement, norms, etc.)
- Institutional system (e.g., first responders, response systems, etc.)
- Technical systems (e.g., warning systems, emergency plans, etc.)
- Economic system (e.g., income, productivity, etc.)
- Environmental system (e.g., fresh water, arable land, etc.)
- Ecological system (e.g., pollination, carbon sinks, etc.)

"Resilience": An Outcome Versus a Process:

Cutter et al. (2008) and Manyena (2006) emphasized the significance of considering resilience as an outcome versus a process. Resilience is considered an outcome when it is defined as the ability to bounce back or cope after any disaster, the ability to survive and cope with a disaster with minimum impact and damage and the capacity to avoid, reduce and minimize impacts of disaster and recover quickly and effectively (Bruneau et al. 2003; Cutter et al. 2008).

Resilience is considered a process when it is defined to be the ability to learn to mitigate future disasters (Tierney and Bruneau 2007; Cutter et al. 2008). The frameworks either suggest activities or processes aimed at building resilience or specify important elements of resilience or both.

Concept and Components of Socio-Ecological Resilience

The concept of resilience in relation to social-ecological systems incorporates the **idea of adaptation, learning and self-organization in addition to the general ability to persist disturbance**. According to Carpenter et al. (2001), social-ecological resilience is interpreted as:

1. The amount of disturbance a system can **absorb** and remain within the same state or domain of attraction;
2. The degree to which the system is capable of **self-organization** versus lack of organization or organization forced by external factors; and
3. The degree to which the system can build and increase the **capacity for learning and adaptation.**

According to Carpenter et al. (2001), Socio-ecological Resilience has three components i.e., absorptive, adaptive and transformative capacity. A brief explanation of these three capacities is as follows:

1. **Absorptive Capacity:** The amount of disturbance a system can absorb and remain within the same state or domain of attraction.
2. **Adaptive Capacity:** The degree to which the system can build and increase the capacity for learning and adaptation.
3. **Transformative Capacity:** The degree to which the system is capable of self-organization.

After describing the concepts of resilience in general and socio-ecological resilience in particular, it is important to learn about the importance of resilience, its co-benefits and resilience dividends.

A) Importance of Resilience

Today many of the international organisations dealing with various developmental issues namely climate change, disaster and sustainable development are emphasising on resilience. Researchers have been working on various research studies across the globe for the last four decades. Some of the arguments are as follows:

- Resilience thinking helps provide an all-hazards approach, consistent with trends in hazards research to evaluate hazards **holistically** (Hewitt, 2004). Resilience deals with the **coupled human-environment systems** and contributes to a comprehensive vulnerability analysis by avoiding the **artificial divide between physical and social emphasis.**
- Resilience **emphasizes the ability of a system to deal with a hazard.** It allows for the **multiple ways in which a response may occur,** including the ability of the system to absorb the disturbance, or learn from it and to adapt to it, or to reorganize following the impact. These processes are often occurring simultaneously, across scale, in subsystems nested in larger subsystems, referred to as panarchy (Holling 2001, 2004).

- As it deals with the dynamics of response to hazards, resilience is **forward-looking and helps explore policy options for dealing with uncertainty and change.** It provides a way for thinking about policies for future environmental change, an important consideration in a world characterized by unprecedented hazards and transformations (Folke et al. 2002).

B) Co-benefits and Resilience Dividends

Rodin (2014) notes that "resilience-building is also a lever for unlocking greater economic development and business investment, as well as improved social services and more broadly shared prosperity."

A conceptual discussion of the resilience dividend has two potential components:

1. The difference between how a disruptive incident and the associated shock or stresses may affect a community that has made resilience-related investments compared to the counterfactual of the community not making such investments; and
2. Investing in resilience can provide several co-benefits to communities including job creation, social cohesion, and equity.

The key components of urban physical resilience and their characteristics as depicted in Fig. 1.4 can be described in four stages i.e., preparation, absorption, adaptation and self-organization (Parizi et al, 2021:731).

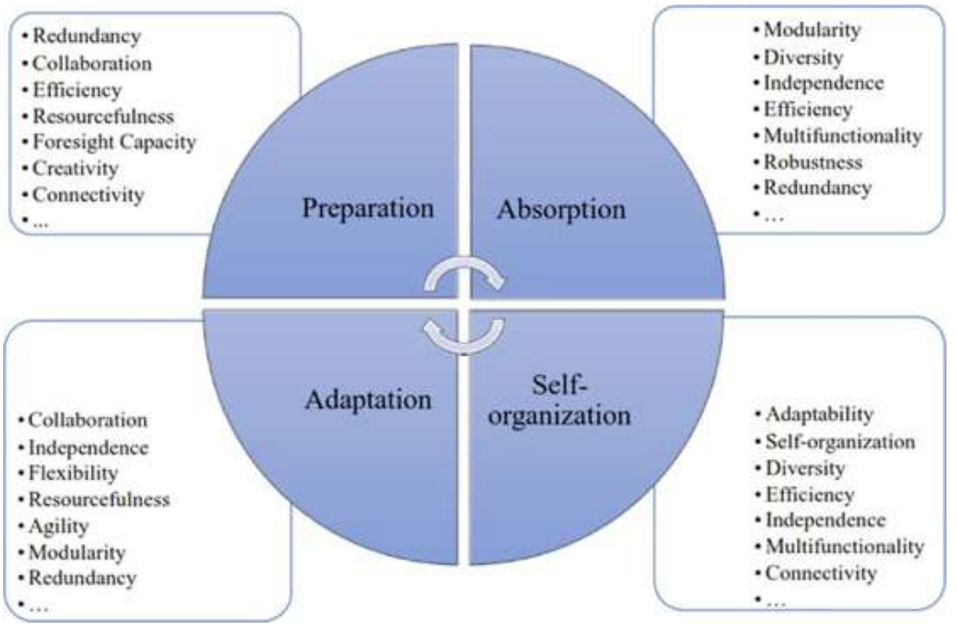


Fig. 1.4: The components of urban physical resilience and their characteristics. (Source: Parizi et al., 2021:731)

Disaster Resilience

This is a part of the broader concept of resilience 'the ability of individuals, communities and states and their institutions to absorb and recover from shocks, whilst positively adapting and transforming their structures and means for living in the face of long-term changes and uncertainty' (OECD, 2013b:1).

Disaster resilience is the ability of individuals, communities, organisations and states to adapt to and recover from hazards, shocks or stresses without compromising long-term prospects for development. According to the Hyogo Framework for Action (UNISDR, 2005), disaster resilience is determined by the degree to which individuals, communities and public and private organisations are capable of organising themselves to learn from past disasters and reduce their risks to future ones, at international, regional, national and local levels.

DFID (2011a:6) expressed resilience as 'the ability of countries, communities and households to manage change, by maintaining or transforming living standards in the face of shocks or stresses – such as earthquakes, droughts or violent conflicts – without compromising their long-term prospects'.

The United Nations (UNISDR, 2004) defined it as 'the capacity of a system, community or society potentially exposed to hazards to adapt, by resisting or changing in order to reach and maintain an acceptable level of functioning and structure'.

In conceptual terms, vulnerability and disaster resilience are closely related. Some authors see vulnerability as the opposite of disaster resilience, while others view vulnerability as a risk factor and disaster resilience as the capacity to respond (Manyena, 2006:436, 439-443).

Measuring Disaster Resilience

Given the novelty of resilience frameworks and the challenges associated with their implementation, researchers tend to rely on approaches and methodologies developed elsewhere – such as in the vulnerable community (e.g., self-assessments, rankings, etc.). Resilience research seems to parallel the trajectory of vulnerability studies, which would explain the development of general resilience frameworks (Cutter et al., 2008; Tobin, 1999), as well as specialized frameworks about a selected threat or for a specific sector or participant (Bruneau et al., 2003). Putting a framework into action requires the selection of indicators, identification of feedback loops and so forth.

Frameworks are a great starting point but many decisions on how to implement the model and measure resilience are left unresolved. Ideally, practitioners and researchers would mirror a framework's approach as much as possible, though this is rarely feasible given limited data availability, uncertain feedback loops and interaction effects, constrained computational resources to model cross-scale interactions and more. Researchers also found that there are frequent gaps and incoherencies between the asserted

definitional and contextual meanings of resilience/vulnerability and their implementation – particularly the absence of explicit frameworks (Hinkel and klein, 2009; Ionescu et al., 2009). For example, in 128 instances of vulnerability assessments, Zou and Thomalla (2008) found only 14 per cent referencing a vulnerability framework. Considering the seemingly insurmountable conceptual as well as methodological challenges, how can one assess resilience? What are existing measures of resilience and how are resilience frameworks operationalized? Is there one model that does the 'best' in assessing resilience? Unfortunately, a sound assessment tool capable of operationalizing resilience in its entire complexity is yet to emerge.

It would appear that resilience assessments are undergoing growing pains similar to those experienced by vulnerability assessments in their early years. Many resilience case studies propose their own frameworks and metrics, limiting their generalizability and applicability in different contexts. Existing resilience assessments tend to compartmentalize the issue at hand by focusing on the resilience of specific localities, groups/ organizations, infrastructure sectors and subsystems or resilience against a specific threat.

At present, there are four categories of resilience assessments, which can contain quantitative, qualitative (e.g., self-assessments) and mixed-method methodologies:

1. Outcome-driven approaches – Focusing on estimating and/or modelling losses, recovery times and similar (e.g.,Miles and Chang, 2006; Cimellaro et al., 2010; Beck et al., 2012).

2. Input-driven approaches – Identifying underlying factors that influence resilience, including vulnerability (e.g., IADB, 2005; Fisher etal., 2009).

3. Scenario-driven approaches - Documenting past or future system responses to a specific risk (e.g., Sempieret al., 2010).

4. Complex system approaches Inventorying independent elements of resilience with unknown feedback loops (e.g., Cutter et al., 2010). A systems approach, meaning an approach capable of capturing the adaptive complex systems of resilience – or a system of systems – is yet to materialize. This is likely attributable to the lack of new and innovative methodologies suitable for representing dynamic, non-linear features and feedback loops. In their absence, the above-listed approaches draw heavily on three different techniques gleaned from vulnerability assessments:

- Probability theory, including fragility curves and stochastic.
- Indexing using a single metric thats cores units of analysis comparatively.
- Qualitative ratings (self-assessments).

Indexing and qualitative rating are static snapshot assessments. While these are valid and feasible techniques for measuring vulnerability, they tend to contort the concept of resilience by removing some of its essential characteristics. For example, indices and rankings do not account for the interactions between system participants. All components are generally treated as independent entities, thereby eliminating the capacity for emergent behaviour. Probability theory, on the other hand, is a promising approach since it allows for dynamic developments, evaluation of system performance and the incorporation of surprises. It is capable of capturing the degree of change a system can accommodate while remaining within specified boundaries and system configurations.

Thus far, though, the methodology has been exclusively applied to infrastructure resilience (Cimellaro et al., 2010) and outcome-driven approaches utilizing an engineering resilience framework that is characterized by system robustness, redundancy, resourcefulness and rapidity (Bruneau et al., 2003). Somewhat problematic, though, the fact is that probability-based approaches tend to rely on performance metrics such as recovery times or disaster losses, which might be flawed in their own way (Rose, 2004; Gall et al., 2009). So, how can we overcome these weaknesses? Joint efforts and knowledge provide largely an untapped source. Evolving beyond vulnerability science, learning from ecological resilience as well as more collaboration between sustainable development, engineering, computer sciences, ecosystem management, disaster management and climate change adaptation, among others, may provide a path forward (Miller et al., 2010).

Geographical Background of the Coastal Odisha

The state of Odisha situated in the eastern part of India has a 480 km long stretch of coastline. It extends from the Subarnarekha in the north-east to the Rushikulya in the south-west. The Odisha Coastal Plains is otherwise also known as Utkal Plains.

These plains are the sedimentary landforms of recent origin. Geologically they belong to the Paleocene and Neocene ages which were approximately 65 to 2.6 million years ago. Their western boundary is at around 250 feet of the Eastern Ghats and they have a nearly straight shoreline in the east. A major part of this region is formed by deltas of the six major rivers i.e., the Mahanadi, the Brahmani, the Budhabalanga, the Subarnarekha, the Baitarani, and the Rushikulya.

According to locations, the coastal plains can be divided into the following sub-regions:

- The north coastal plains-the deltas of the Subarnnarekha and the Burhabalanga up to the river Baitarani,
- The middle coastal plains-the combined deltas of the Baitarani, the Brahmani and the Mahanadi; and
- The southern coastal plains - the Rushikulya plains.

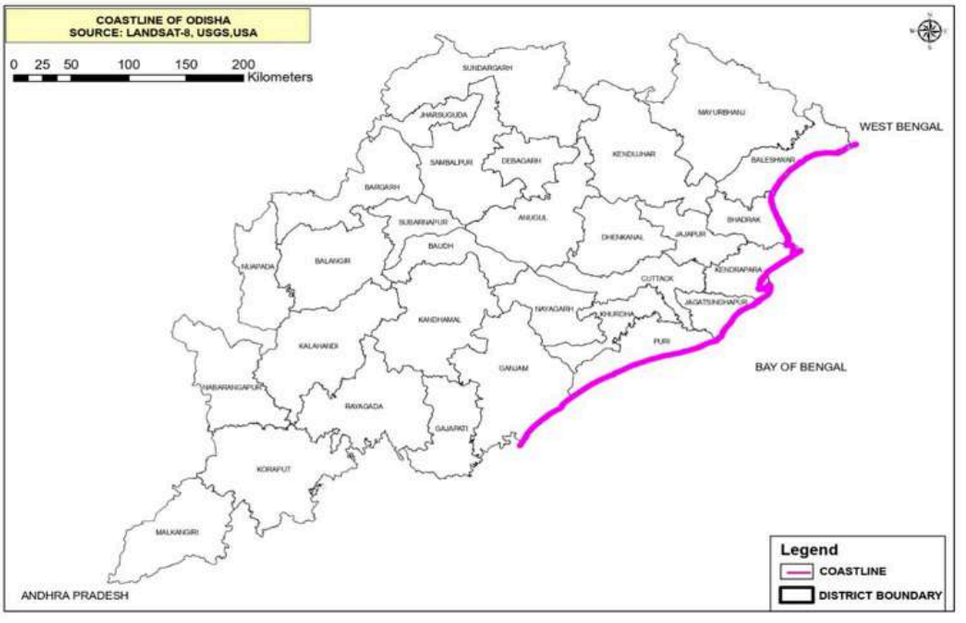


Fig. 1.5: Coastline of Odisha.

It has the maximum width near the Mahanadi Delta in the Middle Coastal Plain. It is narrower in the Northern Coastal Plain in Baleshwar District and narrowest in the Southern Coastal Plain in Ganjam District. This region hosts several lakes. In general, the combined deltas of the Brahmani and the Baitarani are fairly stable in contrast to that of the Mahanadi where the free delta formation is restricted by the strong littoral current from the southwest. The delta development of the Brahmani is also obliterated by the encroachment of the distributaries of the Mahanadi and the Baitarani from the south and the north, respectively. The geographical background of Odisha can be described in detail in the following sub-points:

A) Physiography of the Coastline: The Odisha coast has bulged out in the middle portion from Brahmagiri at Chilika lake in the southwest to Chandbali in the north-north-east where rivers namely the Mahanadi, Brahmani and Baitarani form a combined delta. In this portion, the coast is convex while from Chandbali to the Subarnarekha River mouth it is concave (Fig. 1.5).

If a straight line is drawn from Chandipur off Balashore coast to Gopalpur, the recent delta formation in the post-tertiary period in the middle portion becomes quite obvious. The protruding nature of the coast is quite evident. The bay sandbars at the mouth of the Chilika Lake, Devi River mouth and on the left bank of the Mahanadi mouth and at other rivers namely Kushabhadra near Konark and Rushikulya are the best examples. In the Mahanadi mouth, the complex spit with multiple hooks is formed due to the offshore long current and the strong longshore drift during rainy seasons when the load discharge in the Mahanadi is maximum. The high tidal prism keeps the mouths of the Devi, the Mahanadi, the Brahmani, the Baitarani

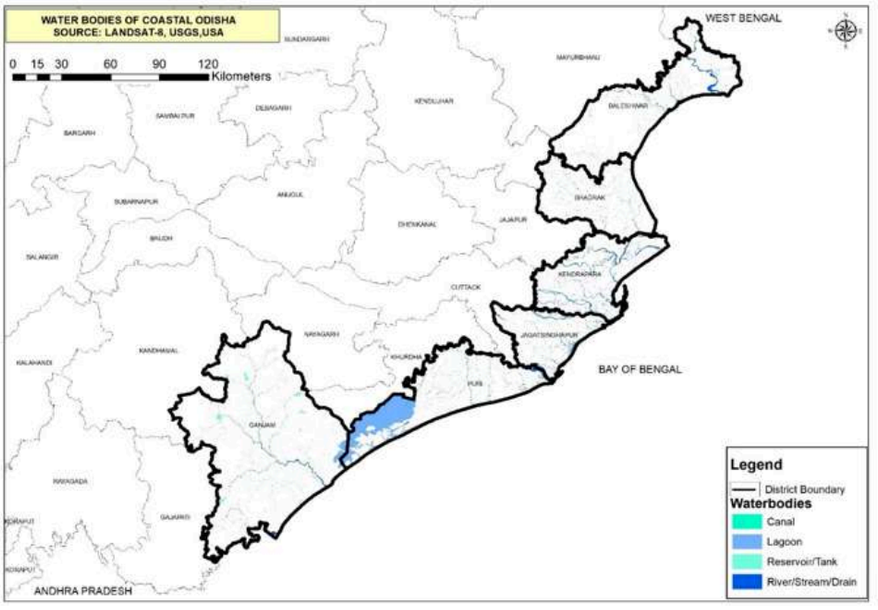


Fig. 1.6: Drainage System of Coastal Odisha.

and the Rushikulya opens to form estuaries. In the north along Balasore the coast is in form of a crescent-shaped embayment with inter-tidal flat development and the mesotidal tidal regime is quite conspicuous (Fig. 1.6).

B) Climate: The climate in the coastal plains of Odisha is mostly mega thermal type having either a moist sub-humid or dry sub-humid type moisture regime. The rainfall is mostly contributed by the monsoon depression during the southwest monsoon season (June - September), and cyclonic storms during the post-monsoon (October-November) and pre - monsoon (March-May) period. The rainfall patterns along the coastal stretches indicate that it is maximum in the north and gradually decreases towards the south.

C) Forest: Forest plays a significant role as far as cyclones are concerned. They act as a shield against high-speed winds. This has been proved time and again after each major cyclone that hit the coastal regions of Odisha. Therefore, it is one of the major cyclone mitigating factors. As the Odisha coastal zone is situated in the tropical climatic zone, the presence of estuaries, flat and protected coastal areas and barrier islands had mangrove vegetation dispersed across protected locations (Fig. 1.7). But due to the developmental interventions along the coast and relatively low tidal range, the mangrove areas have been degraded and are of intermittent in their characteristics (Panda, Mishra and Chatterjee, 2022). After the cyclone Yaas, the Government of Odisha planned to develop 3,500 hectares of area available for coastal shelter belt plantation to mitigate the impact of cyclonic winds (bio-shields), and 400 hectares for creating mangrove forests in six coastal districts." (Barik, 2021). It has also been decided to plant different varieties of cyclone-resistant trees namely Neem, Karanja, Baula, Jamu, Khaira, Arjun, Ashok, Harida, Bahada, Shisu, Champa and Dimiri.

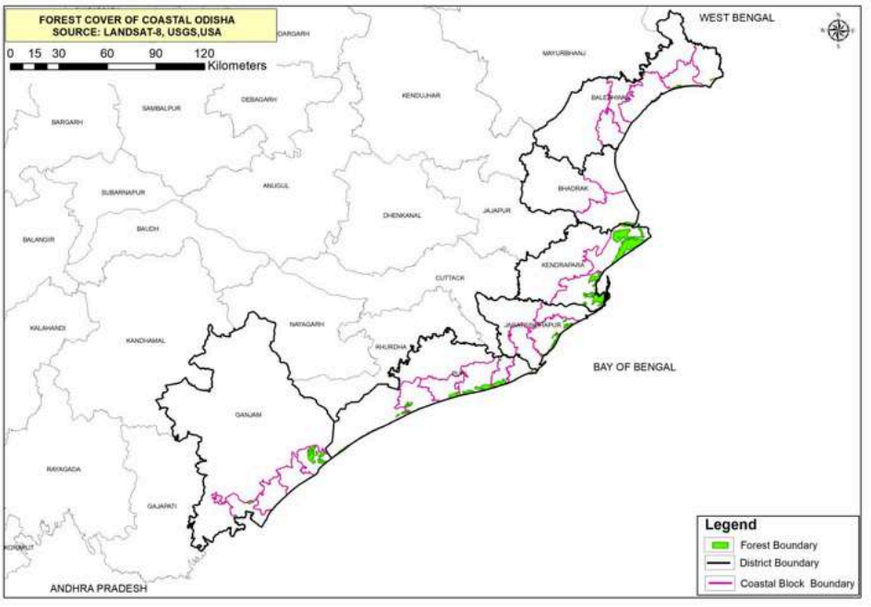


Fig. 1.7: Distribution of Forest Cover in the Coastal Odisha.

Mangroves: Mangroves play a vital role in the coastal ecosystem because of their role in mitigating coastal erosion, contributing to coastal fishery, as nurseries for a variety of fish and prawns and as barriers to tidal and storm surges associated with tropical cyclones. As per the State of Forest Report 2021, mangroves in Odisha are spread over an area of 259 Sq. Km. of the coast. Kendrapada district has maximum mangrove cover in the state (209.25 Sq. Km.), followed by adjacent Bhadrak district (34.87 Sq. Km.), Jagatshinghpur district (8.33 Sq. Km.), 5.4 Sq. Km. of mangrove forest is found in Balasore district and 1.13 sq km in Puri district. An analysis of the river basins reveals that mangroves are found along the six major river deltas of coastal Odisha. These major river deltas are Subarnarekha, Budhabalanga, Bramhani-Baitarani, Mahanadi, and Devi. Besides, the Chilika Lagoon also has a very small patch of mangroves. The Bhitarkanika National Park in the Bramhani-Baitarani deltaic area has the largest mangrove patch in Odisha covering an area of about 150 sq. km. It harbours India's richest mangrove forests in terms of species diversity. Mangroves in other areas are mostly degraded due to various factors. The most significant factor has been conversion to brackish water fish ponds. It has been observed that mangrove vegetation in Odisha reduced from 234 Sq. Km. to 199.19 Sq. Km. from 1975 to 1993. Forest Survey of India (FSI) report for 2021 showed that mangrove vegetation in Odisha was somewhere around 195 Sq. Km. during the period 1991-1993 with a substantial increase in the mangrove cover of 259 sq km. A total of 73 species of mangroves and mangrove-associated species are found along the Odisha coast (Government of Odisha, n.d). The rich species diversity is mainly attributed to the estuarine environment created by the fresh water inflow from river Mahanadi, Brahmani and Baitarani, and the high tides from the Bay of Bengal.

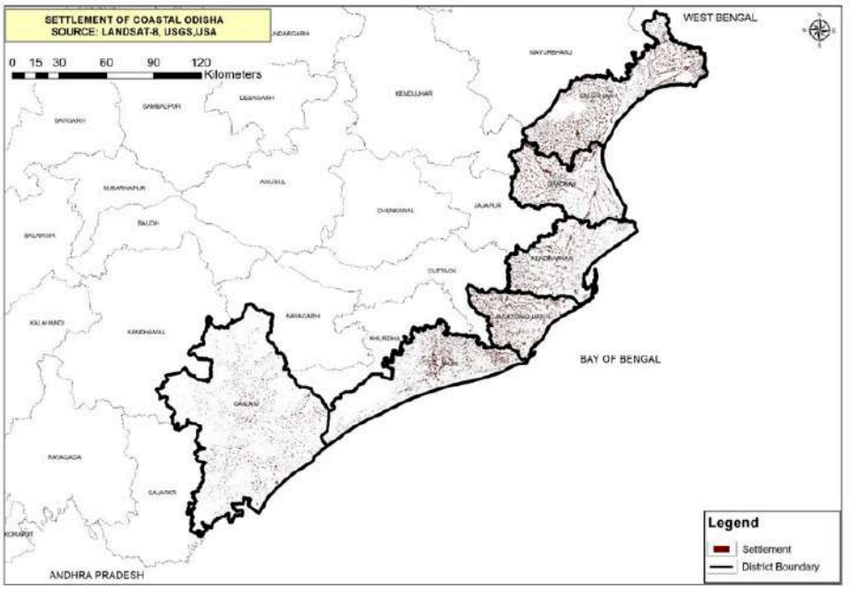


Fig. 1.8: Distribution of Settlements in Coastal Odisha.

It has been reported that three species have become extinct, one endangered, four vulnerable, and three threatened along the Odisha coast.

D) Population and Settlements: All six coastal districts are densely populated. Nearly one-third of the total population of the state lives in these coastal districts. Major cities & important towns namely Puri, Gopalpur, Paradeep and Dhamra of the state are located along the coast. Bhubaneswar, Cuttack, Khurdha and Berhampur are within 60 kilometres of the coast (Figs. 1.8 & 1.9).

E) Administrative Setup: It consists of six districts namely Baleshwar, Bhadrak, Kendrapada, Jagatsinghpur, Puri and Ganjam. These six districts consist of 61 Community Development (CD) Blocks. Out of 61 CD Blocks, 22 CD Blocks are located along the coast (Fig. 1.10).

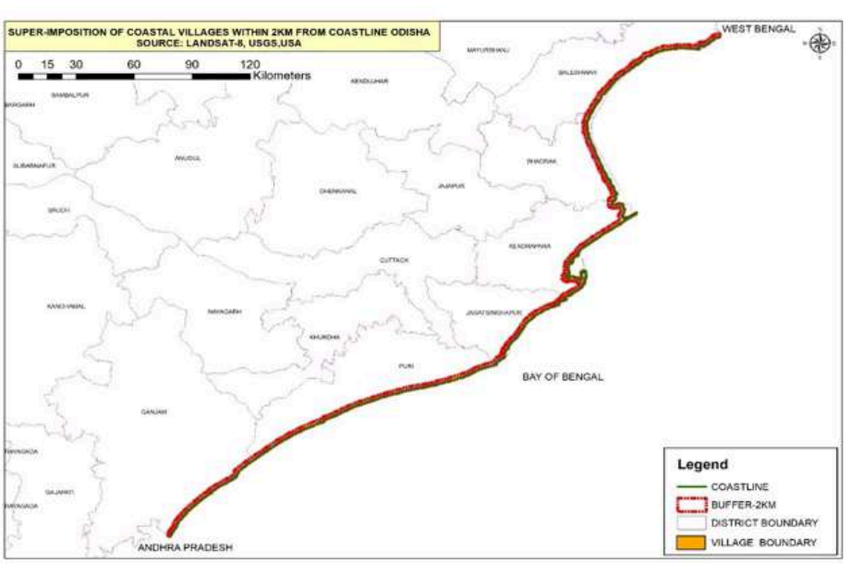


Fig. 1.9: Coastal Villages within 2 km from Coastline.

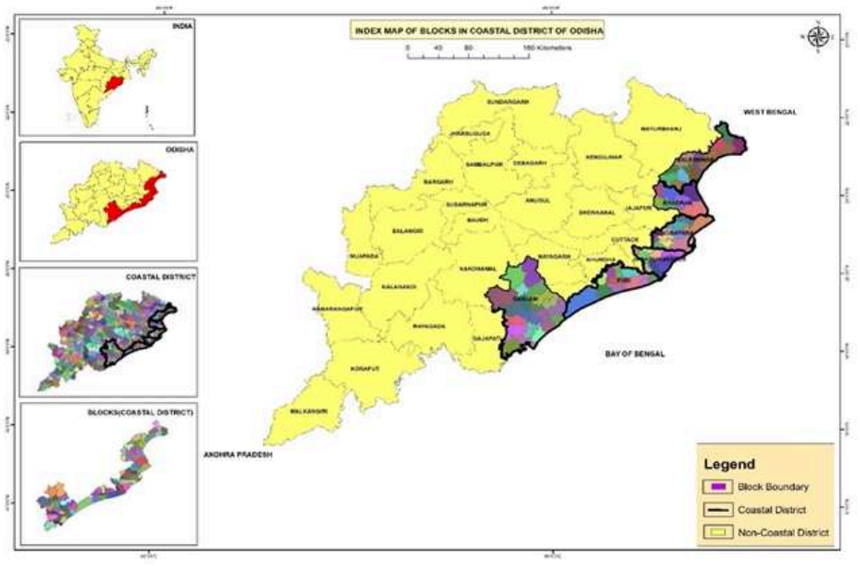


Fig. 1.10: Location of the Study Area.

Objectives

The major objective of the case study was to assess the levels of socio-ecological vulnerability to cyclone disaster at the micro-level i.e., Community Development Blocks and identify the factors that needs to be strengthened at the community and household levels to enhance socio-ecological resilience to cyclone vulnerability through a collaborative effort of scientists, policy-makers and relevant stakeholders.

The specific objectives are as follows:

- To analyse the trend, pattern and seasonality of cyclones in Coastal Odisha;
- To construct a micro-level cyclone disaster vulnerability index taking Community Development Blocks as a unit area of analysis;
- To identify the factors that need to be strengthened for enhancing socio-ecological resilience to cyclone vulnerability both at household and community levels in coastal Odisha.

Data Sources and Tools for Data Collection

Data sources and tools for data collection are the most essential parts of the research. Generally, data sources illuminate various thoughts for researchers to find out the literature and solutions to issues. The collection of data is also significant in research to assess and validate earlier research and connect it with present issues. The data sources and tools for data collection have been described in the following sub-headings:

Data Sources

The present study used both secondary and primary data for analysis. The secondary data have been used for analysing trends and patterns of cyclones and for assessment of the district and the block-level cyclone disaster vulnerabilities. The primary data has been used for the assessment of household-level resilience to cyclone vulnerability,

and analysing the resilience strategies as well as barriers being perceived by households in implementing the resilience strategies.

A) Secondary Data Sources: The secondary data relating to all four socio-ecological parameters namely bio-physical, socio-economic, built-environment and institutional parameters have been collected mainly from government publications. The demographic parameters have been collected from the District Census Handbook (DCH), the District Disaster Management Plan, 2019 and the District Statistical Handbooks, 2018 of all six coastal districts. The details about the specific secondary data sources are provided in the chapters specifically Chapter 2 and Chapter 3.

B) Primary data sources: The primary data at the household level has been collected by using a structured questionnaire between the months of October 2021 to January 2022. In the month of October 2021, a reconnaissance survey was carried out to understand the complexity of the processes that lead to cyclone disaster vulnerability at the local level. Based on the field experience, a draft questionnaire was developed. The draft questionnaire has been tested in the month of November 2021. Based on feedback received during questionnaire testing, the same has been modified and finalized for data collection. The field study was conducted in 12 villages spread across 6 coastal blocks in six districts of Coastal Odisha.

The responses through questionnaires were mainly collected from the household heads and in case he/she was not available, the next oldest household member was preferred for the responses. The minimum age of 35 years was considered for obtaining responses. The rationale behind the minimum age of 35 was that the individual would be in a position to explain the disaster history of the last twenty years.

Tools for Data Collection

A structured questionnaire was used to collect the primary household data. The questionnaire was mainly divided into four sections. In the first section, questions were related to the socio-economic profile of the respondent, whereas in the second section, questions were related to various resilience strategies adopted by the household at all three phases namely before, during and after the cyclone. In the third section, the respondents were asked about assets possessed by the households under five livelihood capitals namely natural, physical, social, financial and human whereas in the fourth section questions relating to the barriers that households perceived for implementing effective resilience strategies. In the last section, respondents' opinions related to various dimensions of resilience capacities were collected by using the Five Point Rating Scale. Several interviews were carried out in the study villages where the sarpanch and other key persons were interviewed.

Besides, the interview was also conducted at the agriculture extension department, animal husbandry department, veterinary doctors and the nodal officer of district disaster management. The above-mentioned data were complimented and supplemented by the geo-spatial data, particularly bio-physical and built-environment parameters.

Methodology

Quantitative and qualitative methods were applied during the field investigation, data collection and analysis. For decades, quantitative and qualitative purists have formed distinct schools of thought. While drawing on strengths and minimizing the weaknesses of both, a new 'mixed method' approach (Creswell and Garrett, 2008, Johnson and Onwuegbuzie 2004) evolved. Quantitative purists powerfully uphold that enquiry in the social discipline should be objective, emotionally detached, and uninvolved with the objects of study in much the same way that physical scientists treat physical phenomena. Conversely, qualitative purists assert that multiple-constructed realities abound, and time-and-context-free generalization of the realities is neither desirable nor achievable. Qualitative research is more concerned with the what, how, why, where and when of the things under query with a 'reflexiveinquiry', while the quantitative approach tends to be confined to the amount or number of things being investigated. The use of scheduled and semi-structured household interviews conducted in this study for the collection of data from large and varied groups of households.

Methods for Assessing Resilience to Cyclone Vulnerability

This study was focused on collecting the primary data from the selected villages along with the secondary data by studying the district reports. To make the outcomes useful, this study combined both qualitative and quantitative approaches to field investigations. Though quantitative data were collected through a household schedule survey, focus was also made on the qualitative data to understand the livelihood strategies for building socio-ecological resilience. The secondary data used in this study were gathered from government records and documents like the District Statistical Handbook (DSH, 2011-12), the District Human Development, Reports, 2011, the Govt. of Odisha and the Census of India, 2011). The vulnerability index was constructed by selecting twenty-one indicators.

These indicators were selected by reviewing various research studies conducted in the areas of hydro-meteorological vulnerabilities in the coastal areas (Bahinipati, 2014; Sharma and Patwardhan, 2008) and in-depth discussions with experts working in this area. However, all these studies have taken 'districts' as the unit area of the study. This is perhaps the first study that attempted to analyse the hydro-meteorological vulnerability in the coastal area by taking the Community Development Block as a unit area of analysis.

A) Assessment of vulnerability using equal weight method: The data collected both from secondary and primary sources were in different units and scales. The data has been standardized to make it unit-free through the process of normalisation. The Human Development Index (HDI) methods have been used for the normalisation.

B) Normalization of secondary data: The normalization method used in this analysis based upon secondary data has been adopted from UNDP's method for calculating the Human Development Index (HDI) (UNDP-HDR, 2007). The normalisation leads the indicator value to lie between '0' and '1'. The formula used for normalisation depends upon the relationships of the indicator with vulnerabilities. The details of the normalization method are explained in Chapter 3.

Normalization of data: Indicators may have different units and scales. Some of them may be incommensurate with the rest of the indicators. Normalisation before analysis is essential to bring them to a comparable range (Vincent, 2004). There were different methods available for normalisation which included ranking the indicator across the country, standardization, rescaling, distance to reference country, and categorical scale indicators above and below the mean. The process of normalisation through the standardization (Z-score) method has been done by using the following formula

Normalized value= (observed value – mean)/standard deviation

A detailed explanation of the method for normalization is mentioned in Chapter 3.

Test for Significance

The test of significance used in the analysis includes an independent sampled t-test and ANOVA. These techniques were used to test the proposed hypothesis.

A) Independent samples t-test: This test is a parametric test used to determine the existence of statistically significant differences between the mean of two independent groups. The test assumes that the data is normally distributed. The data was divided in two equal portions respectively for determining the difference in the mean between the two parts. The null hypothesis (Ho) states that the mean of the two-data group is equal, whereas the alternate hypothesis can be that either the means are not equal, or one portion may have a higher mean than the other.

B) ANOVA: The analysis of variance is a powerful technique for determining the difference in mean between three or more independent populations. There are two types of ANOVA which include one-way and two-way. In the present analysis, one-way ANOVA where there is one independent variable has been used for determining the statistically significant differences in the mean value of vulnerability, adaptations and barrier indices scores.

Qualitative Methods

To supplement and complement the quantitative analysis has been carried out using the following methods:

A) Observations: The method of observation provides a direct way to study various aspects related to human behaviour and provides an opportunity for recording real life situations. The observation technique is of two types that are participant and non-participant observations and in this present study both types were used.

B) Focus group discussion: As defined by Cameron, the FGDs involve discussion within a small group of community on the issues or problems of the research (Cameron 2005). As mentioned earlier, a qualitative approach was the focus of the study, and a bottom-up participatory strategy was followed throughout the fieldwork. The focus group interview was initially held in 6 villages of Coastal Odisha with selected groups comprising ten to fifteen people, using a semi-structured question guide and a checklist. In each hotspot village, separate Focus Group Discussions were done with men and women. They were asked some basic questions on livelihood options, socioeconomic scenarios, cyclone hazards, and adaptations of the villagers and the future adaptation needs. As the facilitator of the session, the Principal Investigator took notes of the detailed discussion with the participants in the Focus Group Discussions. The participants consisted of men and women of varying age and wealth class; from 45 years and above and from extremely poor to the richest, with different occupations. Any disagreements among the participants that came up were also properly noted down. The facilitator, rather than asking direct questions, tried to present a clear sequence of issues and their logical explanations, in a natural village setting, in the context of local livelihood option available. The data obtained were analyzed by the participants of the Focus Group Discussions to reconfirm and at times they were crosschecked with other villagers who were not in the Focus Group Discussions.

C) Interview: A semi-structured interview sch edule was used to interview respondents from the stakeholders in the twelve selected villages of six sampled blocks of Coastal Odisha. This was used as a complimentary and supplementary to the questionnaire to gain in-depth information about his/her family members, income sources, assets, the impact of hazards, adaptation techniques, the costs involved, future plans and the role of local/ government institutions in assisting the village community. It is an informal conversation through which the Principal Investigator tried to elicit information like the perception towards climatic events, scarcity of water, health issues, cattle menace livelihood diversification and other adaptation strategies as well as barriers in an unstructured format from the households and other community members.

Sampling

Sampling is one of the most important part of research. Areas along the 480 kilometers coastline of Odisha is the universe for the study. Multi-stage sampling was used in this study. Landfall sites of major cyclones that occurred during the last thirty years were selected as samples. A list of very highly vulnerable villages was prepared in consultation with functionaries of district administration, officials of state disaster management authority and various reports generated after each major cyclone. Two villages from each district were selected randomly out of all the listed vulnerable villages. Altogether 12 villages were selected for the study. In each village, stratified random sampling was used to give an adequate representation of socio-economic strata within the village. Economic strata were divided into two categories namely household Below Poverty Line and household Above Poverty Line. In the social category, caste composition was given representation by selecting households of general Castes, Other Backward Castes and Scheduled Castes. A total of 206 households were selected from the above-mentioned twelve villages of the six coastal districts. The details of the sampling have been discussed in Chapter 4.

CYCLONESCAPE OF COASTAL ODISHA – AN OVERVIEW

Introduction

Analysis of disaster and its impact on people and places of a particular geographical region needs a detailed understanding of various associated dimensions that either aggravate or reduce the impacts of natural hazards. Therefore, there is a need for a detailed analysis of the geographical locations of the area, its ecosystem, history of hazards and people's response to hazards. The concept of hazard has been gradually developed through an interdisciplinary approach. Several theories have been developed to understand the hazards and disasters from different perspectives. Behavioural models of hazards were based on the human adjustments to the environment (Handmer, 2004; Smith; 1992, Ericksen, 1986, Burton et al., 1978). Vulnerability theories (Wisner et al., 2003, Bohle, 2001) focused on weaknesses in the human systems. The other notable perspectives are sustainability assessment (Turner et al., 2003); resilience (Paton, 2006), ecosystem (Mileti, 1999) and place vulnerability (Cutter et al., 2000).

An unidirectional view of hazards and disasters constrained geographies to see how the environment would respond to the changes incurred through human activities (Khan, 2010). Studies of hazards and disasters predominantly focused on a single hazard assessment for an area, and this marked a gap in the literature - dealing with multiple hazards and associated issues (Khan, 2010). Thus this chapter studies the concept of 'hazardscape' and provides an opportunity to analyse multiple hazards and their impact on particular landscapes and its ecology in an integrated manner.

This chapter attempts to analyse resilience to cyclone vulnerability in Coastal Odisha and their impact on the fragile ecosystems consisting of environmental processes, physical susceptibility of places and people's vulnerability. This chapter is broadly divided into three sections. Section 2.2, provides a brief discussion about the concept of hazardscape. Section 2.3, presents a brief description of the elements and characteristics of hazardscape. In section 2.4, the hazardscape of Coastal Odisha is presented by using the concept, elements and characteristics of hazardscape.

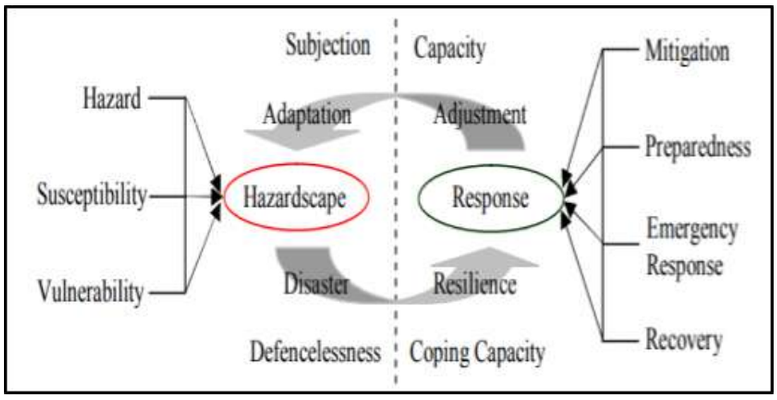


Fig. 2.1: Relationship between Hazardscape and Response (Adapted from Khan 2012:5).

Concept of Hazardscape

The term 'hazardscape' was first defined by Corson in the year 1999 in his paper entitled 'Hazardscapes in Reunified Germany' (Corson, 1999). This paper was predominantly focused on technological hazards. In this paper, Corson defined hazardscape as ***"the spatial distribution and attributes of human engineered facilities.....that contain or emit substances harmful to humans and environment"*** (Corson, 1999:57). Several researchers have made an attempt to develop similar kinds of concepts. Cutter et al. (2000) used the word 'hazardscape' interchangeably with 'riskscape'. However, they did not define the term.

Gray (2021) used the word hazardscape to describe the collective areas of risks associated with hazards. Mustafa (2005) described hazardscape as an integrative concept, and defined it as "both an analytical way of seeing that asserts power, and as a social-environmental space where the gaze of power is contested and struggled against to produce a lived reality of a hazardous place" (Mustafa, 2005: 569-570). The definition of hazard as "an agent (event, process or situation), which can cause damage to life and property" (Glade et al., 2005:782), implies that "hazards exist not only because of unstable characteristics of environmental processes (when it says agent or process), but are also due to the physical susceptibility of the place (i.e., situation, which implies place characteristics) and human vulnerability (relating to damage to life and property)" (Khan and Crozier, 2009:2).

Hazards, physical susceptibility and vulnerability change through time to give a dynamic character to hazardscapes. An hazardscape is defined here as "a dynamic scape which reflects the physical susceptibility of a place and vulnerability of human life and assets to various hazards in a given human ecological system" (Khan, 2010:363).

There is also a need for a holistic approach to explain various aspects of hazards, risks and disasters at a place. Khan (2012) attempted a schematic presentation to bring together different concepts and phenomena relating to hazards and responses and assess them with each other (refer Fig. 2.1).

Hazardscape: Elements and Characteristics

To understand the hazardscape of a particular place, there is a need for a critical analysis of six aspects of ecosystems. These aspects are space, processes, connectivity, change, uncertainty and scale (Wessel, 2006; Khan, 2012). In simple terms, hazardscapes can be expressed as "the relationship between humans and environment in an ecosystem where it operates and changes through time" (Khan, 2012:4). Therefore, a hazardscape consists of three essential elements namely process, place and people. The characteristics of these three elements give shape to its resultant characteristics i.e., hazards, physical susceptibility and human vulnerability. The Venn diagram below explains the inter-relationship among the above-mentioned six concepts (See Fig. 2.2).

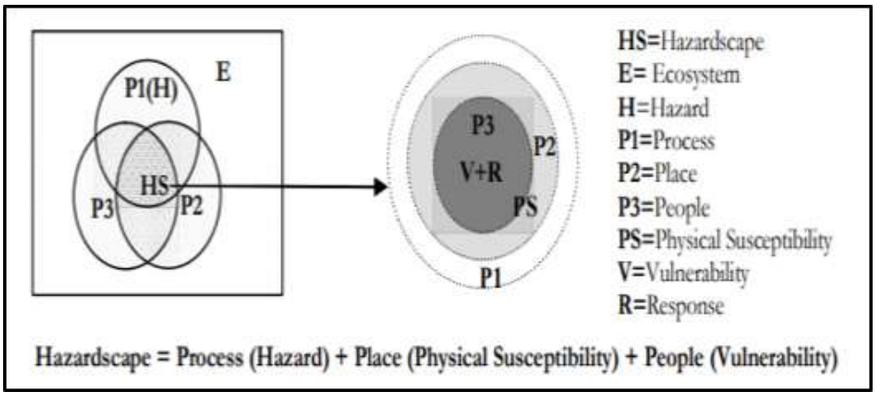


Fig. 2.2: A Venn diagram of Hazardscape, (Adapted from Khan 2012:3).

Hazardscape: Elements and Characteristics

Ecosystem is one of the fundamental concepts in ecology. However, human ecologists used it in a different Sense. Tansley who used this term for the first time in 1935 defined ecosystem as 'not only the organism complex, but also the whole complex of physical factors forming what we said the environment of the biome-the habitat factors in widest sense' (Tansley, 1935: 299). Further, Catton explains a system without 'environment or eco', which is simply a population system. This conception was shared by many sociologists of that time, but it disqualified many ecological principles, that applied to other living beings in their ecosystems (Catton, 1994: 78). Hawley wrote a detailed theoretical essay on human ecology, defining ecosystems as an 'arrangement of mutual dependence in a population by which the whole operates as a unit and maintains a viable environmental relationship' (Hawley, 1986: 26).

A hazardscape therefore, reflects most of the processes and associated changes operating in an ecosystem, which shape its various characteristics. As most of the processes are inter-connected and influenced by each other, change in one process gets easily transferred to others and contributes to uncertainty in the process behaviour. Due to the connectivity of various processes and the nested characters of ecosystems, changes at the lower levels in nature that are large scale are brought by the small-scale processes operating at a higher order. This explains the occurrence of hazards at a local level, induced by the changes in global processes such as climate change or economic recession (Khan, 2012).

Hazards as Environmental Processes

The explanation of hazards has developed gradually from a concept of 'acts of God' to an attribution as 'environmental hazards', which exist at the interface of natural events and human use systems (Smith, 1992:10). Burton, et al., (1978) called them negative resources, produced during the human-nature interaction.

However as discussed earlier, the depiction of humans and the environment as two different systems does not explain all hazards, especially those where such interactions are not visible in the same place (Khan, 2012). Therefore, they need to be defined in the context of ecosystems and the definition of hazards as 'extreme fluctuations or deviations in environmental processes (Smith, 1992: 10), which could be dangerous to the community' is more relevant. "Hazards can occur through change in both biophysical and human environmental processes. However, biophysical hazards prove to be more dangerous than those derived from human change. As a community often lacks control measures for extreme fluctuations in biophysical processes, which are often sudden and drastic in nature" (Khan, 2012:48). Since each hazard varies in its frequency, duration, areal extent, speed of onset, spatial dispersion and temporal spacing (Burton, 1993:34), it poses a differential threat over diverse space and different communities.

Physical Susceptibility of Place

The place is constructed by the interplay of location, locale and sense of place (Agnew, 1987). In describing the characteristics of hazardscapes, the place is one of the important elements of the ecosystem that represents the ecological relationship of the community with its environment. Each place holds individuality with its specific location and physical characteristics such as geology, landforms, climate etc.

These characteristics could play a key role in turning an environmental process into a hazard by governing the process behaviours. Hewitt termed the physical susceptibility of a place as the "intervening conditions of disaster, which intervene between hazard and vulnerable structures" (Hewitt, 1997: 28). Cutter, Boruff and Shirley, put these under the category of biophysical vulnerability (Cutter et al., 2003: 243). However, tagging vulnerability to susceptibility is inaccurate in the sense that even though biophysical characteristics govern the behaviour of various environmental processes of a place, variation in the degree of damage is a function of human vulnerability (Khan, 2012).

The physical characteristics contributing to the susceptibility of a place to hazards can be classified into three categories i.e., locational, intrinsic and modified. "The location (absolute or relative) of a place amid various environmental processes often plays an overriding influence on hazard occurrence. The intrinsic characteristics of a place including physiography, geology, hydrology, drainage or vegetation are mainly shaped by the biophysical processes" (Khan, 2012). All three characteristics in combination result in varying susceptibilities to different hazards and produce diversity in a hazardscape.

People's Vulnerability

People are the third most essential element of the ecosystem, and hazardscapes exist because of their vulnerabilities to hazards. Vulnerability can be defined as the inability of the community to resist damage to life and assets in a situation of hazard occurrence (Khan, 2012). The notion of vulnerability has expanded from unidirectional concepts of internal risk factors to multidimensional vulnerability encompassing physical, social, economic, environmental and institutional features (Birkmann, 2006:17). The various aspects of vulnerability can be broadly classified into three categories of exposure, fragility or lack of resistance, and lack of resilience or coping capacity (IDEA, 2005:105; Cordana, 2006:195; Birkmann, 2006a). Exposure represents the susceptibility of the population to damage by hazards, while fragility refers to weakness in the face of initial hazard impacts. Lack of coping capacity or resilience, on the other hand, defines the inability of the community to regain its original state after disasters (Paton, 2006:7).

The various aspects of vulnerabilities are not only contributed by the population characteristics but also by the environmental conditions governed by biophysical and ecumenical processes (Khan, 2012). Biophysical processes shape the basic socio-cultural norms related to livelihoods, food and other habits, whereas the ecumenical processes define the systems of production, and development along with other vulnerability factors such as entitlement, empowerment or political economy (Semple, 1911; Bohle, 2001; Wilhite, 1998 as cited in Birkmann, 2006: 120). However, vulnerability is not all about the intrinsic characteristics of a population under normal environmental conditions, but how these intrinsic characteristics would behave during an unanticipated change in environment (Patt, et al., 2009:4-5).

People's Response

People are one of the major factors to bring any change in an ecosystem, and thereby they modify hazardscape. It is important to study hazardscape with reference to response, as it is this relationship, which determines the intensity of hazardscape and disaster outcomes. The response of people is a two-way relationship with hazardscapes. It not only modifies hazardscape, but is shaped and influenced by the nature and characteristics of hazardscape (refer fig 2.3). Response is a broad term, which applies to all sorts of actions namely adaptation or adjustments that are taken by people, communities or institutions in an ecosystem in respect of natural hazards. These are classified into four broad categories: mitigation, preparedness, emergency response and recovery.

Mitigation includes all the efforts and actions from the community to reduce or prevent the hazard occurrence. It is generally a long-term process that is carried out both during disaster as in pre-disaster and post-disaster situations.

Preparedness refers to all those efforts by a community to cope with a hazard that may occur in future. It includes emergency response planning, warning systems and arrangements of emergency materials to cope with a hazard.

Emergency response is the third category of overall response and refers to the immediate and short-term actions, practised just after the realisation of hazards like search and rescue and provision of food shelter and clothing.

Recovery involves long term reconstruction in the community after any damaging event.

The nature and characteristics of these responses are often governed by the hazardscape characteristics both individual (i.e., hazards, physical susceptibility and human vulnerability) and combination of three characteristics (Khan, 2012). However, certain other responses such as doing nothing, accepting loss or denial of hazards contribute to social vulnerability leading to tipping points in humanitarian crises. Despite adjustments and adaptations made for perceived hazards in the hazardscape, the hazard remains and at high magnitude may turn into a disaster (Khan, 2012). The possibilities of post-mitigation damages are embodied in the concept of residual risk. The assessment of hazardscape and response of the community to each other defines the overall characteristics of hazardscape and highlights the awareness, perception, past experience, response culture and trust in various response measures and agencies.

This helps to identify the areas and causes of weakness and shortcomings that contribute to social vulnerability and builds tipping points for crises (Khan, 2012).

Cyclonescape of Coastal Odisha

This section attempts to analyse the cyclonescapes of Coastal Odisha. As discussed in the previous sections, hazardscape is the total outcome of the three elements i.e., hazards as environmental processes, physical susceptibility of place and people's vulnerability within an ecosystem (Khan, and Crozier, 2009). In the last three decades, it was observed that this area has been frequently devastated by cyclone disasters. This section provides a detailed discussion of the ecosystems, hazard processes, places and people of Coastal Odisha to get a holistic view of the cyclonescape of the study area.

Floods, cyclones and droughts have made Odisha the disaster capital of India (Fig. 2.3). If we analyse 100 years of the twentieth century (1901-2000), the state has been disaster-affected for 90 years; floods have occurred for 49 years, droughts for 30 and cyclones have hit the state for 11 years. Since 1965, calamities have not only become more frequent but have struck areas that never had a vulnerability record (DTE, 2001). Similarly, if we analyse the first twenty years of the twenty-first century (2001-2021), Odisha experienced eight cyclones. Out of these eight cyclones, six were very severe and made landfall in Odisha in the last ten years i.e., between 2011-2021.

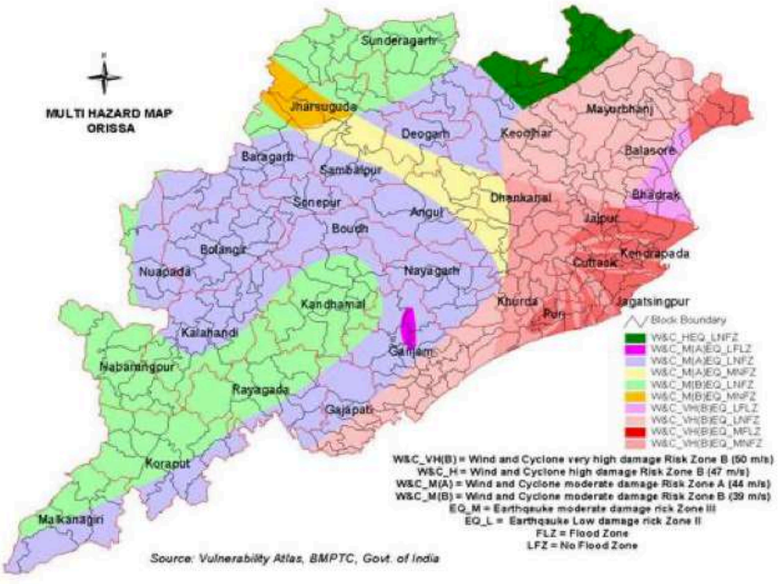


Fig. 2.3: Odisha: Multi Hazard Zones.

Cyclones: The entire east coast of Odisha along the Bay of Bengal is vulnerable to cyclone-related hazards of varying frequencies and intensities. On average, about five to six tropical cyclones form in the Bay of Bengal every year, of which two to three may be severe. Cyclones are most deadly when crossing the coastal areas. This was mainly because of the serious storm surge problem in this area. The impact of these cyclones is confined to the coastal districts, the maximum destruction being within 100 km from the centre of the cyclones and on either side of the storm track (see Fig. 2.4). The worst devastation takes place when and where the peak surge occurs at the time of the high tide. In the last 100 years, 13 cyclones with rising frequency have hit the east coast. The Odisha super cyclone in October 1999 left the state virtually paralyzed with communication and infrastructure wrecked. The cyclone severely affected around 13 million people in 12 districts, and sea waves reaching 7 meters rushed 15 km inland.

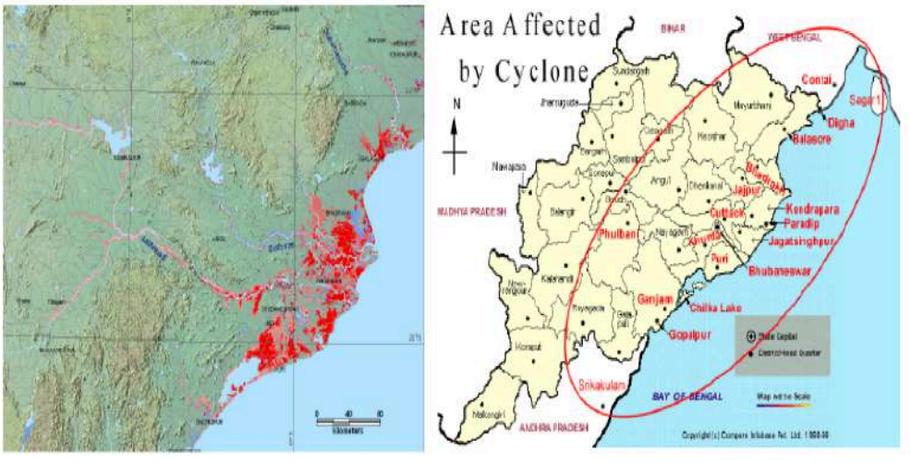


Fig. 2.4: Odisha: Areas affected by Cyclone.

Trends and Patterns of Cyclone in Coastal Odisha: A total of 1301 tropical cyclonic storms were generated over Bay of Bengal during the past 121 years (1891-2011). Among those 33% (389) had their landfall on Odisha coast. Out of these tropical cyclonic storms, 73% were tropical depression, 20% were cyclonic storms and 7% were severe cyclonic storms. While the east coast of India is one of the most cyclone-prone areas in the world, Odisha is twice as vulnerable as compared to the other eastern States. During the last decade, Odisha faced disasters like cyclones, floods, or droughts every year. From 1891 to 2018, the number of Cyclones, Severe Cyclones and Super Cyclones that crossed the Odisha coast was 98, which is the highest in all the east coast States of India. The latest report of the State Government on 'Vulnerability to Cyclone' reveals that while Odisha has only 17 per cent of the Indian east coast, it has been affected by nearly 35 per cent of all cyclones and severe cyclones that have crossed the east coast of India. Cyclonic storms that hit the east coast and associated storm surges that often inundate large tracts of Odisha cause large-scale damages to life and properties. As per the report, while Odisha faced 98 cyclones, West Bengal faced 69 and Andhra Pradesh 79.

While Odisha had the first impact of a Super Cyclone way back on October 7-12, 1737, another Super Cyclone crossed the State's coast at False Point on September 22, 1885, and took a toll of 5,000 lives. The State faced its first Very Severe Cyclone on October 31, 1831, which crossed the coast near Balasore and the loss of life was a whopping 50,000 (The Pioneer, 2019). Post-independence, the state was hit by two very severe cyclones in the year 1967 in the month of October. The first Very Severe Cyclone crossed the Odisha coast between Puri and Paradeep on October 8-11, 1967. Just after fifteen days, another Very Severe Cyclone crossed the coast near Paradeep on October 26-30, 1967 and the loss of life was 10,000. Odisha faced another devastating Super Cyclone on October 29-31, 1999 which crossed near Paradeep on October 29, killing over 10,000 people. On October 12-14, 2013, Very Severe Cyclone Phailin crossed the Odisha coast near Gopalpur. On October 12-14, 2014, Very Severe Cyclone Hudhud crossed Andhra Pradesh at Visakhapatnam and impacted south Odisha. Titli, another Very Severe Cyclone crossed near Palasa in Andhra Pradesh on October 11, had serious impacts on Ganjam, Gajapati, Rayagada and Kandhamal districts.

Spatial analysis of cyclones are much needed to save the lives and livelihoods of residing people. The number of cyclonic events occurred from 1891-2018 is 98 which was more devastating for people (Table 2.1).

Table 2.1: Spatial Analysis of Major Cyclone in Odisha 1891-2018

Sr. No.	District	No. of Cyclone
1	Balasore	32
2	Cuttack	32
3	Puri	19
4	Ganjam	15
5	Odisha	98

(Source: National Cyclone Risk Mitigation Project https://ncrmp.gov.in/cyclones-their-impact-in-india/)

As per the Wind and Cyclone Hard Zones Map of Odisha, out of the State's 30 districts, 14 are categorised as 'High Damage Risk Zones', either fully or partially.Table 2.2 explains the intensity of cyclones along with their names and their associated year since 1970.

Table 2.2: Occurrences of Major Cyclones in Odisha since 1970

Year	Intensity of Cyclones
1967	Cyclone
1968	Cyclone
1971	Very Severe Cyclone
1982	Cyclone
1986	Cyclone
1987	Cyclone
1999	Super Cyclone
2005	Cyclone
2006	Cyclone
2013	Very Severe Cyclone (Phailin)
2014	Very Severe Cyclone (Hudhud)
2018	Very Severe Severe Cyclone (Titli)
2019	Very Severe Cyclone (Fani)
2020	Very Severe Cyclone (Amphan)
2021	Very Severe Cyclone (Yaas)

A) Coastal Ecosystem: It contains one of the largest areas of mangrove forests, with high levels of floral and faunal diversity (The World Bank, 2014). Mangroves are a transition from the marine to freshwater and terrestrial systems and provide critical habitat for numerous species of small fish, crabs, shrimps etc. in this region. During cyclones, these mangrove protects from land and soil erosion. At the time of high tide, major parts of the area get inundated and receive the major inputs from estuarine water and soil deposition of sediments. During low tide, the receding water takes away a huge amount of mangrove litter contributing to the adjoining aquatic subsystem (Chakraborty, 2011). The deposit feeders (viz. crabs, molluscs, nematodes etc.) through their feeding activities turn over the surface sediment layer, thereby exposing new litter surfaces to microbial actions. The three main decomposition processes as outlined by Heal and French (1974) are the release of carbon in gaseous form by microflora and fauna (respiration), leaching out of soluble materials and corrosion (physical breakdown) by fauna and physical factors. Converting and transporting nutrients and energy while responding to diurnal tidal and seasonal periodicities (Odum, and Barrett,1971).

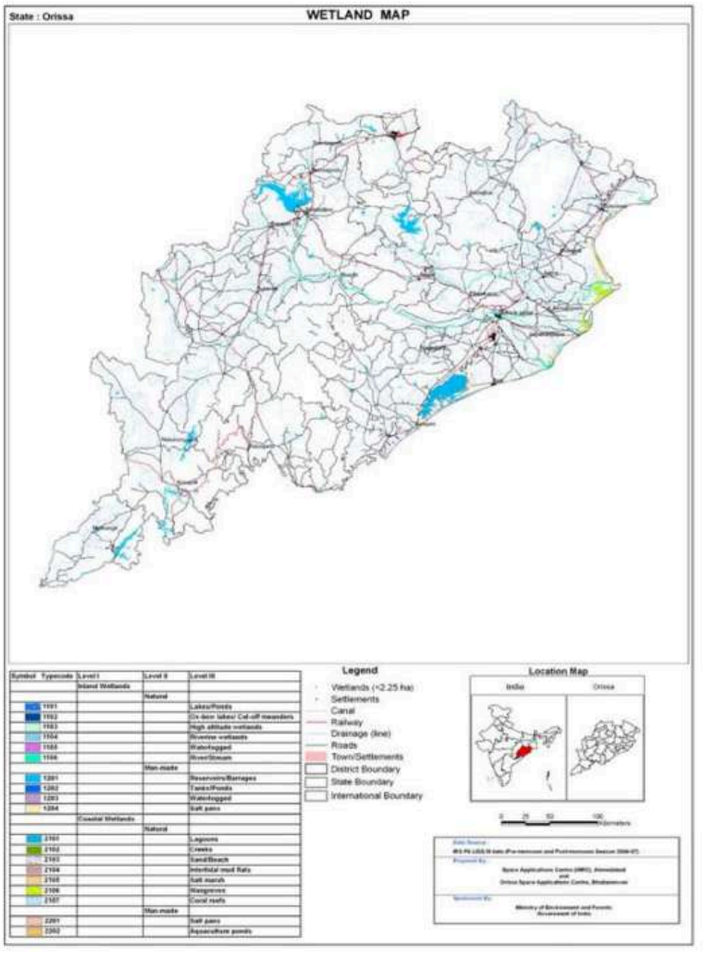


Fig. 2.5: Major Wetlands of Odisha.

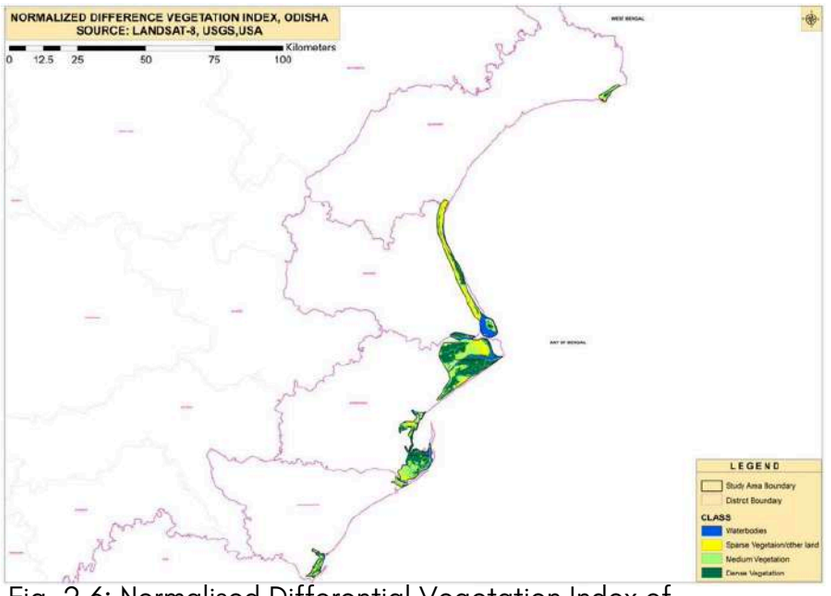


Fig. 2.6: Normalised Differential Vegetation Index of Coastal Odisha.

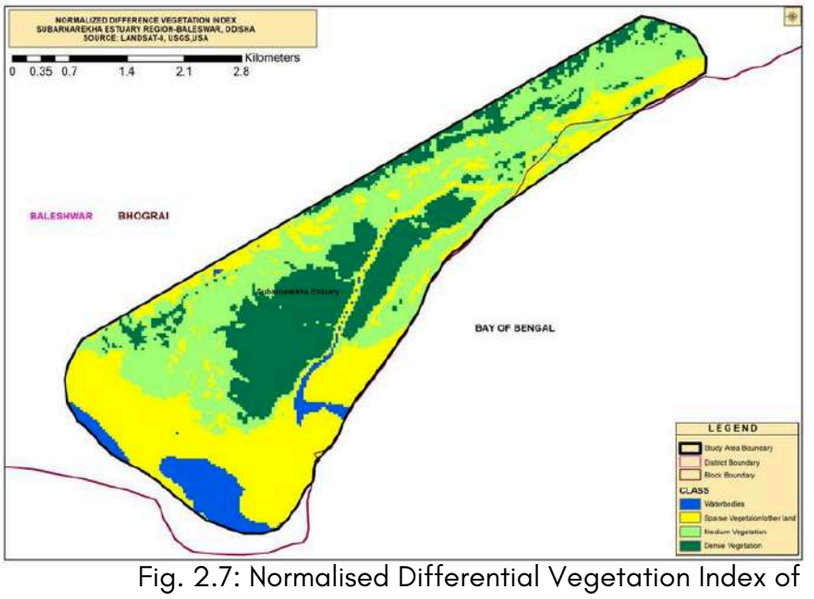


Fig. 2.7: Normalised Differential Vegetation Index of Subarnarekha Estuary Region.

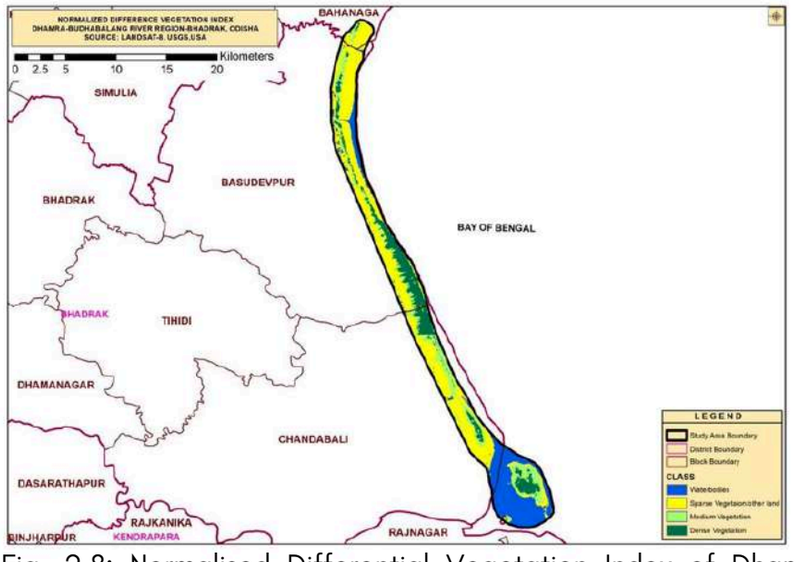


Fig. 2.8: Normalised Differential Vegetation Index of Dhamra-Budhabalanga Region.

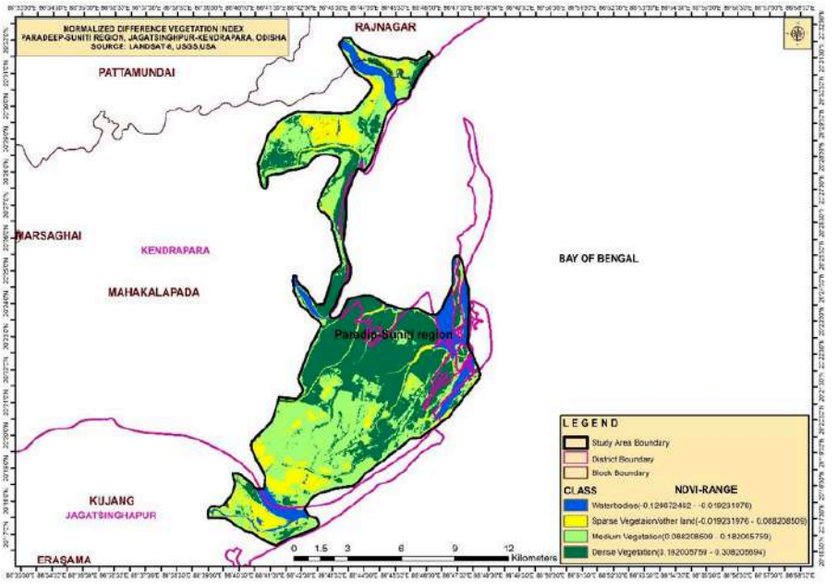


Fig. 2.9: Normalised Differential Vegetation Index of Paradeep-Suniti Region.

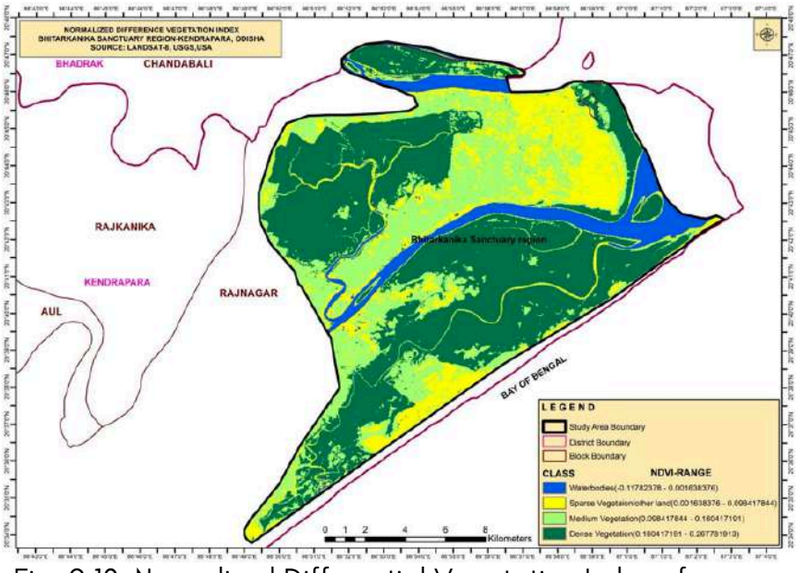


Fig. 2.10: Normalised Differential Vegetation Index of Bhitarkanika Sanctuary Region.

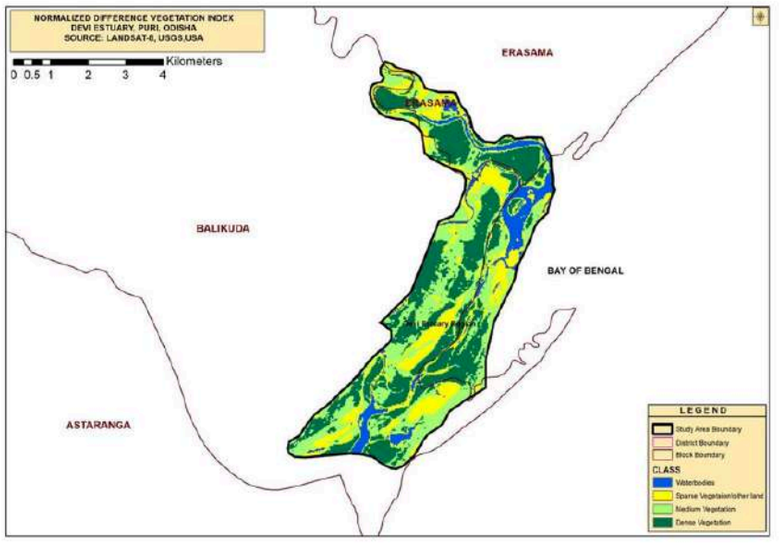


Fig. 2.11: Normalised Differential Vegetation Index of Devi Estuary Region.

Land use Land Cover Analysis: LULC analysis revealed that there was no significant change in the land use land cover pattern. There were minor improvements in the forest and mangrove cover. The entire coast was divided into five sections and details about LULC of all five sections are given below:

(i) In the **Subarnarekha** River estuary region, dense and medium mangrove vegetation cover comprised 40.93 % of the total area, whereas Sparse vegetation along with other land was found to be 40.16 %. It shows the sparse vegetation is abundant as a plantation of Mangrove in the estuary.
(ii) In the **Dhamra to Budhabalang** region, dense and medium mangrove vegetation cover was found to be 11.69 % of the total area, while sparse vegetation along with other land comprises 27.16 % which suggests the degradation of dense vegetation (Fig.2.7).
(iii) In the **Bhitarkanika Sanctuary** region, dense and medium mangrove vegetations cover 33.44 % of the total area, whereas sparse vegetation along with other land comprises of20.62 %. It was observed that the mangroves present in the core regions are not disturbed but, a decrease in mangroves was seen in the landward sides.
(iv) In the **Paradeep to Suniti** region, dense and medium mangrove vegetation cover was found to be 52.66 % of the total area, and sparse vegetation along with other land comprises 11.11 % which showed a luxuriant growth of Mangroves particularly in the Jamboo and Suniti region located in the north of Mahanadi river bank.
(v) In the **Devi estuary** region, dense and medium mangrove vegetation covers 59.32 % of the total area, while the Sparse vegetation along with other land comprises 29.45 %. A healthy growth of mangroves is seen in the area.

B) Hazards: From the above discussion, it was observed that the study area is being affected by hazards every year. Therefore, the seasonality of hazards has been discussed below.

I) Seasonality of Hazard: When a very severe cyclonic storm approaches the coast, the enormous storm surge generated by the wind pressure submerges the coastal belt at the time the storm crosses the belt. From the table 2.3, it was observed that most of the cyclones occurred in two distinct seasons namely April to June and October to December. Out of the two seasons, maximum cyclones in Odisha occurred from October to December. Month-wise study reveals that maximum cyclones occurred in the month of October followed by November and May. In the month of April to June, cyclones are more violent affecting humans, crops and animals. (Jana, Mohapatra and Gupta, 2017, OSDMA, 2019).

Table 2.3: Seasonality of Cyclone Hazards and Vulnerability in Coastal Odisha

Type of Hazard	Jan – Mar				April - June				July - Sep				Oct – Dec			
					H	C	A	I					H	C	A	I
Cyclone					Yes	Yes	Yes						Yes	Yes		

Note: H: Human, C: Crop, A: Animals, I: Infrastructure
(Source: Indian Meteorological Department and Odisha State Disaster Management Authority)

II) Risk Assessment of Cyclone: Generally, risk means the possibility of loss and damage. In Coastal Odisha the cyclone risk level is high because of lightweight structures and those built of mud, wood, older buildings with weak walls and structures without proper anchorage to the foundations. That is why the study area would be at great risk. Settlements located in low-lying coastal areas would be more vulnerable to the direct effects of the cyclones such as wind, rain and storm surges. Settlements in adjacent areas would be vulnerable to floods, due to heavy rains. Other elements at risk are roads, infrastructure, telephone, fishing boats and large trees, horticultural plants namely banana, beetle leaves, coconut and areca nut trees etc. Detailed risk assessment has been carried out based on the probability of hazard occurrences in table 2.2. High winds cause major damage to infrastructure and houses, in particular fragile constructions. They are generally followed by heavy rains and floods and in flat coastal areas by storm surges riding on tidal waves and inundating the land over long distances inland. Structures would be damaged or destroyed by the cyclonic wind force. The potential impact on houses, embankments, crops, big trees, life and livelihoods and all the blocks of Coastal Odisha become vulnerable but the twenty-two blocks located along the coast of all the six coastal districts of the study area were highly vulnerable to cyclone disaster because cyclone leads flood which affects crops as well as fish production. Wind speed at the time of cyclone severely affects horticulture like beetle vine, coconut, areca nut and banana plantation to name a few. It also damages the infrastructure. So, the livelihoods of the people of coastal Odisha have been facing difficulties.

III) Threat from cyclone: It was observed that the threats from cyclones have increased and the livelihood of the people has also been affected. Besides, disaster threats, other disturbances were recorded like the rise of water level in the rivers, shifting of depositional bars and shoals, change of river courses, inundation and flooding over the inland tracts, embankment breaches etc. (Paul, 2009, Chakraborty, 2011). Thus, any major cyclonic event shortly may turn out to be a humanitarian crisis involving a huge economic cost. It has been found that the frequency of cyclones and floods has increased in the last three decades as depicted in table 2.3.

To protect Odisha's coast which is vulnerable to tidal surge, the Water Resources (WR) Department has chalked out a plan to construct a 380 km saline embankment at an estimated investment of Rs. 1,944 crores. A Detailed Project Report (DPR) is being prepared under the supervision of the Water Resources Department for the first-phase construction of a 380 km saline embankment.

Table 2.4: Risk Assessment of Cyclone Hazard in Coastal Odisha

Type of Hazard	Time of Occurrence	Potential Impact	Vulnerable areas
Cyclone	April, May, October and November.	Damage of house (Fully/ Partly)	All Blocks of Coastal Districts are vulnerable but the twenty-two coastal blocks are most vulnerable.
		Washing out of embarkation.	
		Damaging electric and tele-communication infrastructure.	
		Damage of Seasonal Crops	
		Uprooting of big trees	
		Impact on livelihood especially climate sensitive livelihoods namely agriculture, horticulture and pisciculture	
		Causes death or injury to human and animal	

(Source: District Disaster Management Plans of all the six Coastal Districts of Odisha)

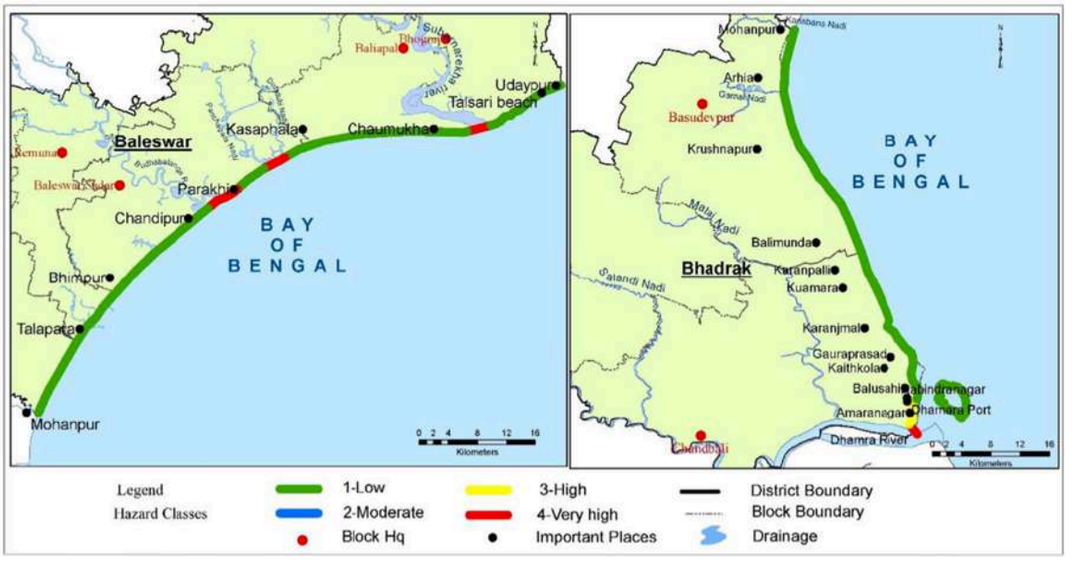


Fig. 2.12: Vulnerability Profile of Erosion along the Coastline of Baleshwar and Bhadrak Districts.
(Source: Panda, Mishra and Chatterjee, 2022)

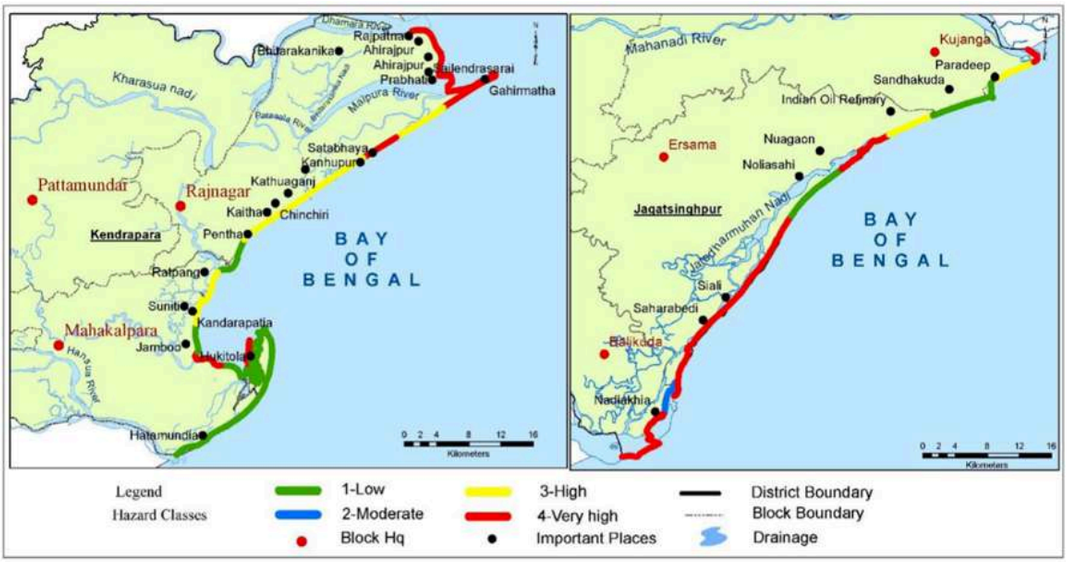


Fig. 2.13: Vulnerability Profile of Erosion along the Coastline of Jagatsinghpur and Kendrapada Districts.
(Source: Panda, Mishra and Chatterjee, 2022)

Table 2.5: District-Level Vulnerability Profile of Erosion along the Coastline of Odisha

Sr. No.	District	Very High	High	Moderate	Low	Total
1	Balasore	12	_	-	76	88
2	Bhadrak	01	04	-	47	52
3	Kendrapada	38	31	-	14	83
4	Jagatsingpur	35	08	04	12	59
5	Puri	05	111	04	17	137
6	Ganjam	14	19	13	15	61
7	Total	105	173	21	181	480

(Source: Panda, Mishra and Chatterjee, 2022)

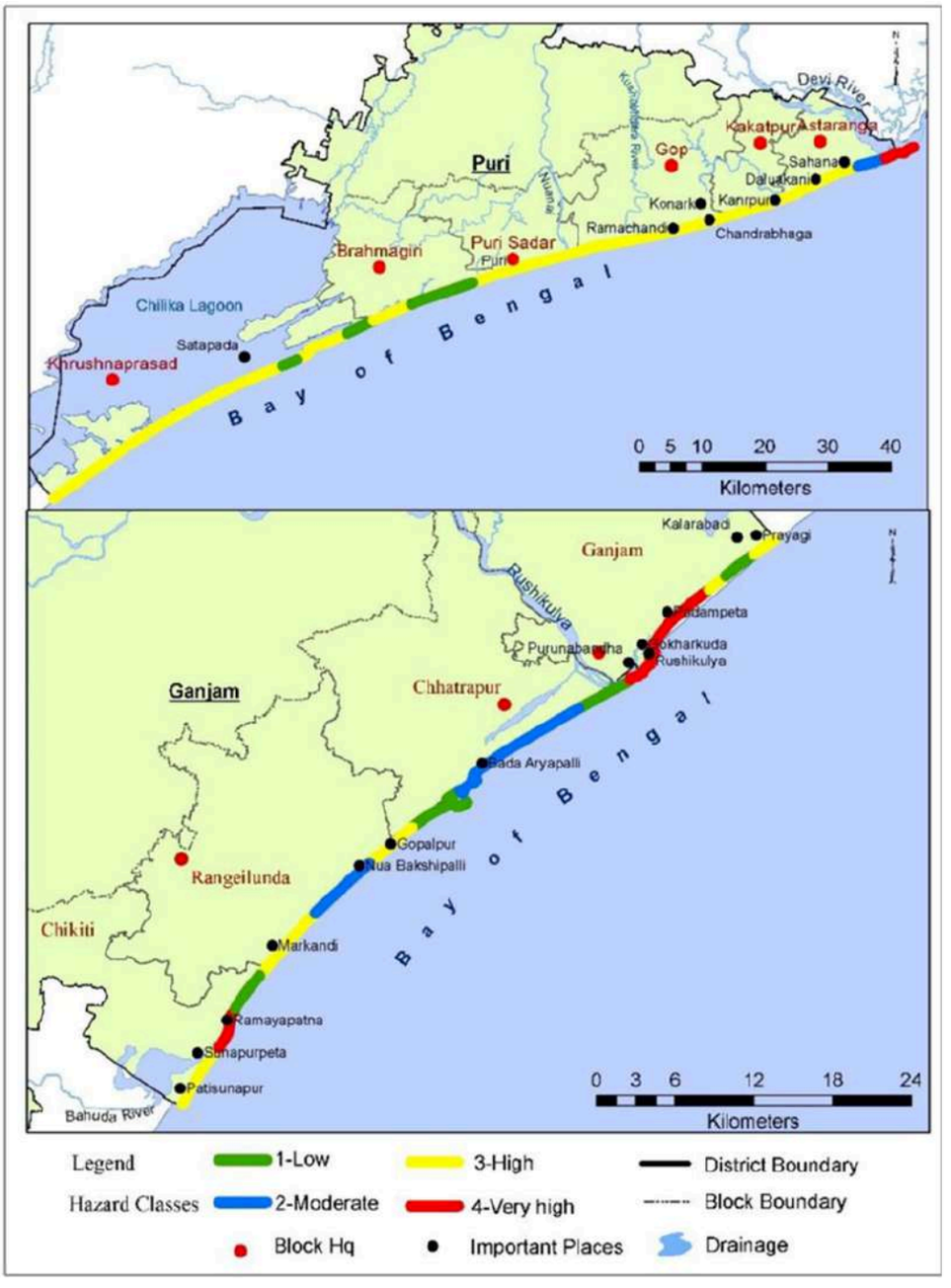


Fig. 2.14: Vulnerability Profile of Erosion along the Coastline of Puri and Ganjam Districts.

(Source: Panda, Mishra and Chatterjee, 2022)

C) Physical Susceptibility of Place:
As mentioned earlier, the study area has a 480 km long coastline. This area has a high-density of population and is home to millions of people. Many rivers and rivulets make a criss-cross in Coastal Odisha. The entire 480 km long coast is prone to erosion problems. Erosion of the coastline was one of the major threats to the study area. The continuous erosion of this coastline is as real as their existence. These were also affected by cyclonic action. Erosion and accretion through these forces maintain varying levels of physiographic change whilst the mangrove vegetation itself provides remarkable stability to the entire system. It can also be found in the plate 2.1.

D) People's Vulnerability: In this section, different vulnerabilities of people to the cyclone disaster have been identified. Anthropogenic stress was one of the major problems in the study area. It was spread in all the six coastal districts of Odisha. Different vulnerabilities have also been identified such as:

- Changes in land use patterns have been considered for the development of aquaculture, fisheries and agriculture promoted large-scale reclamation of land of virgin coastal areas leading to deforestation (Hazra et al., 2002).
- Fishermen camps often lead to disturbances to the coastal ecosystem functioning because of the release of different waste materials as well as the operation of an increased number of nylon nets having small mesh sizes to the death of marine turtles, migratory birds and threatened fish species.

Plate 2.1: Loss of huge Forest Cover in Balukhand Reserve Forest along the Puri-Konark Marine Drive after the Cyclone Fani in 2019.

Plate 2.2: Severe Coastal Erosion at Siali in Ershama Block of Jagatsinghpur District.

Plate 2.3: Intrusion of Sea water at Nolia Sahi in Ershama Block of Jagatsinghpur District

- Construction of embankments and dredging of riverbeds hamper the water circulation, distabilise bottom sediments, increase turbidity and affect the settlements of flora and fauna (Chakraborty, 2011).
- Eco-tourism in different parts of coastal areas (Chilka, Bhitar Kanika, Puri, Konark, Gopal Pur etc) contributes profusely to the eco-degradation of the Odisha coast.

The above discussion suggests that there is a need to understand the response of the people of coastal Odisha. The response of the people has been discussed in the following section.

E) People's Response: People's responses have been identified in the context of hazardscapes. An adequate number of cyclone and flood shelters should be created. The existing shelters cannot accommodate the vulnerable populations of the study area in case of a major cyclone emergency.

Recently Government of Odisha has planned to establish more cyclone and flood shelters in the state. The effectiveness of these shelters depends on multiple variables, such as the location, accommodation capacity, durability, maintenance, and availability of resources such as medical aid and safe water supplies (The World Bank, 2014). An example of an adequate/ideal cyclone and flood shelter is one that includes the creation of a network of multipurpose cyclone shelters with elevated space for livestock and overhead water storage. During times other than emergencies, when cyclone shelters would otherwise not be used, they can be put into service as primary schools or office space for other economically productive activities (Paul, 2009). Mangrove acts as a foundation for coastal ecosystems in Odisha. They provide food and shelter for animals, as well as numerous ecosystem services for the local population (Banerjee, 2010, The World Bank, 2014). Conservation of land, by converting the most saline, flood-prone, and erosion-prone agricultural land back to mangrove forests and mud flats, can provide many benefits to coastal Odisha. One can assume that converted agricultural land will transform into mud flats (The World Bank, 2014).

As Nanda et al., (2001) report, mud flats are made up of soft-grain mud and act as a sustainable habitat for a variety of fauna and flora, including mangrove and marsh vegetation. Laffoley and Grimsditch (2009) suggest that tidal salt marshes could accumulate up to 2.1 tons of carbon per year

Conclusion

Hazardscape analysis not only provides a holistic framework to study various aspects of hazards but connects the loose ends of various theories, concepts and processes, which are essential for understanding hazards and social vulnerability. The concept of hazardscape transcends administrative boundaries and could be applied across time and space, in different contexts of both developed and developing countries and for natural and social hazards. It not only relates to the current hazards in a community related to the current environment but also to changing environmental conditions.

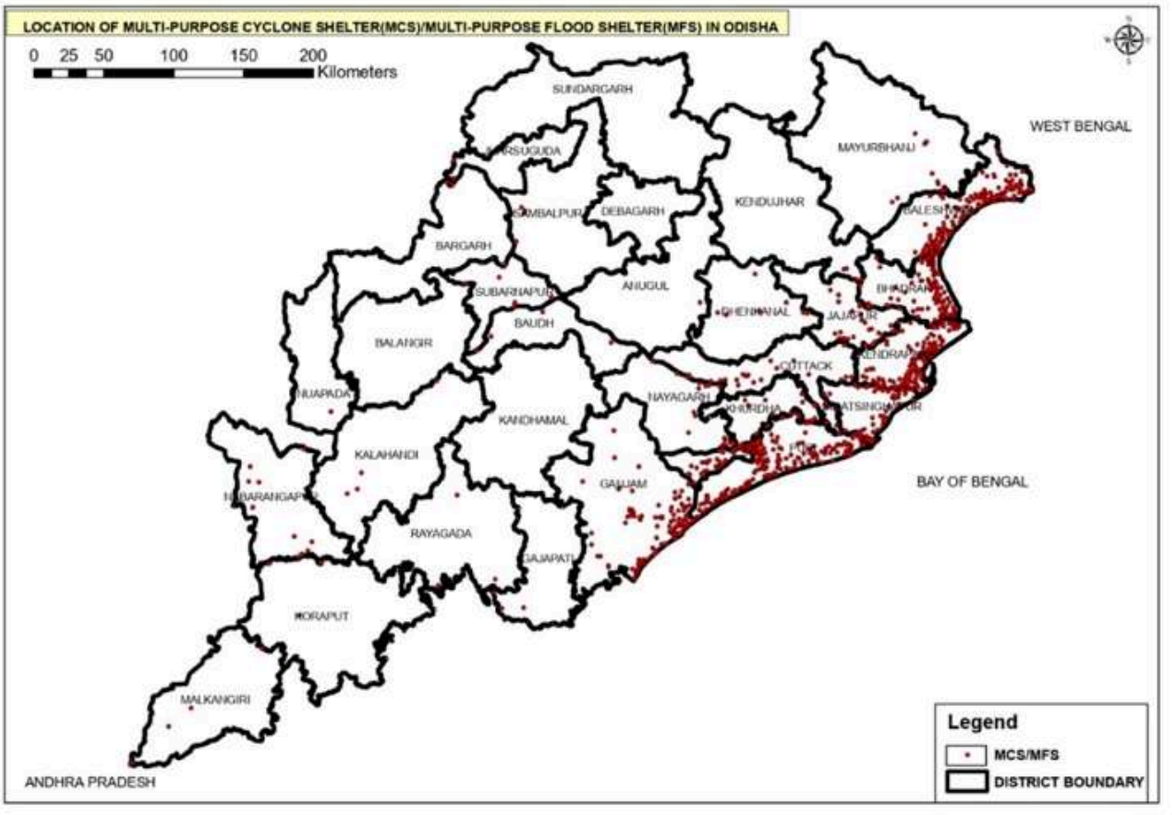


Fig. 2.15: Location of Multi-Purpose Cyclone Shelter and Multi-Purpose Flood Shelters.

SOCIO-ECOLOGICAL RESILIENCE TO CYCLONE VULNERABILITY IN COASTAL ODISHA: A BLOCK-LEVEL ANALYSIS

Introduction

A very severe cyclonic storm led to a storm surge that submerged the coastal belt at the time the storm crossed the area apart from devastating the area due to high-speed wind. Therefore, cyclone leads to floods and inundations of coastal plains. It affects lives, livelihoods, fragile and sensitive ecosystems and infrastructure, built environment of Coastal Odisha on which these livelihoods are intimately connected. On 8th October 2003, former UN Secretary-General Kofi Annan in his message on the occasion of International Day for Disaster Reduction rightly said that "hazards only become disasters when people's lives and livelihoods are swept away" (cited from Birkmann, 2006:9). As pointed out by Human Development Report, 2014, these natural disasters "can impair human capabilities and threaten human development in all countries-especially in the poorest and most vulnerable" (HDR, 2014:48).

Therefore, it is essential to examine the vulnerabilities of people, places and livelihoods for climate-related disasters. This would provide an insight for building resilience. In this chapter, an attempt has been made to construct a socio-ecological resilience index by taking both district and Community Development Blocks (hence-forward simply referred as 'block') as unit areas of analysis. The concept of resilience in general and socio-ecological resilience in specific and its various dimensions have already been discussed in the introduction chapter. This would help us in constructing the index and identifying weak areas in which interventions are required.

This chapter is broadly divided into seven sections. The following sections explore methodology, data sources, results and discussion.

Indicator Approach for Assessing Socio-Ecological Resilience to Disaster Vulnerability

The indicator approach is one of the most popular quantitative methods employed in resilience assessments both at local and global levels. There were numerous vulnerability assessment studies conducted in India at different levels. (Bahinipati, 2014; Sharma and Patwardhan, 2008; Kumar et al., 2006; O' Brien et al., 2004). Similarly, various studies were also conducted on the vulnerabilities of Coastal Odisha on the impacts of disasters and climate change on lives and livelihoods (Patnaik et al., 2013; Bahinipati, 2014; Sudha et al., 2015; Sahoo and Bhaskaran, 2018; Mani et al., 2018; Padhan and Madheswaran, 2022; Mandal & Dey, 2022; Hazra et al., 2022; Ramakrishnan et al., 2023). The method involves assessing vulnerability by defining certain proxy indicators which

can be evaluated by aggregating them into indices or estimating their arithmetic mean (Hahn et al., 2009; Piya et al., 2015; Toufique and Yunus, 2013).

There have been many researchers who have contributed in developing various quantitative indicators for assessing vulnerability to climate-related disasters in the last three decades (Brooks et al., 2005; Eriksen and Kelly, 2007; Barnett et al., 2008; Hahn et al., 2009; Leichenko and O'Brien, 2002; Deressa et al., 2009; Fussel, 2010). The concepts of vulnerability are negative and multi-dimensional in nature which is difficult to measure directly due to their complexities and hence there is a need for identifying proxy variables and indicators.

Proxies should be visible, capable of simplifying and can quantify or summarize several properties (Moss et al., 2001). Gallopin (1997:14) defined an indicator as a "sign that summarizes relevant information about phenomena." An indicator is "a variable which is an operational representation of characteristics or quality of a system able to provide information regarding the susceptibility, coping capacity and resilience of a system to an impact of ill-defined event linked with a hazard of natural origin" (Birkmann, 2006:57).

Data Sources

The present study was conducted based on secondary data sources. Secondary data were collected from government records and documents like the State Disaster Management Plan, 2019, the District Statistical Handbooks (DSH) and the Census of India (2011).

Socio-ecological Vulnerability to cyclone disaster index was constructed by selecting eighteen indicators giving representation to bio-physical, socio-economic, built environment and institutional components of socio-ecological vulnerability. These indicators were selected by reviewing various research studies conducted by various researchers as mentioned in table 3.1. It has been found that most of these studies have taken 'districts' as the unit area of analysis. This is perhaps the first study that attempted to analyse the socio-ecological resilience to cyclone disaster vulnerability in coastal Odisha by taking Community Development Block as the unit area of analysis. The details about the indicators and their source were presented in the table 3.1.

Justification for Selected Indicators

It is needless to mention the selection of indicators must depend on the analytical frame and should be relevant given the objectives of the study. That is why the justification for the selection of the indicator must be sought not through the abstract logic of mathematics but in the underlying conceptualization of social reality.

A. Indicators related to Bio-physical Component: The bio-physical indicators of resilience explain how the area is being protected from exposure and reduce the vulnerability to cyclones. The three indicators have been taken into consideration to construct a composite index showing the exposure of each block of Coastal Odisha.

Table 3.1: Components and Indicators of Vulnerability and their description (Unit Area of analysis is District and CD Block)

Sr. No.	Variables	Indicators	Unit of Measurement	Functional Relationship	Data Sources
1	Bio-physical	Total length of Coast line	Square Kilometers	Positive	Odisha State Disaster Management Authority
		Total area under mangrove forest	Square Kilometers/ Percentages	Positive	Odisha State Disaster Management Authority
		Total Forest Cover	Number	Positive	Odisha State Disaster Management Authority
		Cyclones affected the block in the last Forty Years	Number	Positive	Odisha State Disaster Management Authority
2	Socio-Economic	Total Population	Number	Positive	Census of India, 2011
		Density of Population	Person per Sq. Km.	Positive	Census of India, 2011
		Literacy	Percentages	Positive	Census of India, 2011
		Population below Poverty Line	Percentages	Positive	Niti Ayog
		Total Non-workers	Percentages	Positive	Census of India, 2011
3	Built-Environment	Pucca house	Percentages	Positive	District Statistical Hand Books, 2018
		Cyclone Shelter	Number	Positive	District Disaster Management Plans, 2019
		All Weather Road	Kilometers	Positive	District Statistical Hand Books, 2018
		Drinking water facilities	Number	Positive	District Statistical Hand Books, 2018
		Coastal river embankment and Coastal Embankment	Kilometers	Positive	District Statistical Hand Books, 2018
4	Institutional	Self-Help Groups	Number	Positive	Odisha State Disaster Management Authority
		Training programme conducted	Number	Positive	Odisha State Disaster Management Authority
		Mock drills conducted	Number	Positive	Odisha State Disaster Management Authority

- **Total Length of Coastline:** This is one of the positive indicators that leads to vulnerability. A block with longer coastal areas would be more vulnerable because the coastal area is mostly affected by cyclones and inundations due to storm surges. So, the livelihoods of the people are affected more and they suffer more than other people in the Coastal Odisha.
- **Total area under mangrove forest:** This acts as a windshield and breaks the wind speed. It helps prevent the loss of lives and properties.
- **Total Forest Cover:** As mentioned above, this also acts as a windshield and puts a break to speeding wind,

helping in preventing life and property losses.

- **Number of cyclone-affected blocks in the last Forty Years:** This indicator will assess the vulnerability of the blocks in the last forty years. It also determines how many times cyclones have hit this area and affected these blocks. It shows the frequency and damage of the area. If occurrences of cyclones are more, then the vulnerability of the place and people would be high.

B. Indicators related to Socio-economic Component: Six indicators of sensitivity describe the socio-economic resilience level of the area due to cyclone disasters. Similarly, these indicators have also been taken into consideration to construct the same composite index showing the socio-economic level of each block of Coastal Odisha.

- **Density of Population in each district and Coastal block:** It means the number of people living per square kilometer area. Population density is one of the major indicators that enhances vulnerability because it increases sensitivity levels. Higher population density restricts income opportunities and limited access to natural resources and raises pressure on land. So, the block with high density would mean highly sensitive because climate-related disasters (cyclones and floods) affect the area directly and indirectly. Natural resources of the region are affected by these types of disasters which makes life and livelihood difficult.

- **Percentage of households in Below Poverty Line (BPL) to the total no of households in the bloc**k: The categorization of households living below the poverty line (BPL) is based on the criterion of income of the family and is a positive indicator with less adaptive capacity. These households have limited access to the basic necessities of life i.e., food, clothes and shelter. Households below the poverty line are deprived of a good quality of life and access to basic requirements such as education. Being the vulnerable segment of society, their adaptive capacity to cope with any natural disasters is minimal. Climate-related disasters are likely to worsen the condition of such households as the additional stress on resources will further increase their vulnerabilities. A block with a high BPL population is likely to be more exposed and vulnerable to cyclones and floods.

- **Literacy rate:** The literacy rate of an area is a clear indicator of the adaptive capacity of the people and how equipped they are in terms of knowledge and education. It shows the degree to which the community can have access to the right kind of knowledge to understand changes in the environment and the management practices required to deal with them. For this analysis, it has been assumed that a block having a higher literacy rate will probably have a better knowledge base to deal with and adapt to climate-related disasters.

- **Percentage of Non-workers in each block:** In Coastal Odisha, agriculture is one of the most important activities and is crucial for its growth as well as food security. A large segment of the population is dependent on agriculture for its livelihoods. Effectively, agricultural workers and labourers give a picture of how much of the working population is dependent on agriculture. A large number of workers dependent on agriculture would mean that the changes in the frequency of climate-related disasters would have an impact on the livelihoods of a large population. If the population has limited means of alternative livelihoods, they will then have very less options for coping with the impacts of climate-related disasters and switching to some other means of income. Block with higher agricultural workers would be more sensitive to cyclones and floods. The higher the land capability, the greater would be the crop productivity from the land. However, it also implies that there is a greater pressure on resources such as water (and would also imply more use of fertilizers). In districts where the land capability is high, it mainly implies greater stress on resources and thus a higher sensitivity. An increase in the net sown area would raise the sensitivity levels of the block towards climate-related disasters.

- **Percentages of Scheduled Caste (SC) and Scheduled Tribe (ST) Population to Total Population of each district and block:** The SC and ST populations are generally marginalized sections of the society. The majority of the population of these communities suffered from socio-economic deprivation. Any disaster in general and cyclone in specific aggravates the vulnerability of these groups. The more the number of population in a particular area, the more is vulnerability.

C. Indicators related to the Built-Environment Resilience Component: Five indicators of the built environment are described below which ensures the coping capacity means these indicators reduce the vulnerability to cyclones. Similarly, these indicators have also been taken into consideration to construct the same composite index showing the level of built-environment resilience of each block of Coastal Odisha.

- **Number of Cyclone Shelters:** A district and block with a higher number of cyclone shelters, would mean better-coping capacities to cyclone vulnerability.

- **Number of Villages Located within 2-kilometer radius from the coast:** This indicator determines the intensity and magnitude of vulnerability to cyclones as villages located within 2 km radius would be the worst affected. If the number of villages is found more, then the probability of vulnerability would be high.

- **Percentage of Pucca Houses to the Total Houses:** The indicator takes into account the percentage of households having a Pucca (permanent) housing structure. Those houses whose roofs are made of permanent materials are considered pucca (permanent) houses. Permanent houses provide resilience to absorb climate-related disaster impacts. In case of disasters, such houses are most likely to withstand the shocks. A higher percentage of permanent houses would indicate a better coping capacity.

- **Percentage of Surface Roads (metalled) to the Total Length of the Roads in the Block:** Road Density has been defined as the ratio between lengths of metalled roads per thousand square kilometres of area. Road networks were a crucial indicator of development and connectivity across the region. A well-structured road network acts as a means of providing access to facilities. It also signifies improved access to the markets for a better income. Especially in the case of rural areas, developed road infrastructure would mean better accessibility of rural communities to the economic centers for trade and business. In the case of extreme events namely cyclones, metaled roads act as a means of providing relief and thus reduce vulnerabilities.

- **Drinking Water Facilities: A** district and block having higher coverage of drinking water facilities means better coping capacity to cyclone vulnerability.

D. Indicators related to the Institutional Resilience Component

- **Number of Self-help Groups:** Self-help groups facilitate in providing information related to the adaptive capacity of the region to cyclone disasters. A district and block having a higher number of self-help groups would mean a better coping capacity for cyclone vulnerabilities. Self-help group also facilitates good networks and relationships among the communities.

- **Number of Training Programme Conducted:** A district and block with a higher number of training programmes would mean better-coping capacities to cyclone vulnerability.

- **Number of Mock Drills Conducted:** A district and block having had more number of mock-drills would be in a better position to handle disaster scenarios, thus with better coping capacity to cyclone vulnerability.

- **Percentages of Villages covered by Early Warning Dissemination Centre:** This is one of the significant indicators for assessing vulnerability. It shows that those villages that had access to the early warning systems were more resilient, while those that did not were more vulnerable.

Methodology

The first and foremost step in any index construction is to convert raw data into standard data. This is very much essential because all the indicators used for developing the index were in different units of measurement. Thus normalisation helps in making all the data scale free. The methodology used for normalisation of data was based on the methodology used for the construction of UNDP's Human Development Index (HDI, UNDP, 1990). After normalization, the values obtained were scale free and lie between 0 and 1. After the process of standardization, it is important to identify the functional relationship between the indicators and vulnerability. Two types of functional relationships are possible. Vulnerability increases with the increase in the value of the indicator.

In other words, the higher the value of the indicator more is the vulnerability. In this case, we say that the indicators have a positive functional relationship with vulnerability. But in some indicators, more value denotes less vulnerability. In this case, indicators have negative or inverse functional relationship with vulnerability. Therefore, values are inversed to bring it in one scale.

Step – 1: Indicators

Values for all the indicators are to be standardized for all the unit areas of analysis namely districts and blocks

Indicator Index (Ix) = Ia– I (Min) / I (Max) – I (Min)
Indicator Index (Ix) =I (Max) – Ia/ I (Max) – I (Min)
– for cases of inversion

Where

- Ix is the standardized value for the indicator
- Ia is the value for an indicator I for the particular unit area, a
- I (Max) stands for the maximum value for the indicator across a particular unit area I (MIN) stand for minimum value for the indicator across a particular unit area

Step – 2: For calculation of Aggregate components value in bio-physical, socio-economic, built-environment and institutional vulnerability

- Indicators index values are combined to get the values for the Components

Components (C) = • ni-1 Ix / n

- Where Ix represents indicators Index
- Where, n number of indicators in the components
- Indicators index I index of the Ith indicators

Step – 3: For calculation of the cyclone Vulnerability Index

The combination of the values of three components will give the disaster vulnerability index, i.e., **Bio-physical+ Socio-economic+ Built-environment and Institutional vulnerability/ Number of Components**

After the calculation of aggregate components, value in and overall Socio-ecological Vulnerability Value at the district and block level, the 6 districts and 22 blocks were categorized by considering Standard Deviation (SD) as an interval from the mean.

Results and Discussions

The results and discussions have been presented in two sections I.e., district and block level. In each section results and discussions were presented in four sub-sections. The first sub-section explained the overall vulnerability of the districts and blocks to cyclone vulnerability. The second sub-section focused on variance in different components of socio-ecological vulnerability. In the third section, the categorization of district and block on the basis of socio-ecological vulnerability has been discussed whereas in the fourth section, the Correlation amongst the sub-indices of the vulnerability index has been discussed.

District Level Analysis

Socio-ecological vulnerability of all the six coastal districts has been calculated using 18 indicators based on secondary data sources. All the 18 above-mentioned selected indicators were grouped under four broad components namely bio-physical, socio-economic, built-environment and institutional. A composite socio-ecological vulnerability was calculated at the district level and presented below in the given table 3.2. Each district was ranked in order of their vulnerability levels to cyclone disasters from 1 to 6. One represents the most vulnerable district whereas 6 represents the least vulnerable district.

All six coastal districts were classified into different groups to identify their levels of socio-ecological vulnerability by using Mean ± 1 SD. By using this formula three classes were created namely low, moderate and high.

As moderate categories have four districts out of six districts, they were further subdivided into two groups namely highly moderate and low moderate. Highly moderate districts are very close to high category vulnerability scores. If proper mitigation as well as adaptation measures are not adopted then these blocks would be highly vulnerable to cyclones in future. On the contrary, lowly moderate districts are very close to low vulnerable districts. Therefore, proper implementation of mitigation and adaptation measures would help these blocks to be less vulnerable in future. However, the overall aim is to make a concerted effort to transform all the moderate and highly vulnerable districts to less vulnerable districts. The four classes, corresponding levels and associated districts are given in Table 3.3.

Socio-ecological vulnerability analysis at the district level revealed that Puri (0.66) is the most vulnerable district whereas Jagatsinghpur (0.26) is the least vulnerable district. If we closely observe the values of all four components of socio-ecological vulnerability for the district Puri, it is observed that the values of all the components are higher apart from the socio-economic parameters (0.47). Values for the bio-physical indicators are extremely high (0.95) followed by institutional (0.67) and built-environment (0.57). On the other hand, analysing the values of all four components of socio-ecological vulnerability for the district Jagatsinghpur, it was found that the values of all the components are low except the bio-physical component (0.60) (See fig. 3.1 and 3.2).

Table 3.2: Socio-Ecological Cyclone Vulnerability Scores for Districts at Coastal Odisha

S. No.	Districts	Bio-Physical	Socio-Economic	Built Environment	Institutional	Socio-Ecological Cyclone Vulnerability Index	Ranks amongst the Districts
1	Balasore	0.69	0.57	0.48	0.17	0.48	3
2	Bhadrak	0.61	0.66	0.35	0.43	0.51	2
3	Ganjam	0.37	0.38	0.46	0.38	0.40	5
4	Jagatsinghpur	0.60	0.30	0.10	0.03	0.26	6
5	Kendrapara	0.31	0.49	0.41	0.76	0.49	4
6	Puri	0.95	0.43	0.59	0.67	0.66	1
	Mean	0.59	0.47	0.40	0.41	0.47	
	SD	0.20	0.11	0.15	0.26	0.12	

Table 3.3: Levels of Socio-Ecological Cyclone Vulnerability of Districts at Coastal Odisha

S.No.	Classes	Levels	Districts
1.	< 0.35	Low	Jagatsinghpur
2.	0.36-0.47	Low Moderate	Ganjam,
3.	0.48-0.59	High Moderate	Balashore, Kendrapara, Bhadrak
4.	>0.59	High	Puri

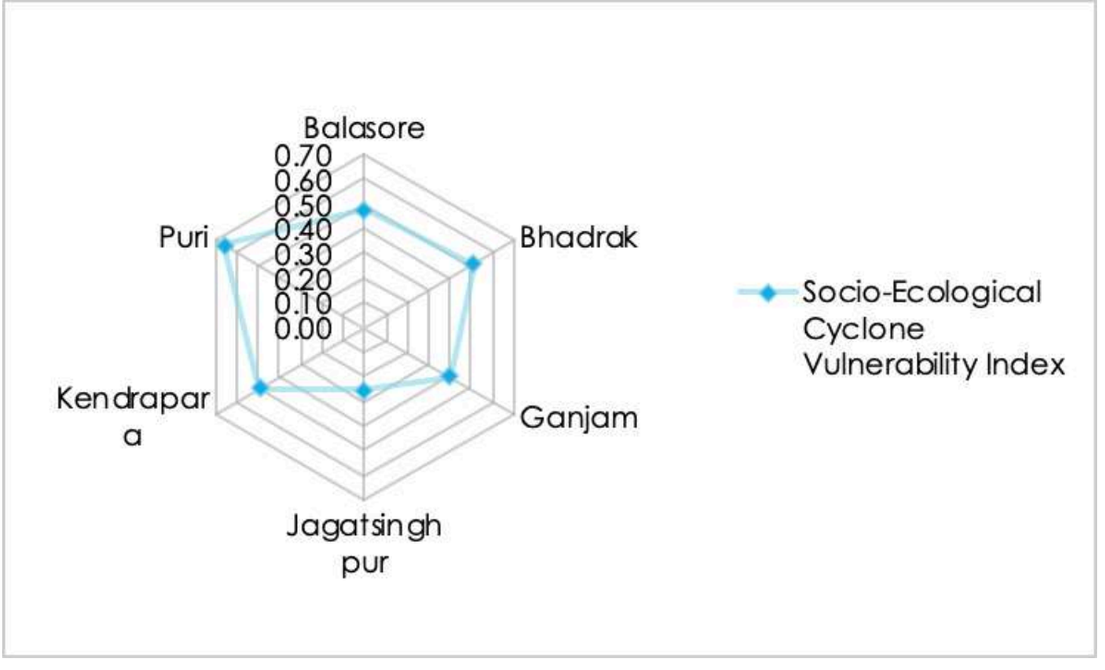


Fig. 3.1: Socio-Ecological Cyclone Vulnerability of Coastal Districts in Coastal Odisha.

Socio-ecological vulnerability analysis at the district level revealed that Puri (0.66) is the most vulnerable district whereas Jagatsinghpur (0.26) is the least vulnerable district. If we closely observe the values of all four components of socio-ecological vulnerability for the district Puri, it is observed that the values of all the components are higher apart from the socio-economic parameters (0.47). Values for the bio-physical indicators are extremely high (0.95) followed by institutional (0.67) and built-environment (0.57). On the other hand, analysing the values of all four components of socio-ecological vulnerability for the district Jagatsinghpur, it was found that the values of all the components are low except the bio-physical component (0.60) (See fig. 3.1 and 3.2).

Component-wise Analysis: On analysing the variations in terms of components, it was observed that the bio-physical (0.59) has the highest value followed by socio-economic (0.47), institutional (0.41) and the least being the built-environment (0.40).

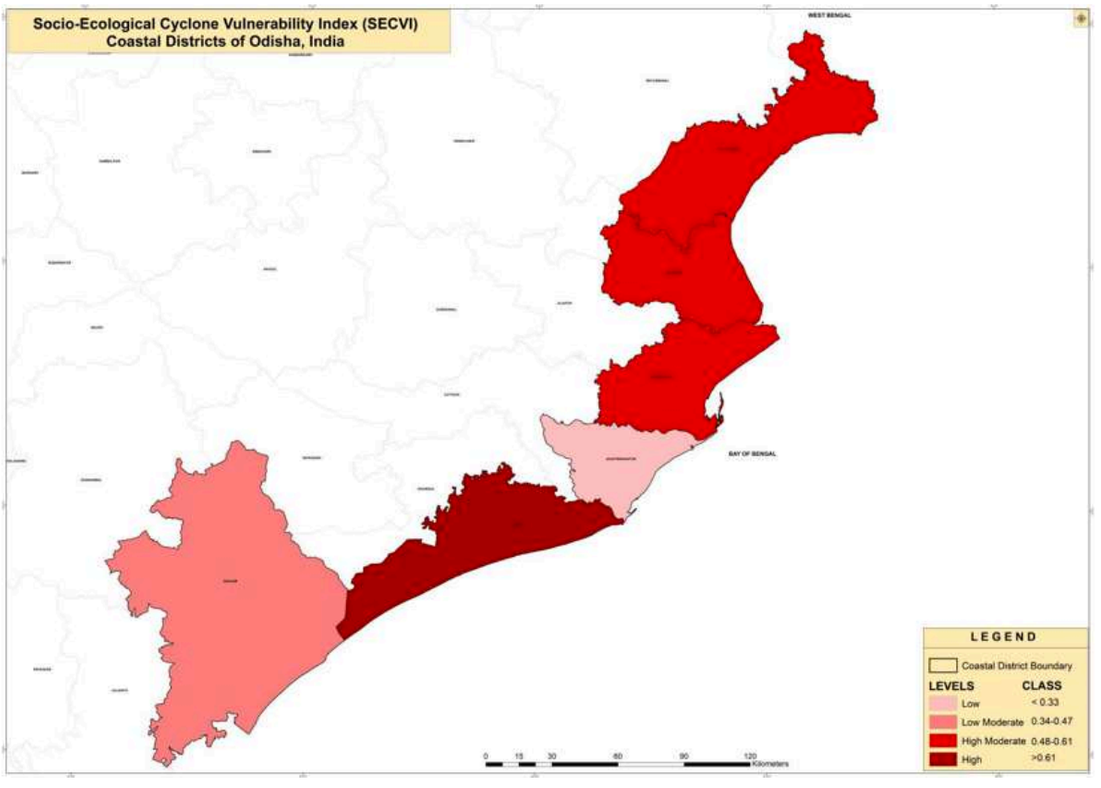


Fig. 3.2: Levels of Socio-Ecological Cyclone Vulnerability in Coastal Odisha.

Table 3.4: Levels of Bio-Physical Cyclone Vulnerability.

S. NO.	Classes	Levels	Districts
1.	< 0.38	Low	Ganjam, Kendrapara
2.	0.40-0.59	Low Moderate	Nil
3.	0.60-0.79	High Moderate	Balashore, Bhadrak, Jagatsinghpur
4.	>0.79	High	Puri

Bio-Physical Vulnerability: The above-given Table 3.4 presents levels of bio-physical vulnerability of Coastal districts. Inter-district analysis of bio-physical components revealed that out of six districts, four districts namely Puri, Balasore, Bhadrak and Jagatsinghpur have value more than 0.60. On the other hand, Kendrapada and Ganjam were the least vulnerable (Less than 0.38). Though Jagatsinghpur was found to have the least socio-ecological vulnerability (0.26), yet the bio-physical vulnerability is high which needs urgent attention. Inter-district levels of bio-physical vulnerability is depicted in Fig. 3.3 and 3.4.

Socio-Economic Vulnerability: Inter-district analysis of socio-economic vulnerability revealed that out of six districts, Bhadrak is the only district that is highly vulnerable (more than 0.60) whereas Jagatsinghpur were least vulnerable (Less than 0.34). Inter-district levels of socio-economic vulnerability are depicted in Fig. 3.5 and 3.6.

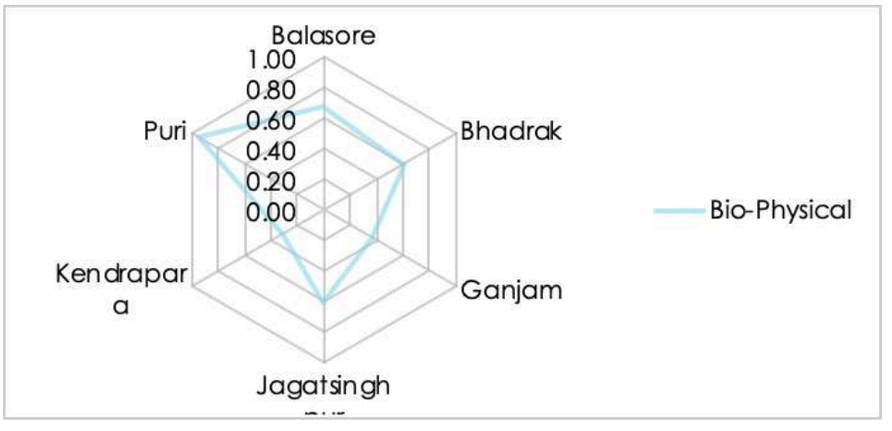


Fig. 3.3: Bio-Physical Cyclone Vulnerability Index.

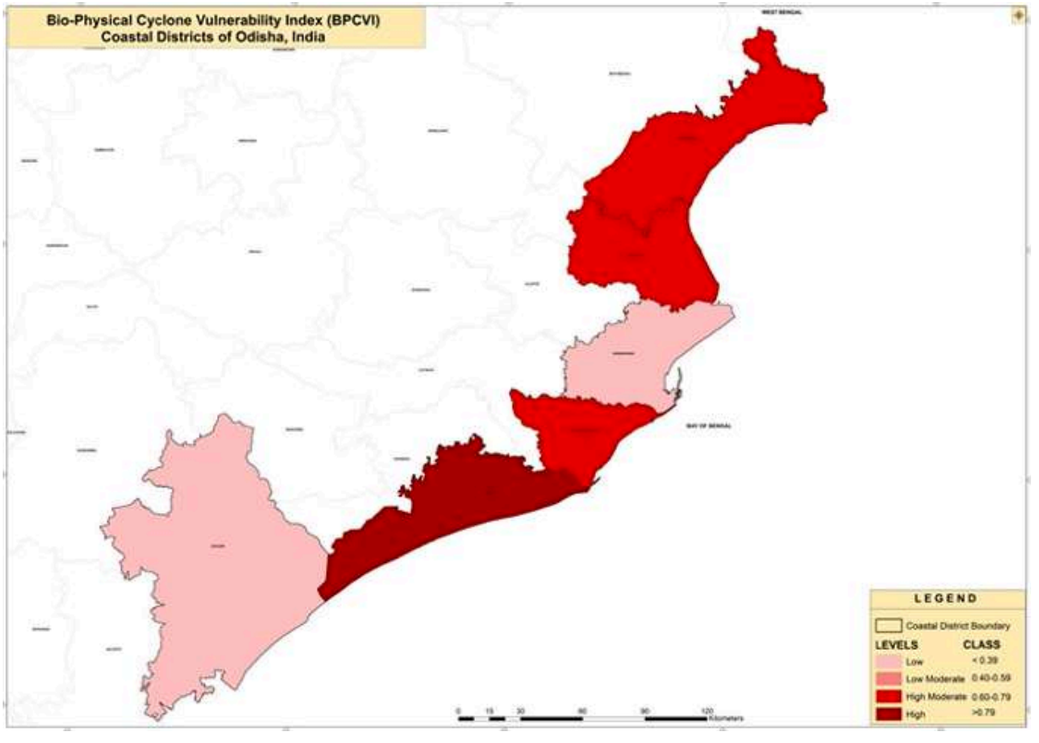


Fig. 3.4: Levels of Bio-Physical Cyclone Vulnerability in Coastal Odisha.

Table 3.5: Levels of Socio-Economic Vulnerability.

S. NO.	Classes	Levels	Districts
1.	< 0.34	Low	Jagatsinghpur
2.	0.35-0.47	Low Moderate	Ganjam, Kendrapara
3.	0.48-0.60	High Moderate	Puri, Balashore
4.	>0.60	High	Bhadrak

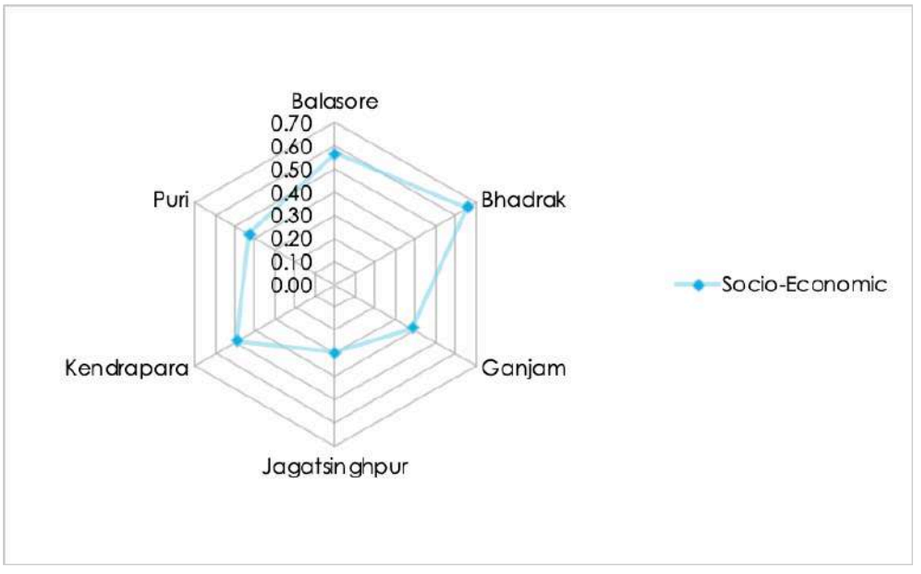


Fig. 3.3: Bio-Physical Cyclone Vulnerability Index.

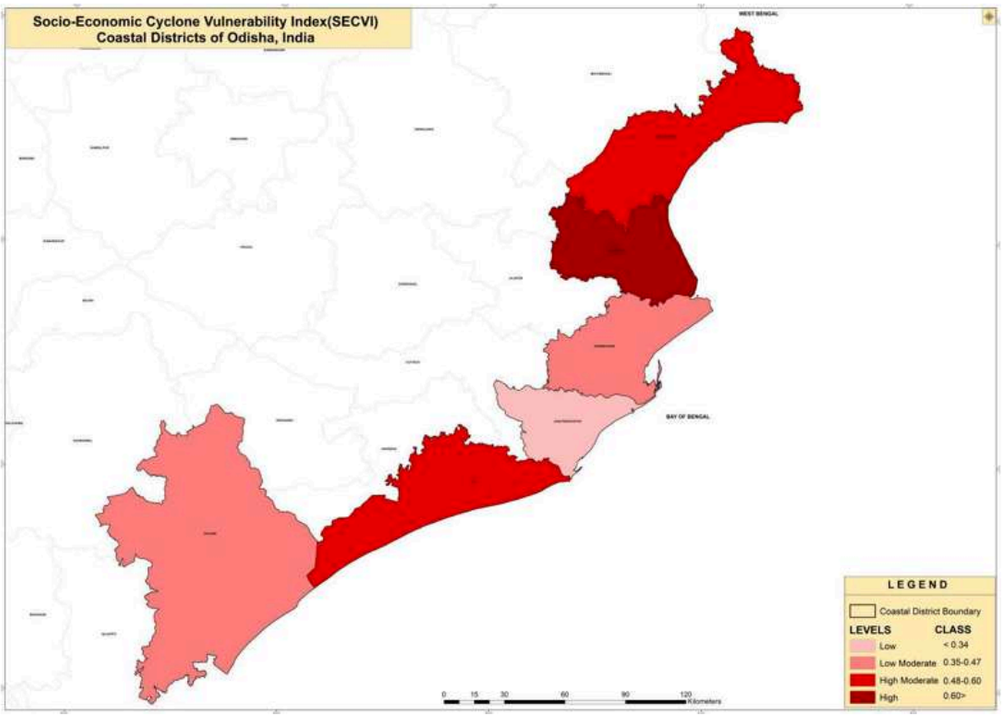


Fig. 3.6: Levels of Socio-Ecological Cyclone Vulnerability in Coastal Odisha.

Built Environment Vulnerability: Inter-district analysis of built-environment vulnerability revealed that out of six districts, Puri is the only district that is highly vulnerable (more than 0.57) whereas Jagatsinghpur were least vulnerable (Less than 0.23) (Table 3.6). Inter-district levels of built-environment vulnerability are depicted in Fig. 3.7 and 3.8.

Institutional Vulnerability: Inter-district analysis of institutional vulnerability revealed that out of six districts, Kendrapada is the only district that is highly vulnerable (more than 0.68) whereas Jagatsinghpur was least vulnerable (Less than 0.14) (Table 3.7). Inter-district levels of built-environment vulnerability are depicted in Fig. 3.9 and 3.10.

Table 3.6: Levels of Built Environment Cyclone Vulnerability Index

S. NO.	Classes	Levels	Districts
1.	< 0.23	Low	Jagatsinghpur
2.	0.24-0.40	Low Moderate	Bhadrak
3.	0.41-0.57	High Moderate	Ganjam, Balashore, Kendrapara
4.	>0.57	High	Puri

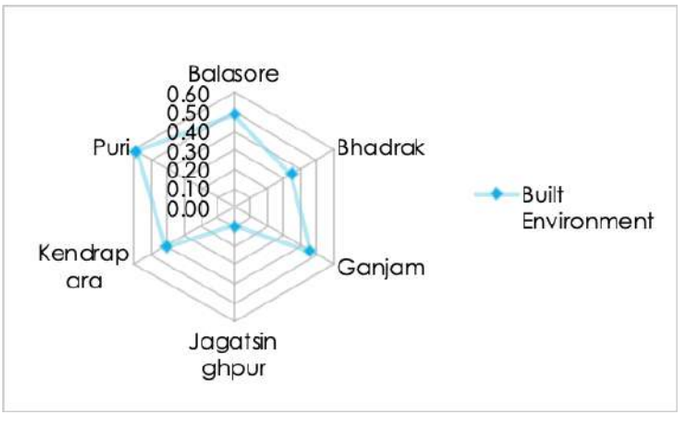


Fig. 3.7: Built Environment Cyclone Vulnerability Index.

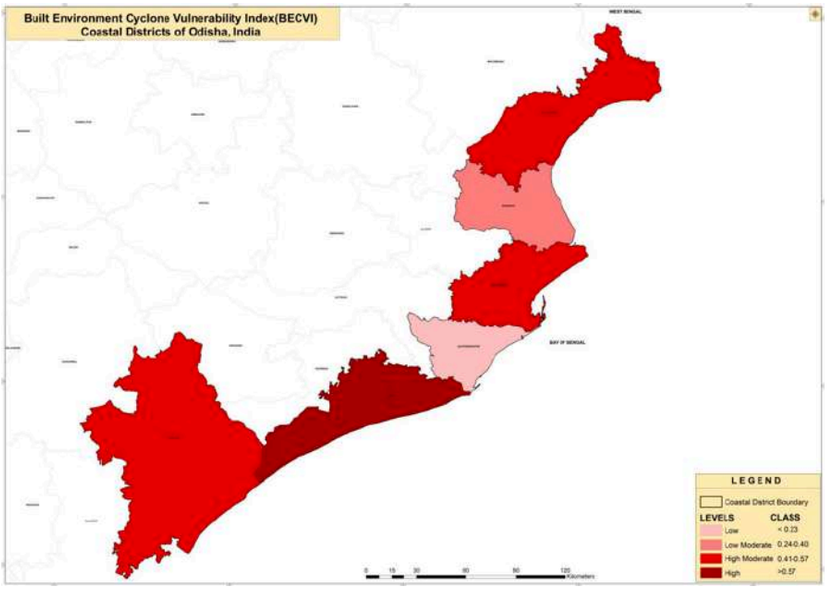


Fig. 3.8: Levels of Cyclone Vulnerability of Built-Environment in Coastal Odisha.

Table 3.7: Levels of Institutional Cyclone Vulnerability Index (ICVI)

S. NO.	Classes	Levels	Districts
1.	< 0.14	Low	Jagatsinghpur
2.	0.15-0.41	Low Moderate	Balashore, Ganjam
3.	0.42-0.68	High Moderate	Bhadrak , Puri
4.	>0.68	High	Kendrapara

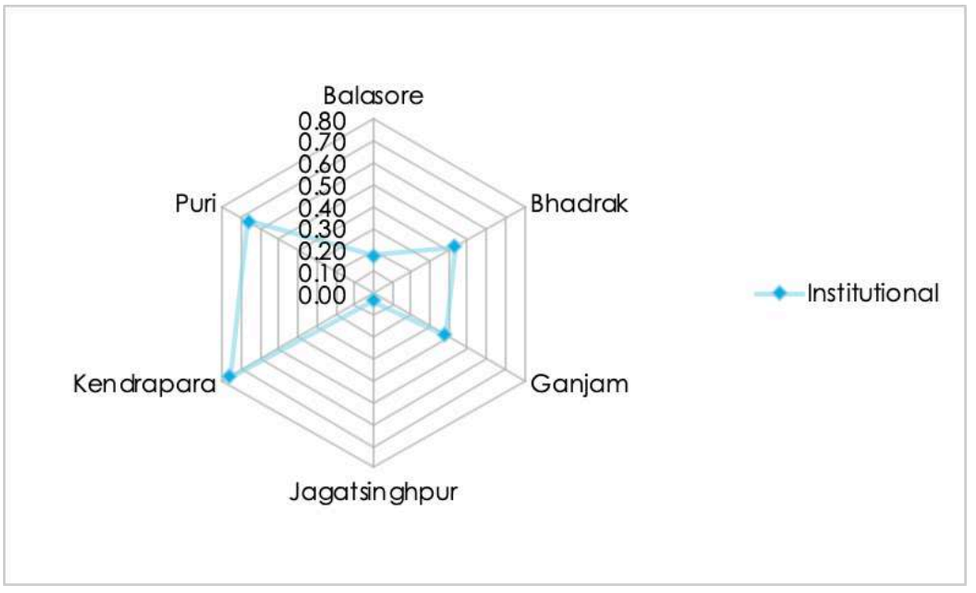


Fig. 3.9: Institutional Cyclone Vulnerability Index.

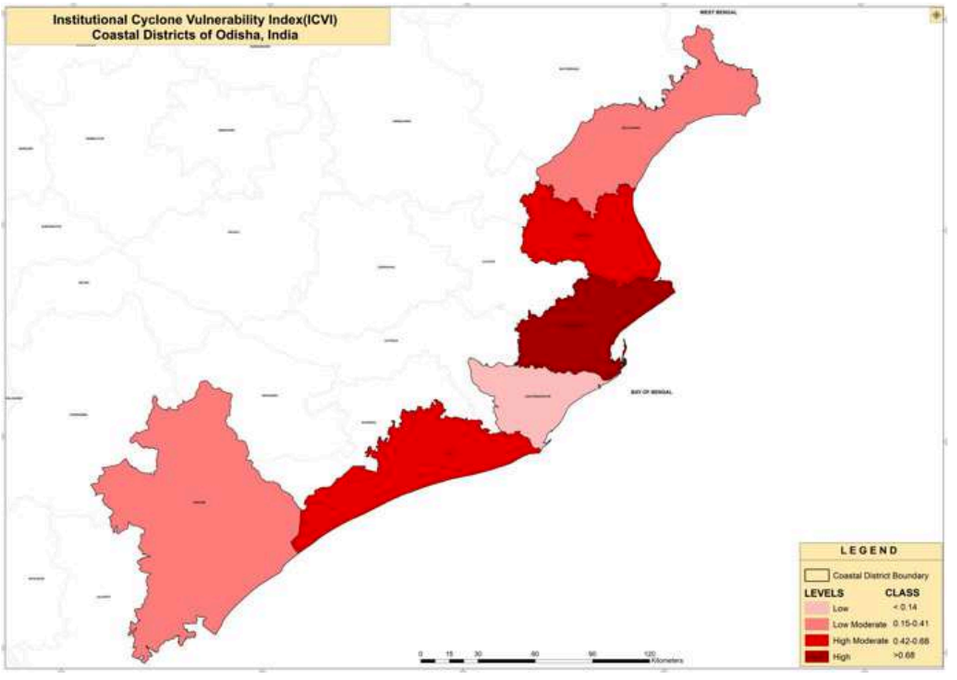


Fig. 3.10: Levels of Institutional Cyclone Vulnerability in Coastal Odisha.

Block Level Analysis

After analysing the socio-ecological cyclone vulnerability analysis, a micro-level analysis was attempted by taking the Community Development Blocks of these six coastal districts located along the coast. There are 22 blocks spread across all the above-mentioned six districts located along the coast. The vulnerability analysis of the blocks has been calculated by using the same 18 indicators used to assess the levels of vulnerability at the district level. These block-level data for 18 indicators were also based on secondary data sources aslisted in Table 3.1. Similarly, calculations were also according to above mentioned selected indicators of the four components namely bio-physical, socio-economic, built environment and institutional and composite socio-ecological vulnerability to cyclone index were calculated at the block level. The composite score and component-wise value have been presented in table 3.9. Each block has been ranked in order of their vulnerability to cyclones and ranked from 1 to 22, in which 1 is represented the most vulnerable block and 22 is represented as the least vulnerable block.These twenty-two coastal Blocks were grouped under three categories by using Mean ± 1 SD. As moderate categories have 17 blocks, they were further subdivided into two groups namely highly moderate and low moderate. Highly moderate blocks are very close to a high category vulnerability score.

Table 3.8: Socio-Ecological Cyclone Vulnerability Scores for Blocks at Coastal Odisha

Sr. No.	Blocks	Bio-Physical	Socio-Economic	Built Environment	Institutional	Total
1	Bahanaga	0.69	0.33	0.28	0.51	0.46
2	Balasore	0.83	0.44	0.50	0.49	0.57
3	Baliapala	0.76	0.35	0.36	0.51	0.50
4	Bhogarai	0.71	0.29	0.45	0.70	0.54
5	Remuna	0.68	0.46	0.20	0.53	0.47
6	Basudevpur	0.80	0.33	0.46	0.57	0.54
7	Chandbali	0.67	0.29	0.42	0.56	0.48
8	Chikiti	0.67	0.36	0.24	0.20	0.37
9	Chatrapur	0.65	0.42	0.38	0.33	0.44
10	Ganjam	0.63	0.44	0.33	0.32	0.43
11	Rangelilunda	0.71	0.35	0.14	0.32	0.38
12	Balikuda	0.72	0.25	0.09	0.29	0.34
13	Erasama	0.53	0.18	0.13	0.38	0.31
14	Kujanga	0.72	0.33	0.08	0.45	0.39
15	Rajnagar	0.46	0.23	0.50	0.49	0.42
16	Mahakalpada	0.69	0.24	0.37	0.57	0.47
17	Astaranga	0.62	0.23	0.31	0.63	0.45
18	Gop	0.54	0.29	0.30	0.45	0.40
19	Krushnaprasad	0.99	0.24	0.51	0.76	0.63
20	Kakatpur	0.33	0.28	0.19	0.41	0.30
21	Puri Sadar	0.72	0.39	0.23	0.44	0.45
22	Brahamagiri	0.73	0.31	0.36	0.53	0.49
23	Mean	0.68	0.32	0.31	0.48	0.45
24	SD	0.13	0.08	0.13	0.14	0.08

If proper mitigation as well as adaptation measures are not taken up then these blocks would become highly vulnerable to cyclones in future. On the contrary, lowly moderate blocks are very close to low vulnerable blocks. Therefore, proper implementation of mitigation and adaptation measures would help these blocks to be less vulnerable in future. However, the overall aim is to make concerted efforts to transform all the moderate and highly vulnerable blocks to less vulnerable blocks. The four classes, corresponding levels and associated blocks are given in Table 3.9. If we compare the level of vulnerability with the spatial location of blocks, then the following conclusions can be derived from table 3.9. Three blocks were categorized as low vulnerable. These three blocks are Kakatpur, Erasama and Balikuda. Out of these three blocks Kakatpur is in the Puri district whereas the rest two namely Erasama and Balikuda are in Jagatsinghpur district. On the contrary, there were two blocks namely Balasore and Krushnaprasad which are highly vulnerable. Ten blocks fall under the highly moderate category, these blocks are Bahanga, Remuna, Baliapala, Bhograi, in Balasore district; Chandbali and Bsudevpur in Bhadrak district; Mahakalpada in Kendrapada district and Brahmagiri in Puri district. As mentioned in the previous paragraph, these ten blocks along with two highly vulnerable blocks need more attention. The different levels of socio-ecological vulnerability are depicted in Fig. 3.12.

Table 3.9: Levels of Socio-Ecological Cyclone Vulnerability amongst the Coastal Blocks

S. No.	Classes	Levels	Districts
1.	< 0.35	Low	Kakatpur, Erasama, Balikuda
2.	0.36-0.45	Low Moderate	Chikiti, Rangelilunda, Kujanga, Gop, Rajnagar, Ganjam, Chatrapur, Astaranga, Puri Sadar,
3	0.46-0.55	High Moderate	Bahanga, Remuna, Mahakalpada, Chandbali, Brahmagiri, Baliapala, Bhograi, Bsudevpur
4.	>0.55	High	Balasore, Krushnaprasad

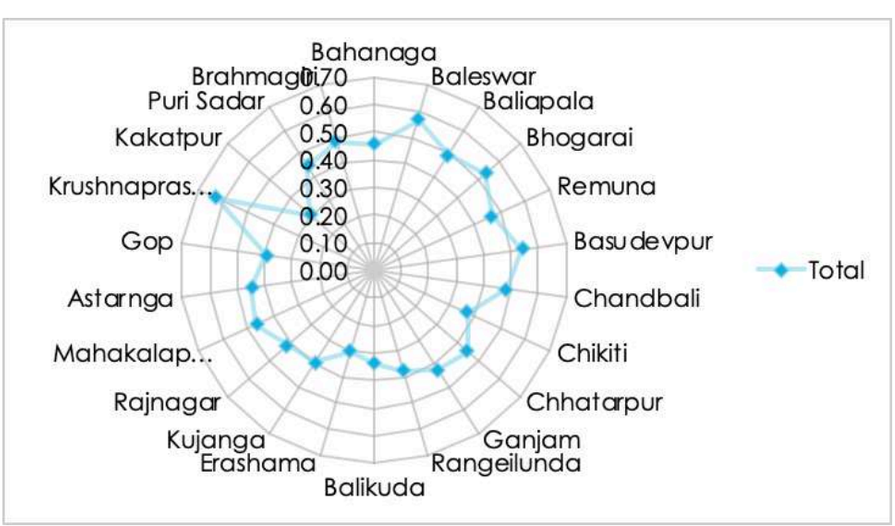


Fig. 3.11: Socio-Ecological Cyclone Vulnerability Index of Coastal Blocks.

Table 3.10: Combination of Socio-Ecological Cyclone Vulnerability

Parameters	District	Community Development Blocks
Highly Vulnerable District and Highly Vulnerable Blocks (HH)	Puri	Krushnaprasad
Highly Vulnerable District and Low Vulnerable Blocks (HL)	Puri	Kakatpur,
Low Vulnerable District and Highly Vulnerable Blocks (LH)	Jagatsinghpur	Nil
Low Vulnerable District and Low Vulnerable Blocks (LL)	Jagatsinghpur	Erasama, Balikuda

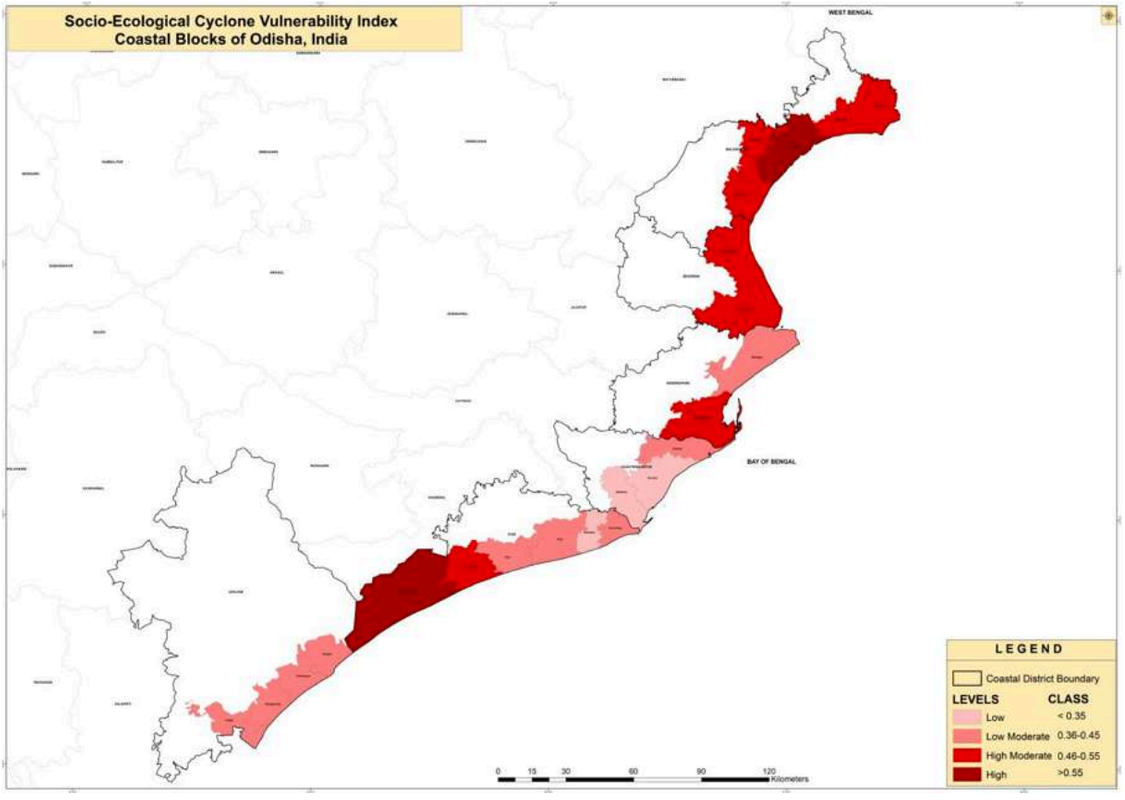


Fig. 3.12: Levels of Socio-Ecological Cyclone Vulnerability in Coastal Odisha.

Component-wise Categorization of Blocks

Component-wise levels of vulnerability are depicted in the table 3.11, 3.12, 3.13 and 3.14.

Bio-Physical Vulnerability: Out of 22 blocks, it has been found that there were two highly vulnerable blocks namely in Krushnaprasad block (0.99) in Puri district and Balasore block (0.83) in Balasore district. This is due to the large length of coastline; very low mangrove and coastal forest cover; and the occurrence of more numbers of cyclones in this region.

Low - vulnerable blocks are found in Kakatpur block (0.33) and Gop block (0.54 in Puri district, Rajnagar block (0.46) in Kendrapada district, and Erasama block (0.53)) in Jagatsinghpur district.

It is because of good mangrove cover in the case of Rajnagar and Erasama and the least coastal length in the case of Gop and Kakatpur.

Table 3.11: Levels of Bio-Physical Cyclone Vulnerability amongst the Coastal Blocks

S. No.	Classes	Levels	Districts
1.	< 0.54	Low	Gop, Kakatpur, Rajnagar, Erasama
2.	0.55-0.68	Low Moderate	Chandbali, Chikiti, Chatrapur, Ganjam, Rangelilunda, Remuna
3	0.69-0.82	High Moderate	Astaranga, Bahanga, Bhograi, Balikhuda, Kujanga, Puri Sadar, Brahmagiri, Baliapala, Basudevpur, Mahakalpada,
4.	>0.82	High	Balasore, Krushnaprasad

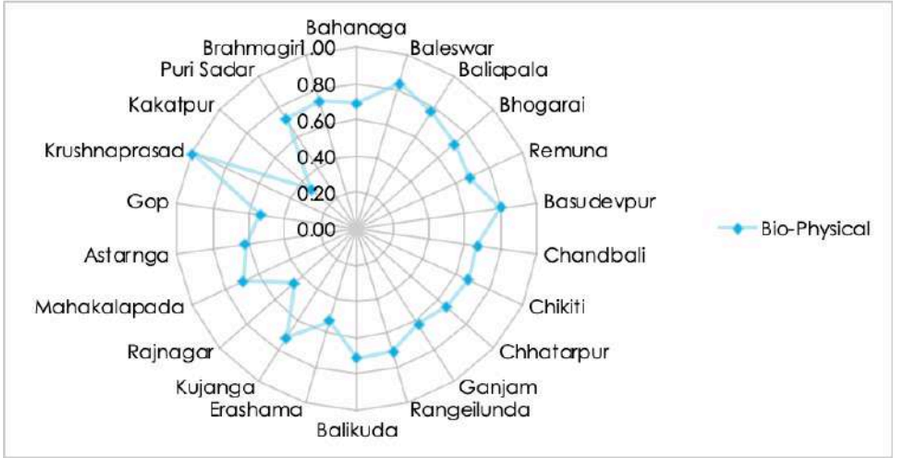


Fig. 3.13: Bio-Physical Cyclone Vulnerability Index of Coastal Blocks.

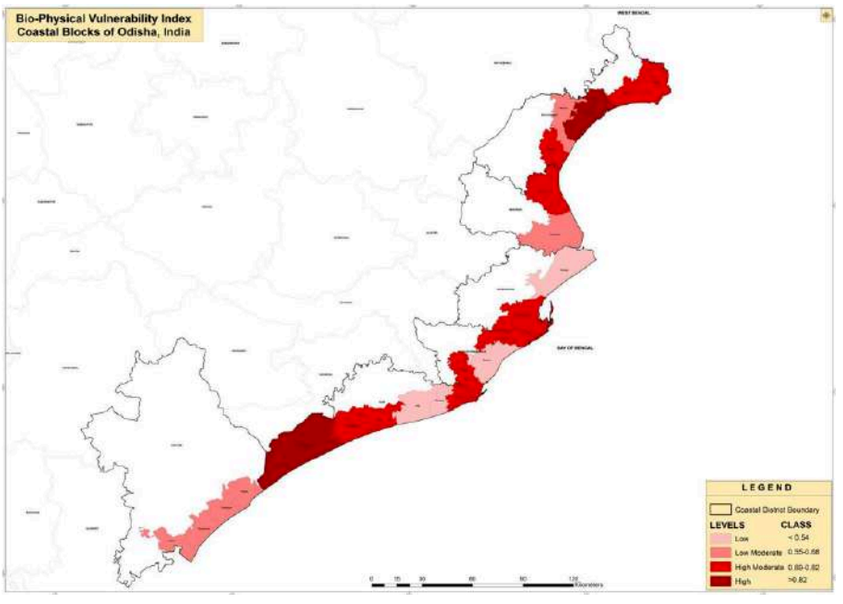


Fig. 3.14: Levels of Bio-Physicical Cyclone Vulnerability in Coastal Blocks.

Socio-economic Vulnerability: High level of socio-economic vulnerability has been observed in the Balasore (0.44) and Remuna (0.46) Blocks of Balasore Ganjam district, while low vulnerability was observed in Erasama Block (0.18) of Jagatsinghpur district. High vulnerability is found because of the high number of living population and high population density. More number of populations below the poverty line enhances the vulnerabilities. A greater number of non-workers also cause poor forms of living conditions.

Table 3.12: Socio-Economic Cyclone Vulnerability Index

S. No.	Classes	Levels	Districts
1.	< 0.22	Low	Erasama
2.	0.23-0.32	Low Moderate	Rajnagar, Astaranga, Mahakalpada, Krushnaprasad, Balikuda, Kakatpur, Bhograi, Chandbali, Gop, Brahmagiri,
3.	0.33-0.42	High Moderate	Bahanaga, Baliapala, Basudevpur, Chikiti, Chatrapur, Rangelilunda, Kujanga, Puri Sadar
4.	>0.42	High	Balasore, Ganjam, Remuna

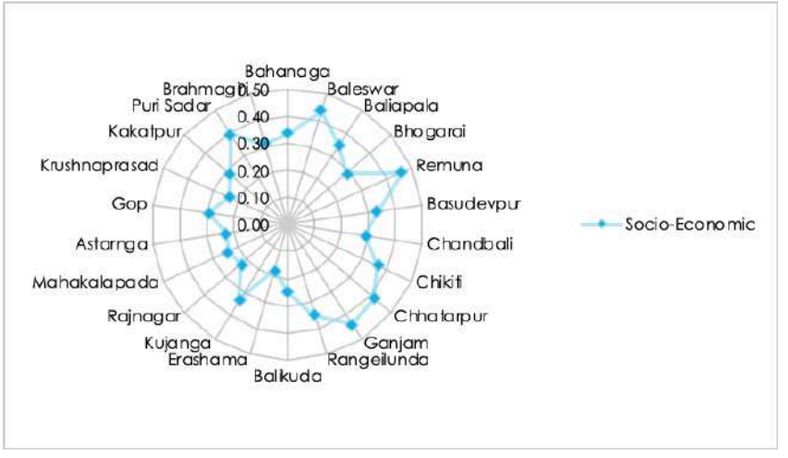


Fig. 3.15: Socio-Economic Cyclone Vulnerability Index of Coastal Blocks.

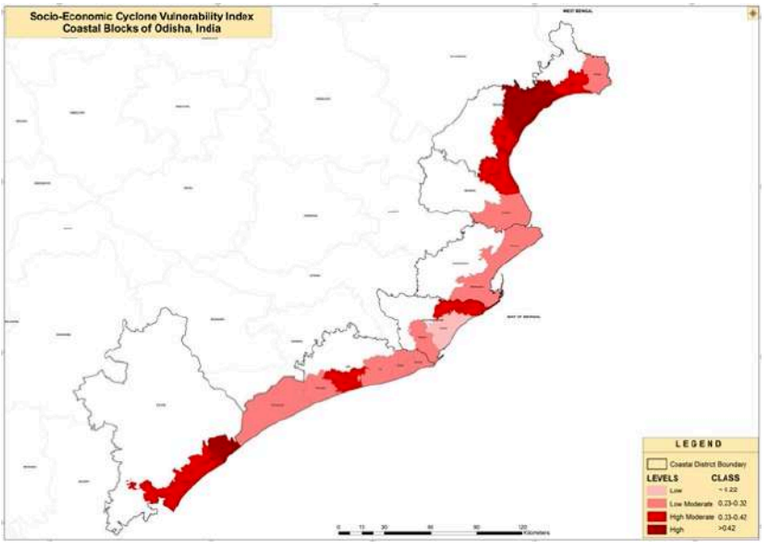


Fig. 3.16: Levels of Socio-Economic Cyclone Vulnerability in Coastal Blocks.

Built-Environment: High vulnerability of built-environment was observed in Basudevpur (0.46), and Balasore Block (0.50) in Balasore district, Rajnagar Block (0.50) in Kendrapada district, and Krushnaprasad Block (0.51) in Puri district, while low vulnerability was observed in Kujanga (0.08), Balikuda (0.09), and Erasama Block (0.13) in Jagatsinghpur district, and Rangelilunda Block (0.14) in Ganjam district. There are certain reasons for high vulnerability in these areas. The most important aspects are the smaller number of pucca houses, lesser number of cyclone shelters and all-weather roads. Drinking water facilities are also not good. Coastal embankments are another significant aspect of vulnerability.

Table 3.13: Built-Environment Cyclone Vulnerability Index

S. No.	Classes	Levels	Districts
1.	< 0.17	Low	Kujanga, Balikuda, Erasama, Rangelilunda
2.	0.18-0.31	Low Moderate	Kakatpur, Remuna, Puri Sadar,Chikiti, Bahanaga, Gop, Astaranga,
3.	0.32-0.45	High Moderate	Baliapala, Bhograi, Chandbali, Chatrapur, Ganjam, Brahmagiri, Mahakalpada
4.	>0.45	High	Basudevpur, Balasore, Rajnagar, Krushnaprasad

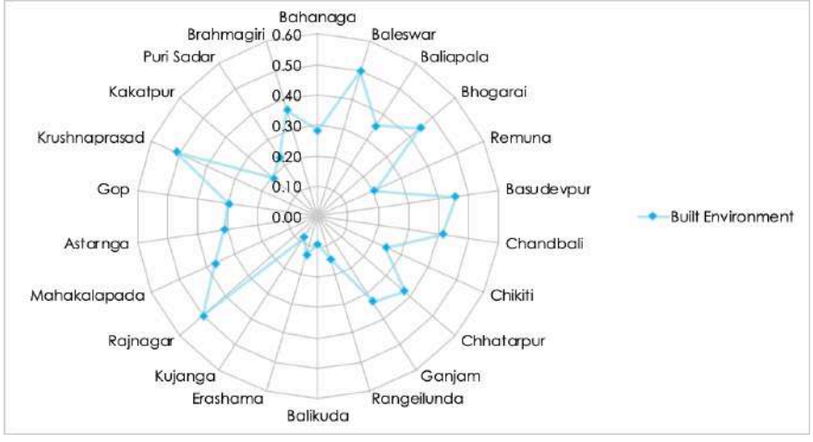


Fig. 3.17: Built-Environment Cyclone Vulnerability Index in Coastal Blocks.

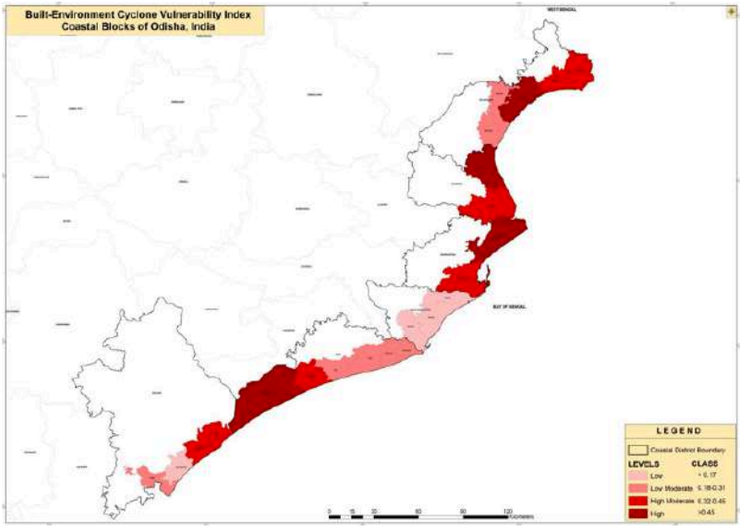


Fig. 3.18: Levels of Cyclone Vulnerability of Built-Environment in Coastal Blocks.

Institutional Vulnerability: High vulnerability was observed in the Astaranga (0.63) and Krushnaprasad (0.76) Block in Puri district and Bhogarai Block (0.70) in Balasore district whereas low vulnerability was observed in Chikiti (0.20), Rangelilunda (0.32) and Ganjam (0.32) Blocks in Ganjam district and Balikuda Block (0.29)in Jagatsinghpur district. The lesser number of training programmes, smaller number of self-help groups and conduction of less number of mock drills were the major factors responsible for enhancing the levels of vulnerability. In contrast, those villages were less vulnerable, where the above-mentioned indicators have shown good performances.

Table 3.14: Institutional Cyclone Vulnerability Index

S. No.	Classes	Levels	Districts
1.	< 0.33	Low	Chikiti, Balikuda, Ganjam, Rangelilunda
2.	0.34-0.47	Low Moderate	Chatrapur, Erasama, Kakatpur, Puri Sadar, Gop, Kujanga,
3.	0.48-0.61	High Moderate	Balasore, Bahanaga, Baliapala, Remuna, Brahmagiri, Chandbali, Basudevpur, Mahakalpada, Rajnagar
4.	>0.61	High	Astaranga, Bhogarai, Krushnaprasad

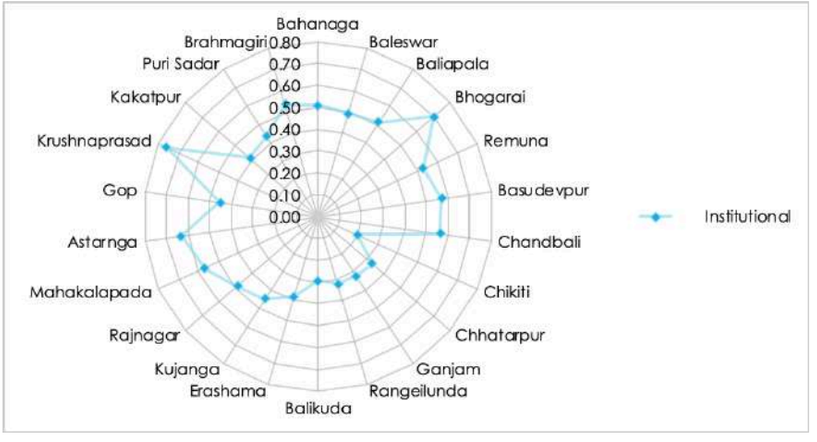


Fig. 3.19: Institutional Cyclone Vulnerability Index of Coastal Blocks.

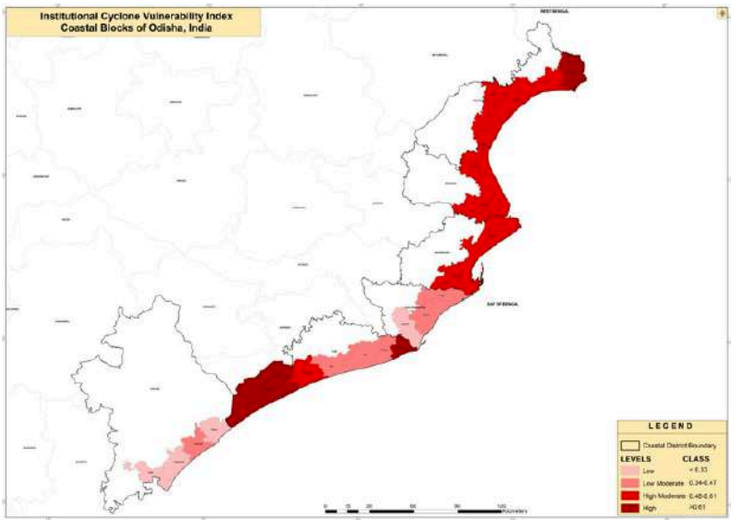


Fig. 3.18: Levels of Cyclone Vulnerability of Built-Environment in Coastal Blocks.

Relationship among the Components of Socio-Ecological Vulnerability to Cyclone

The correlational analysis of the overall composite score of the socio-ecological vulnerability to cyclone index and its various sub-components or indices i.e. bio-physical, socio-economic, built-environment and institutional are presented in Table 3.15.

It has been observed that except for socio-economic indices, rest three sub-indices i.e., bio-physical, built-environment and institutional have a high positive correlation with the overall vulnerability. It has also been found that these correlations are highly significant at a 1% level. On the other hand, it was found that the relationship between socio-economic indices with the overall vulnerability was low and non-significant. This might be due to high levels of socio-economic values in all the selected indicators and the least variations among all the 22 blocks of all the six coastal districts.

As far as the relationship among all four sub-indices is concerned, it was observed that not much strong relationship was found among all four sub-indices except the relationship between built environment and institutional indices. There is a high correlation between the built environment and the institutional indices (0.59). This is because most of the activities namely mock drills, training programmes etc. are conducted regularly at cyclone shelters.

However, it is not clear from the above analysis the specific indicators out of eighteen indicators that played a significant role in socio-ecological vulnerability to cyclones. To find out those specific indicators a Step-wise regression was used.

Table 3.15: Relationship among the Components of Socio-Ecological Cyclone Vulnerability with over all Socio-Ecological Cyclone Vulnerability

Indicators	Bio-Physical	Socio-Economic	Built Environment	Institutional	Socio-Ecological Vulnerability
Bio-Physical	1.00	0.24	0.32	0.38	0.76**
Socio-Economic		1.00	0.02	-0.30	0.21
Built Environment			1.00	0.59	0.79**
Institutional				1.00	0.75**
Socio-Ecological Vulnerability					1.00

** Correlation is significant at the 0.01 level (2-tailed).

Step-wise Regression Analysis

Step-wise regression is generally used to find a set of independent variables that significantly influence the dependent variable by using a series of tests of significance namely F-tests and t-tests. In other words, the R-Squared (R2) is a statistical measure of fit that indicates how much variation of a dependent variable is explained by the independent variable(s) in a regression model. In this analysis, overall socio-ecological vulnerability to cyclone score was taken as the dependent variable and indicators under each component were taken as the independent variables. In the below given Tables i.e., 3.16, 3.17 and 3.18 analysis of indicators under the bio-physical environment variable is provided, which reveals that out of the four indicators, two indicators were found to be highly significant (Significant at 1% level). These two indicators are total forest cover and total length of the coastline (Refer to Table 3.16).

However, the Socio-Economic model was not found significant. This might be due to the least variations among all the six indicators selected under the socio-economic variables.

Table 3.16: Relationship of Bio-Physical Indicators with Socio-ecological Vulnerability to Cyclone.

Factors	Coefficients	Std. Error	t test
(Constant)	0.269	0.037	7.219**
Total Forest Cover (%)	0.157	0.040	3.907**
Total Length of Coast Line (%)	0.165	0.051	3.267**
	R^2=0.587	F=13.521**	

** Significant at 1% level of significance

Table 3.17: Relationship of Built Environment Indicators with Socio-ecological Vulnerability to Cyclone

Factors	Coefficients	Std. Error	t test
(Constant)	0.330	0.022	15.195**
Cyclone Shelter (No.)	0.176	0.032	5.495**
Drinking Water Facilities (%)	0.089	0.028	3.161**
	R^2=0.677	F=19.924**	

** Significant at 1% level of significance

Analysis of indicators under the built environment variable revealed that the number of cyclone shelters and availability of drinking water facilities played a highly significant role (1% level of significance) in deciding the levels of vulnerability.

Table 3.18: Relationship of Institutional Indicators with Socio-ecological Vulnerability to Cyclone

Factors	Coefficients	Std. Error	t test
(Constant)	0.356	0.028	12.785**
Mock Drill	0.095	0.028	3.370**
Early Warning Dissemination Service	0.121	0.056	2.170*
	R^2=0.435	F=7.314**	

** Significant at 1% level of significance
* Significant at 5% level of significance

Analysis of the indicators under institutional variable revealed that mock drills played a highly significant role (Significant at 1% level) whereas the early warning dissemination services played a significant role (Significant at 5% level) in deciding the levels of vulnerability.

Table 3.19: Step-wise Regression for Overall Indicators

Factors	Coefficients	Std. Error	t test
(Constant)	0.105	0.036	2.901**
Built Environment CS (No.)	0.149	0.027	5.568**
Bio-Physical TAMF (%)	0.104	0.031	3.332**
Bio-Physical TFC (%)	0.104	0.021	4.928**
Built Environment DWF (%)	0.070	0.016	4.306**
Bio-Physical TLCL (%)	0.113	0.033	3.446**
Socio-Economic D (sq km)	0.069	0.029	2.342**

** Significant at 1% level of significance

Step-wise regression analysis reveals that out of all the eighteen indicators grouped under four variables, it was found that six indicators played a major role in deciding the levels of socio-ecological cyclone vulnerability with a high significance level (Significant at 1% level of significance). These six indicators are total area under mangrove forest, total forest cover, total length of coastline, cyclone shelter, drinking water facility, and density of population.

Out of these six, three indicators belong to the bio-physical variables, two variables belong to the built environment and one indicator belongs to the socio-economic variable. Not a single variable under the institutional variable was found to be significant. This might be due to the least variations amongst all the twenty-two blocks of six coastal districts

Confirmatory Factor Analysis

Confirmatory Factor Analysis (CFA) is a statistical technique used to verify the factor structure of a set of observed variables. CFA allows the researcher to test the hypothesis that a relationship between observed variables and their underlying latent constructs exists.

Conclusion

Secondary-level data analysis revealed the spatial and sectoral socio-ecological vulnerabilities. Spatial analysis revealed the levels of socio-ecological vulnerability of all six coastal districts and twenty-two coastal blocks. It has also revealed the levels of socio-ecological vulnerability in all four components namely the bio-physical, socio-economic, institutional and built-environment. Further, correlation analysis among all four components revealed that there is a highly significant correlation observed amongst all the components except for the socio-economic component. Step-wise regression analysis further revealed that out of all the eighteen indicators grouped under four variables, it was found that six indicators played a major role in deciding levels of socio-ecological cyclone vulnerability with a high significance level. This was also reconfirmed by Confirmatory Factor Analysis. This above-mentioned secondary analysis helped to bring clarity and helped in conducting primary surveys to identify the processes that made the households vulnerable.

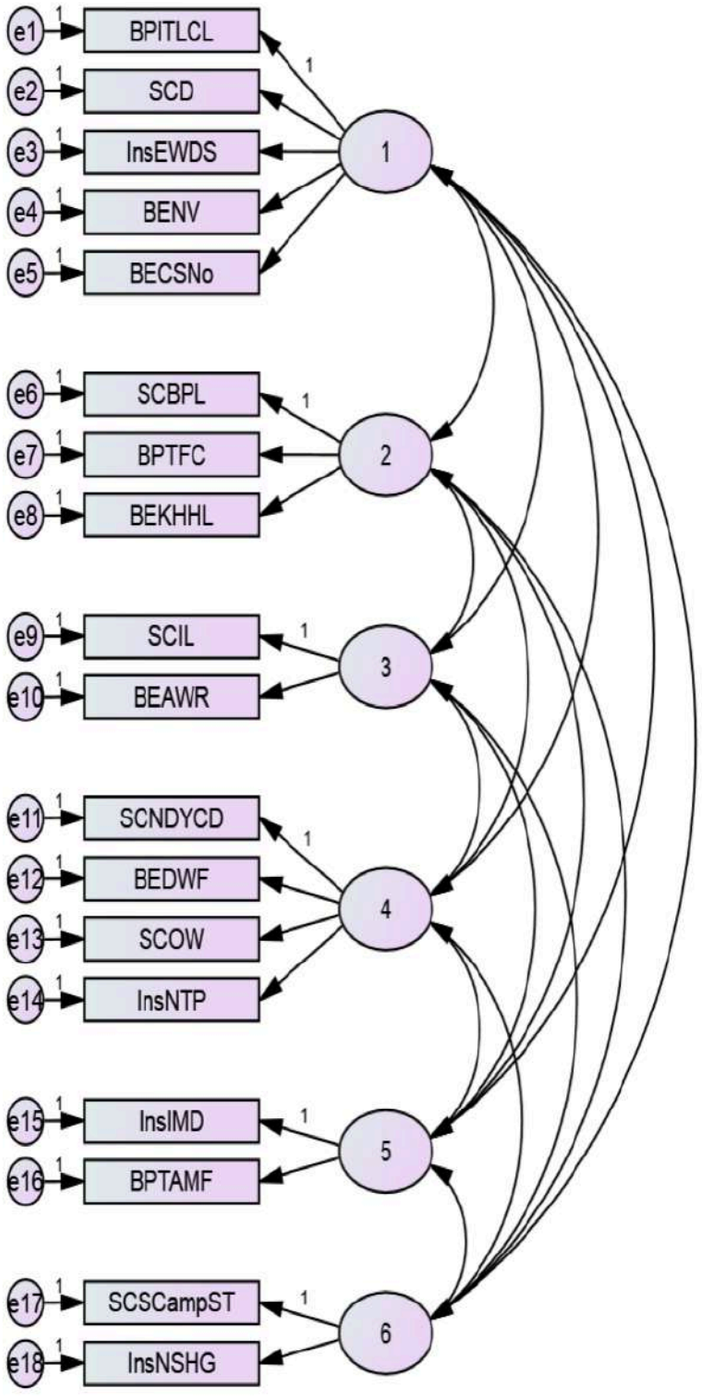


Fig. 3.21: Confirmatory factor analysis.

SOCIO-ECOLOGICAL RESILIENCE TO CYCLONE VULNERABILITY IN COASTAL ODISHA: A HOUSEHOLD-LEVEL ANALYSIS

Introduction

With the increasing population, there is huge pressure on particular places where people have tried to access their basic needs through different livelihood practices. Climate-related disasters namely cyclones and cyclone-induced flooding directly or indirectly affect the lives and livelihoods. According to the Centre for Research on Epidemiology of Disasters, around 93.1 million people annually are affected by disasters, causing 86,473 fatalities, and substantial loss of assets and infrastructures (CRED, 2023). About 85 per cent of people exposed to earthquakes, tropical cyclones, floods and droughts live in countries with either medium or low levels of development (UNDP, 2008). In the case of coastal Odisha, the lives and livelihoods of this region in general and rural livelihoods in particular are affected due to multiple shocks and stresses due to cyclones and cyclone-induced flooding. This chapter aims to analyse the social, economic and ecological vulnerability and insecurity to cyclone disasters in coastal Odisha, particularly at the household and community levels. Therefore, this analysis would help in identifying the social, economic and ecological aspects that need to be strengthened to achieve socio-ecological resilience to cyclone vulnerability in the study area.

Methodology

The available literature was reviewed and used for developing a conceptual framework. Primary as well as secondary data was collected for the study. The research design is a detailed plan of action for research. It constitutes the blueprint for collection, measurement, tabulation and analysis of the data. It has financial implications were also considered under various phases of the disaster management cycle which incorporates a descriptive research design. The research methodology adopted in this research is discussed based on the landfall locations of the cyclones (Table 4.1). In the next stage, two villages from each block were selected by using purposive sampling. Furthermore, sampled households were selected by using stratified random sampling techniques. Due representations were given to social (general and SC/ST) and economic (APL and BPL) categories. The tabular presentation of the detailed sampling design of the study is presented in Fig. 4.1.

Table 4.1: Sampled villages on the basis of Landfall locations of Cyclone

(N=206)

Name of the Districts	Name of the Blocks	Name of the Cyclone	Coastal Villages
Ganjam	Gopalpur	Phailin, Hudhud	New Buxipalli
			Rameya Patana
Puri	Puri Sadar	Fani	Penthakata
			Beladala
Balasore	Basudebpur	Yaas	
Bhadrak	Chandbali	Yaas	
Jagatsinghpur	Ershama	1999 Super Cyclone	Dhinkia Gobindpur Sandhakuda Nolia Sahi
Kendrapada	Mahakalapada	1999 Super Cyclone	Bagapatia Pentha Barahipur Jamboo

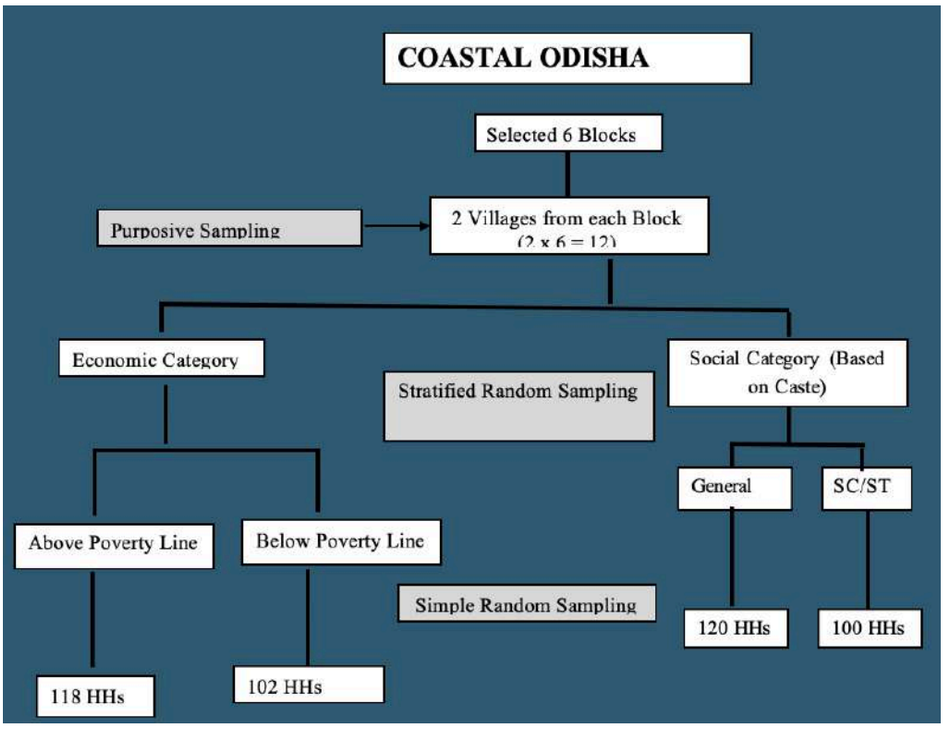


Fig. 4.1: Multi-stage sampling design used for household sampling for primary survey.

Socio-economic Profile of the Sampled Households

The socio-economic characteristics of the respondent's households are presented in Table 4.2.

1. Demographic Profile: Under the demographic compositions, the age and sex of the sampled respondents were taken into consideration. Out of 206 respondents as high as 163 (79.1%) respondents were male and the rest 43 (20.9%) were female. As far as age composition is concerned, people above 30 years of age were taken as the sample respondents. This was done to get comprehensive feedback about the experiences related to cyclones over the last two decades. Therefore, out of 206 sampled respondents, the majority of the respondents i.e., 113 (54.9%) respondents were in the age group of 30-45 years. This was followed by 46-60 years and above 60 years age groups. Seventy-three (35.4%) belong to the age group of 46-60 years whereas 20 (9.7%) belong to the age group of above 60 years.

2. Social Profile: It includes the educational status and social groups of sampled respondents. An effort was made to give a proportional representation of different social groups in consonance with their presence in Coastal Odisha. OBC constitutes a majority proportion of the population, followed by Scheduled Caste and the General Category.

Table 4.2: Socio-Economic Profile of Sampled Households

(N=206)

Category	Sub-Category	Number (Percentage)
Sex	Male	163 (79.1)
	Female	43 (20.9)
Age	30-44	113 (54.9)
	45-60	73 (35.4)
	60>	20 (9.7)
Social Group	General	45 (21.8)
	OBC	107 (51.9)
	SC and ST	54 (26.3)
Education	Illiterate	68 (33)
	Primary	70 (34)
	Matric	35 (17)
	Higher Secondary	20 (9.7)
	Graduation	8 (3.9)
	Post-Graduation	5 (2.4)
Occupation	Government	1(0.5)
	Private	1(0.5)
	Business	25 (12.1)
	Agriculture	59 (28.6)
	Fisheries	79 (38.3)
	Agriculture Labour	16 (7.8)
	Allied Activities	12(5.8)
	Self Employed	13(6.3)
Assets	Motorcycle	64(31.1)
	Car	19(9.2)
	Tractor	3(1.5)
	Cycle	36(17.5)
	None	84(40.8)
Housing Type	Pucca	77(37.4)
	Semi-Pucca	56(27.2)
	Kutcha	73(35.2)

The presence of Scheduled Tribe population is the least in Coastal Odisha. This study has combined SC and ST sampled respondents together. Out of the 206 (100%) sampled respondents 107 (51.9%), 54 (26.3%) and 45 (21.8%) belonging to OBC, General and SC and ST categories respectively. The other attribute taken into consideration under the social category was literacy. Out of 206 (100%) respondents, 68 (33%) were illiterate and rest of the 138 (67%) were literate. There was a sizeable proportion of illiterate respondents because of the out-migration of literate and skilled persons to different parts of the country as well as to different parts of the world in search of livelihood. If we further analyse the educational qualifications of the total respondents, there were only 13 (6.3%) respondents who were graduates and post-graduates as per their qualifications. There were 55 (26.7%) respondents who matriculated and the rest of the respondents i.e., 70 (33%) had up to primary level of education.

3. Economic Profile: The study included occupations, assets and house types under the economic profiling of the respondents. While analysing the occupation profile of the respondents it was observed that the maximum respondents were dependent on fisheries (38.3%) followed by agriculture (28.6%). This was followed by business (12.1%), agricultural labourer (7.3%), and self-employed (6.3%).

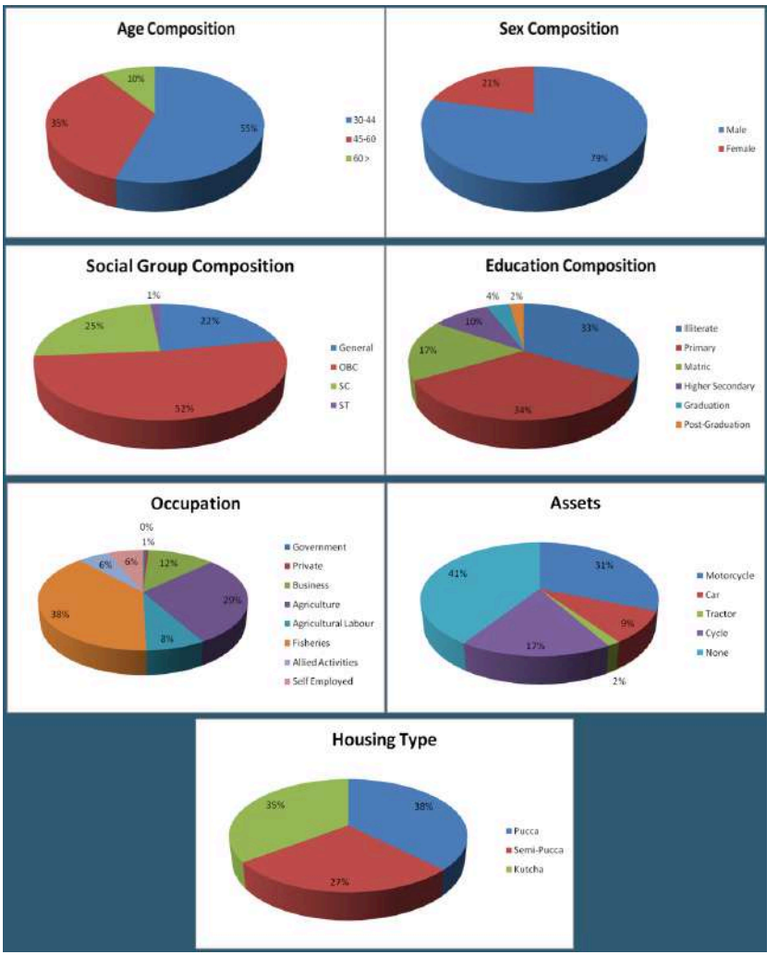


Fig. 4.2: Socio-Economic Profile of the Sample Households

Results and Discussions

On the basis of the primary survey at household level, the results have been tabulated and presented in the following sections.

Status of Socio-Ecological Parameters in the Sampled Households: The below given Table 4.3 presents profile of the socio-ecological parameters of the 206 sampled households. Table 4.3 represents the status of the socio-ecological parameters of sampled households. The seven selected parameters were proximity, accessibility, infrastructure, income and savings, community awareness and cohesiveness, community-based preparation, and community participation.

In proximity, all the indicators show the distances of living people from any particular location. These are proximity to the sea, proximity to cyclone shelters, and proximity to major roads. All of these were categorised into three categories: less than 1 km, 1-2 km, and greater than 2 km. The majority of the households are located within 1 km proximity to the sea (63.1%), proximity to a cyclone shelter (72.3%) and proximity to a major road (69.9%).

Under the accessibility category, indicators were transport availability, clean water access, access to health services, and internet accessibility. These indicators were assessed based on three parameters: high, moderate, and low.

A majority of the respondents believed that accessibility was poor for access to clean water (44.2%), access to health services (54.9%), and access to telecommunication facilities (69.9%). In general, telecommunication facilities are below the national average in rural Odisha.

Under the infrastructure category, indicators were, effective early planning, evacuation plans, during and post-cyclone support. All indicators were assessed in three categories: low, medium, and high. In all four indicators, majority of the sampled respondents were of rated their experience as either moderate or high (Refer to Table 4.3).

During field surveys, it was observed that majority of the sampled households had a single source of income (95.1%) and were climate-sensitive in nature. As the source of income was climate-sensitive, cyclones had severe impacts on their livelihoods. As their amount of income was meagre, these households did not have much savings to be used at the time of disasters.

Community awareness and cohesiveness about the cyclone, the sampled population have a fair amount of knowledge (about 90%) of cyclones and most of this knowledge they have is due to experiential learning by handling previous cyclones.

Cohesiveness amongst the local people was found to be moderate to high, as their realization suggests that they will help themselves even before the arrival of government help and support.

Six Indicators under community-based preparation and community participation were also assessed in the same three categories namely low medium and high. Out of the six indicators, respondents had an opinion that the majority of women participated in community-based DRR activities. On the other hand, about half of the respondents have not attended any community-based training programmes.

Table 4.4 depicts the household's response to various aspects related to the cyclone. These questions pertain to cyclone-related problems, services, and strategies. In the case of a cyclone, information about the forthcoming cyclone is the most significant aspect for residing people to vacate their homes and move to a safer place. Out of 206 respondents, 123 (59.7%) respondents informed that they received information from sources that include the forest department,

Table 4.3: Status of Socio-Ecological Parameters in the Sampled Households (N=206)

S. No.	Parameters	Category	Sub-Category	Number (Percentage)
1.	**Proximity**	Proximity to sea	< 1 km	130 (63.1)
			1-2 km	17(8.3)
			> 2 km	59 (28.6)
		Proximity to cyclone shelter	< 1 km	149(72.3)
			1-2 km	42(20.4)
			> 2 km	15(7.3)
		Proximity to major road	< 1 km	144(69.9)
			1-2 km	44(21.4)
			> 2 km	18(8.7)
2.	**Accessibility**	Transportation Availability	Poor	21(10.2)
			Moderate	134(65.0)
			Good	51(24.8)
		Clean Water Access	Poor	91(44.2)
			Moderate	91(44.2)
			Good	24(11.7)
		Health services access	Poor	113(54.9)
			Moderate	84(40.8)
			Good	9(4.4)
		Internet Accessibility	Poor	144(69.9)
			Moderate	56(27.2)
			Good	6(2.9)
3.	**Infrastructure**	Effective early warning	Low	40(19.4)
			Medium	78(37.9)
			High	88(42.7)
		Evacuation plan	Low	36(17.5)
			Medium	90(43.7)
			High	80(38.8)
		During cyclone support	Low	64(31.1)
			Medium	104(50.5)
			High	38(18.4)
		post cyclone support	Low	43(20.9)
			Medium	124(60.2)
			High	39(18.9)
4.	**Income and Savings**	Personal income (yearly)	< 1 lakh	191(92.7)
			1-3 lakh	13(6.3)
			>3 lakh	2(1.0)
		Diverse income	1 source	196(95.1)
			2 sources	8(3.9)
			> 2 sources	2(1.0)
		Savings	No Savings	141(68.4)
			<50,000	58(28.2)
			>50,000	7(3.4)
5.	**Community Awareness and Cohesiveness about Cyclone**	Cyclone Awareness	Poor	19(9.2)
			Moderate	94(45.6)
			Good	93(45.1)
		Local knowledge	Poor	59(28.6)
			Moderate	65(31.6)
			Good	82(39.8)
		Get help	Don't have	50(24.3)
			May be have	85(41.3)
			Certainly have	71(34.5)
		Willing to help	Low	39(18.9)
			Medium	104(50.5)
			High	63(30.6)
		Community Activities	Low	37(18.0)
			Medium	113(54.9)
			High	56(27.2)
		Experience learning	Low	66(32.0)
			Medium	42(20.4)
			High	98(47.6)
		Trust and hope among Community	Low	30(14.6)
			Medium	119(57.8)
			High	57(27.7)
		Level of community connectivity	Low	28(13.6)
			Medium	112(54.4)
			High	66(32.0)

fishermen, and the local panchayat head (Sarpanch). Police (38.3%) were the next source of information among all the categories. Cyclone exercises were most important for local people to understand about cyclones. While discussing this question, 117 (56.7%) respondents answered affirmatively about existing cyclone exercises in their area, while 89 (43.2%) responded answered negatively. In the case of the regular conduct of cyclone exercises, about 54% of the respondents believed that it did not happen regularly. It increases the vulnerability of local people. Most of the households (88.8%) followed the guidelines related to cyclones as provided by the government. This is a positive aspect of local people saving lives and owning assets.

It has been observed that the use of multi-media namely electronic media, print media, cable channels, street shows, and screening documentary shows has not been used extensively for creating awareness. Among all the above-mentioned informatory bodies providing cyclone information, the role of print media is quite good in comparison to others. The government and local bodies should increase the use of these multi-media in creating awareness about cyclone preparedness.

6.	**Community based preparation**	Level of preparation	Less	43(20.9)
			Moderate	75(36.4)
			Good	88(42.7)
		Hazard Coping Plan	Don't have	72(35.0)
			May be have	48(23.3)
			Certainly have	86(41.7)
		Volunteer provision	Don't have	86(41.7)
			May be have	52(25.2)
			Certainly have	68(33.0)
7.	**Community Participation**	Decision making	Low	40(19.4)
			Medium	102(49.5)
			High	64(31.1)
		Training Participation	Low	101(49.0)
			Medium	53(25.7)
			High	52(25.2)
		Women Participation	Low	51(24.8)
			Medium	108(52.4)
			High	47(22.8)

Table 4.4: Sampled Household Response related to Cyclone (N=206)

S. No.	Category	Sub-Category	Number (Percentage)
1.	Information of forthcoming cyclone	Police	79 (38.3)
		Others	123 (59.7)
		Ambulance Services	3 (1.5)
		All of Above	1 (0.5)
2.	Cyclone Exercise	Yes	117 (56.8)
		No	89 (43.2)
3.	If yes, regularly conducted	Yes	95 (46.1)
		No	111 (53.9)
4.	Follow guidelines and regulations	Yes	183 (88.8)
		No	23 (11.2)
5.	Advertisement in EM	Yes	19 (9.2)
		No	187 (90.8)
6.	Print Media	Yes	109 (52.9)
		No	97 (47.1)
7.	Cable Channels	Yes	30 (14.6)
		No	176 (85.4)
8.	Street Shows	Yes	18 (8.7)
		No	188 (91.3)
9.	Screening Documentary	Yes	32 (15.5)
		No	174 (84.5)
10.	Any Other	Yes	27 (13.1)
		No	179 (86.9)

Table 4.5: Barriers and Constraints to Cyclone Resilience under Five Capitals

(N=206)

S. No.	Capitals	Category	Sub-Category	Number (percentage)
1.	**Human Capital**	Lack of execution of plan	No	77 (37.4)
			Yes	129 (62.6)
		Migration led labor scarcity	No	104 (50.5)
			Yes	102 (49.5)
		Lack of knowledge	No	102 (49.5)
			Yes	104 (50.5)
		Health Facility during cyclone	No	92 (44.7)
			Yes	114 (55.3)
2.	**Natural Capital**	Cyclone frequency	No	3 (1.5)
			Yes	203(98.5)
		Sea Proximity	No	4(1.9)
			Yes	202(98.1)
		Severity of cyclone damage	No	18(8.7)
			Yes	188(91.3)
3	**Physical Capital**	Lack of institution to accurate dissemination of news	No	64(31.1)
			Yes	142(68.9)
		Lack of onset cyclone support	No	73(35.4)
			Yes	133(64.6)
		Effective Early Warning System	No	72(35.0)
			Yes	134(65.0)
		Proximity to cyclone shelter	No	37(18.0)
			Yes	169(82.0)
		Proximity to all weather roads	No	87(42.2)
			Yes	119(57.8)
4	**Financial Capital**	Income Constrains	No	66(32.0)
			Yes	140(68.0)
		Lack of diversified livelihood income source	No	34(16.5)
			Yes	172(83.5)
		No Savings for economic Stability	No	38(18.4)
			Yes	168(81.6)
		Loans	No	153(74.3)
			Yes	53 (25.7)
		Lack of banking awareness	No	75(36.4)
			Yes	131(63.6)
		Absence of market for selling products	No	83(40.3)
			Yes	123(59.7)
5.	**Social Capital**	Lack of strong organization	No	49(23.8)
			Yes	157(76.2)
		Lack of discussion platform	No	61(29.6)
			Yes	145(70.4)
		Lack of social cohesiveness	No	52(25.2)
			Yes	154(74.8)
		Lack of trust and hope as community among each other's.	No	89(43.2)
			Yes	117(56.8)
		Community participation (Training/ Experience)	No	102(49.5)
			Yes	104(50.5)
		Lack of community Institution and network	No	60(29.1)
			Yes	146(70.9)

Analysis of twenty-four indicators under five capitals reveals the following facts: Table 4.5 depicts the socio-ecological resilient status of the sampled household. Twenty-four indicators were selected under five capitals. Out of twenty-four indicators, eleven indicators were found as major socio-ecological barriers (more than 70% of sample households) to resilience. Out of these eleven indicators, four indicators are from social capital followed by three each from natural and financial capital and one indicator from physical capital.

Under the **natural capital** majority of the respondents (more than 90%) felt that frequent cyclones, proximity to sea and severity of cyclone damage were perceived as major barriers. Out of these three indicators, about 98% of the respondents across the state considered frequent cyclones and proximity to the sea as the most prominent barriers to cyclone-resilient communities.

Analysis of the household responses on the **physical capital** indicators revealed that out of five indicators, one indicator namely proximity to cyclone shelter is still acting as a major barrier (about 82%). However, the state has constructed a large number of cyclone and flood shelters along the coastal belts across the state.

In **financial capital**, out of five indicators, two indicators namely lack of diversified livelihood income source and no savings for economic stability were considered as major economic barriers.

More than 80% of the sample households felt that there is a need for the diversification of livelihoods especially from the climate-sensitive sectors to climate-neutral sectors.

In **social capital**, the majority of sampled households have responded that there were so many weaknesses related to social capital to address the cyclone vulnerability namely lack of strong organisation, discussion, social cohesiveness, and community institutions and networks. These factors were the major barriers to coping with the human vulnerability to cyclones. Community participation in the context of training or experience is moderate, which is also the prime cause of vulnerability.

Under **human capital**, more than fifty-five per cent people have reported that there was a lack of an execution plan and health facilities during cyclones. While addressing the knowledge of cyclones, it was observed that levels of awareness were moderate, i.e., 51.5%. Local people and the government should address this matter and increase knowledge and awareness of cyclones among the masses.

In the last section of the questionnaire, a Five-point Rating Scale was presented on nine different aspects that are related to resilience capacity. Below given are the opinions of all the 206 sampled population (Refer to Table 4.6).

Table 4.6: Resilience Capacity Rating of the Sampled Population

(N=206)

S. No.	Category	Sub-Category	Number (Percentage)
1.	**Absorptive Capacity**	Agree	4(1.9)
		Strongly Agree	13(6.3)
		Disagree	100(48.5)
		Strongly Disagree	7(3.4)
		Neither Agree nor Disagree	82(39.8)
2.	**Adaptive Capacity**	Agree	10(4.9)
		Strongly Agree	2(1.0)
		Disagree	108(52.4)
		Strongly Disagree	81(39.3)
		Neither Agree nor Disagree	5(2.40)
3.	**Anticipatory Capacity**	Agree	38(18.4)
		Strongly Agree	4(1.9)
		Disagree	139(67.5)
		Strongly Disagree	19(9.2)
		Neither Agree nor Disagree	6(2.9)
4.	**Transformative Capacity**	Agree	51(24.8)
		Strongly Agree	3(1.5)
		Disagree	81(39.3)
		Strongly Disagree	63(30.6)
		Neither Agree nor Disagree	8(3.9)
5.	**Financial Capital**	Agree	72(35.0)
		Strongly Agree	4(1.9)
		Disagree	59(28.6)
		Strongly Disagree	57(27.7)
		Neither Agree nor Disagree	14(6.8)
6.	**Social Capital**	Agree	97(47.1)
		Strongly Disagree	22(10.7)
		Disagree	63(30.6)
		Neither Agree nor Disagree	24(11.7)
7.	**Political Capital**	Agree	88(42.7)
		Strongly Agree	4(1.9)
		Disagree	49(23.8)
		Strongly Disagree	30(14.6)
		Neither Agree nor Disagree	35(17.0)
8.	**Learning**	Agree	117(56.8)
		Strongly Agree	59(28.6)
		Disagree	24(11.7)
		Strongly Disagree	1(0.5)
		Neither Agree nor Disagree	5(2.4)
9.	**Early Warning**	Agree	63(30.6)
		Strongly Agree	65(31.6)
		Disagree	76(36.9)
		Strongly Disagree	1(0.5)
		Neither Agree nor Disagree	1(0.5)

The analysis of people's responses revealed the following points:

(i) Absorptive capacity: Despite various measures undertaken by the state government, the majority of the households (about 52%) still felt that they were not sure that they could bounce back from any challenge that life throws at them. However, a significant proportion of sampled households were unsure (about 40%) about their absorptive capacity.

(ii) Adaptive capacity: Adaptation is one of the major strategies for reducing cyclone vulnerability at the household level. The questions asked under this category were that whether they have developed an adaptive capacity to counter threats by frequent and intense cyclones? About 53% of people had the opinion that they do not have the adaptive capacity to deal with the adverse situation that emerged due to the cyclone. It shows that people are still more vulnerable to the intensity of cyclones.

(iii) Anticipatory capacity: This capacity discusses how much individual households are prepared to face the cyclone in the future. Cyclones have been a recurring phenomenon in this part of the state. Therefore, households need to anticipate and develop their capacity to (i) address the cyclone vulnerability. About 70% of the respondents believed that they lacked the capacity to prepare their house to face any cyclone vulnerability. It is because of poor assets, income, savings, and a lack of knowledge.

(i) Transformative capacity: It refers to the capacity to transform themselves and their society during times of hardships by changing their primary income or source of livelihood if needed. About 40% of the respondents had an opinion that It would be difficult to change the source of income due to limited opportunities, especially in rural areas.

(ii) Financial Capital: This capital shows how much people can access financial support at the time of need, i.e., hardship. About Thirty-five percent of respondents agreed that people and government are both helpful. They have provided help to the people during the time of hardship.

(iii) Social Capital: This capital refers to the fact that the affected people's households can rely on the support of other people, i.e., family and friends when they need help. About 47 percent of people agree that they rely on friends and family in times of need. It is because of limited resources and living conditions.

(iv) Political Capital: It describes the role of politicians and the government in providing help to households in handling situations that emerged due to cyclones. Political capital is the kind of support that strengthens the local people. About 42% of people agreed that the government would help during the cyclone. The government also supports the people in the form of basic amenities like water, food, shelter, and sanitation.

(i) Early Warning: It refers to advance information to households related to any forthcoming disasters. An early warning system addresses the risks and minimises them by alerting people. About 37% of the respondents revealed that they receive the information and alertness through the Early Warning Systems. It has been improving day by day, but the government should also think about developing a better plan at the local level.

Factors Affecting the Resilience Strategies for developing Socio-Ecological Resilience: To investigate the Socio-ecological resilience affecting the resilience strategies (pre, post and during) the following multiple regression model has been applied.

$$Y=\beta 0+\beta 1X1+\beta 2X2+...+\beta nXn$$

In the above model Resilience strategies score was used as dependent factors (Y) and various questions of the Socio-Ecological Resilience used as independent factors (Xi's).

Out of seven parameters, four parameters namely proximity to sea, accessibility to various facilities, infrastructure and community participation do not have any significant relationship with strategies adopted for developing socio-ecological resilience.

On the contrary, three parameters namely income and savings, community awareness and cohesiveness about cyclone and community-based preparation have significant relationships

Table 4.7: Step-wise Regression Analysis for Identification of Factors affecting the Resilience Strategies in relation to Socio-ecological Status of the Sampled Households

	Socio-Ecological Resilience	Coefficients (βs')	Std. Error	't' value
	Constant	1.68	0.89	1.89
X_1=	Proximity	0.00	0.07	0.04 NS
X_2=	Accessibility	-0.08	0.07	1.13 NS
X_3=	Infrastructure	-0.04	0.07	0.64 NS
X_4=	Income and Savings	-0.38	0.12	3.17**
X_5=	Community Awareness and Cohesiveness about Cyclone	0.17	0.05	3.89**
X_6=	Community-based preparation	0.35	0.08	4.22**
X_7=	Community Participation	0.11	0.08	1.50 NS
	F value = 48.283**			
	R Square=0.631			
	Adjusted R Square=0. 618			

**** Significant at 1% level of significance**
*** Significant at 5% level of significance**
NS - indicating the values are not significant at the desired level of significance

with strategies adopted for developing socio-ecological resilience. Out of these three, one parameter namely income and savings had a negative effect whereas two parameters namely community awareness and cohesiveness about cyclone and community-based preparation had a positive effect.

Factors Affecting as Barriers to the Resilience Strategies: To investigate the barriers affecting the resilience strategies (pre, post and during) the following multiple regression model has been applied.

$$Y=\beta 0+\beta 1X1+ \beta 2X2+...+ \beta nXn$$

In the above model, the Resilience strategies score was used a dependent factor (Y) and various questions of resilience and barriers were used as independent factors (Xi's)

It has been observed that some barriers are not providing good results and showing non-significance results. To find out the potential explanatory barriers that are affecting the resilience strategies, the stepwise regression has been fitted. As mentioned earlier Stepwise regression is the step-by-step iterative construction of a regression model that involves the selection of independent variables to be used in a final model.

Table 4.8: Step-wise Regression Analysis for Identification of Barriers to the Resilience Strategies

Barriers /Constrains in Resilience (Factors)		Coefficients(β_is')	Std. Error	't' value
	Constant	8.33	0.39	21.25**
X_1=	Health facility during cyclone	1.22	0.20	6.17**
X_2=	Lack of banking awareness	-0.65	0.21	3.03**
X_3=	Income Constrains	-1.24	0.20	6.35**
X_4=	Lack of social cohesiveness	-1.04	0.23	4.59**
X_5=	Lack of diversified livelihood income source	-0.60	0.25	2.41*
X_6=	Lack of discussion platform	-0.62	0.24	2.55*
X_7=	No savings for economic Stability	-0.59	0.24	2.50*
X_8=	Absence of market for selling products	0.72	0.21	3.38**
X_9=	Lack of strong organization	-0.88	0.31	2.84**
F value = 40.223**				
R Square=0.649				
Adjusted R Square=0.633				

**** Significant at 1% level of significance**

*** Significant at 5% level of significance**

It involves adding or removing potential explanatory variables in succession and testing for statistical significance after each iteration.

Out of twenty-four indicators under the five capitals namely natural, physical, human, social and financial, nine indicators were found significant. Out of these nine, six indicators had a negatively significant effect whereas the other three indicators had a positively significant effect. The factors having a significant negative impact on households of the coastal villages were health facilities during cyclones, lack of banking awareness, income constraints, lack of social cohesiveness, lack of diversified livelihood income source, lack of discussion platform, no savings for economic stability and strong organization. Contrary to this, health facilities during the cyclone and the absence of a market for selling their products have a very significant positive impact on households of the coastal villages.

Out of these nine factors six factors namely lack of banking awareness, income constraints, lack of social cohesiveness, and strong organization are significant at 1% level of significance. Lack of diversified livelihood income source, lack of discussion platform, and no savings for economic stability are significant at 5% level of significance.

Relationships between Factors affecting the Resilience Strategies and Socio-Economic Profile of the Sampled Households: In this analysis, an attempt has been made to find out the effects of different socioeconomic statuses on resilience strategies adopted by the households pre, post and during the disaster. To investigate the Socio-economic indicators affecting the resilience strategies (pre, post and during) the following multiple regression model has been applied.

$$Y=\beta 0+\beta 1X1+ \beta 2X2+...+ \beta nXn$$

In the above model, the Resilience strategies score was used as dependent factors (Y) and various indicators of Socio-economics used as independent factors (Xi's).

The analysis revealed that two demographic variables namely age and sex did not have any significant relationship in deciding strategies adopted by the household pre, post and during the disaster. On the contrary, the other three socio-economic statuses namely social group, education and primary occupation played a significant role in deciding strategies adopted by the household pre, post and during the disaster. Out of these three, education and primary occupations were found highly significant whereas social groups were found to be significant.

Table 4.9: Step-wise Regression Analysis for Identification of Factors affecting the Resilience Strategies in relation to Socio-Economic Profile of the Sampled Households

	Socio-economic factors	Coefficients (β_is')	Std. Error	't' value
	Constant	5.966	0.711	8.385**
X_1=	Social Group	-0.408	0.171	2.389*
X_2=	Sex	0.457	0.300	1.523^{NS}
X_3=	Age	0.069	0.174	0.399 ^{NS}
X_4=	Education	0.631	0.096	6.603**
X_5=	Primary Occupation	-0.392	0.093	4.191**
	F value = 18.29**			
	R Square=0.314			
	Adjusted R Square=0.297			

**** Significant at 1% level of significance**

*** Significant at 5% level of significance**

NS - indicating the values are not significant at the desired level of significance

Relationships between Factors affecting the Resilience, Capacity Rating and Barriers to Socio-ecological Resilience: To investigate the resilience and barrier indicators affecting the resilience capacity rating the following multiple regression model was applied.

$$Y=\beta 0+\beta 1X1+ \beta 2X2+...+ \beta nXn$$

In the above model resilience capacity rating scores were used as dependent factors (Y) and various questions of resilience and barriers were used as independent factors (Xi's).

Out of twenty-four indicators under five capitals namely natural, physical, human, social and financial, six indicators were found significant.

Out of these six, three indicators are negative significant effect whereas the other three indicators are positive significant effect. The severity of cyclone damage and, the absence of market and loan facilities have significant negative impact on households in the coastal villages.

The severity of cyclone damage and loan facilities are significant at 5% level of significance whereas the absence of a market is significant at 1% level of significance. Contrary to this, migration-led labour scarcity, income constraints and lack of banking awareness have a very significant positive impact on households of the coastal villages.

Table 4.10: Step-wise Regression Analysis for Identification of Factors affecting the Resilience Capacity Rating and Barriers to Socio-ecological Resilience

	Resilience and Barriers	Coefficients(β_is')	Std. Error	't' value
	Constant	17.742	0.613	28.940**
X_1=	Migration led labor scarcity	1.771	0.329	5.383**
X_2=	Income Constrains	1.074	0.325	3.306**
X_3=	Severity of cyclone damage	-1.177	0.523	2.251*
X_4=	Lack of banking awareness	0.884	0.331	2.670**
X_5=	Absence of market for selling products	-0.957	0.314	3.048**
X_6=	Loans	-0.787	0.349	2.255*
	F value =19.387 **			
	R Square=0.369			
	Adjusted R Square=0.350			

**** Values are indicating significant at 1% level of significance**

***** Values are indicating significant at 5% level of significance**

Conclusions

The house-old level analysis reveals the situation at the grassroots level. It has also highlighted everyday geographies of ordinary people, everyday actions, and commonplace events. Analysis also revealed barriers namely lack of diversification of livelihoods, financial awareness, availability of loan facilities, concrete houses etc. to name a few.

However, it has also brought out the good progress made at institutional, socio-economic and built-environment levels. Continuous efforts should be made to enhance especially adaptive and transformative capacity by strengthening all five capitals in general and physical and financial capital in specific.

Plate 4.1: Good and Bad Facets of Cyclone Shelter

Plate 4.2: Interactions with Community and Cyclone Shelter Management Committee Members

Plate 4.3: Interactions with Government Officials of Local Administration

Plate 4.4: Interactions with Fishing Communities at New Buxi Palli (Gopalpur) in Ganjam District and Nolia Sahi (Ershama) in Jagatsinghpur District.

STRATEGIC RECOMMENDATIONS

Technical Findings

In the present study, vulnerability assessment at the district, block and household levels has been taken into consideration besides adaptations and barriers to it. The major findings of the study were as follows-

1. Spatio-temporal analysis of the cyclones reveals that maximum cyclones in the state occur in October and November followed by May and June. In terms of spatial locations of cyclone landfall is concerned, maximum land fall occurs in and around Paradeep in Jagatsinghpur district followed by Gopalpur in Ganjam district and in and around Puri in Puri district.

2. Severe coastal erosion has been observed along the 480 km long coastline during the field visit and analysis of satellite imagery. Maximum coastal erosion in terms of percentages has been observed in Puri district (116) followed by Kendrapada district (69), Jagatsinghpur district (43) and Ganjam district (33).

Some of the vulnerable stretches of coast where villages are on the verge of submergence undersea that need immediate action are:

- Satabhaya and Pentha in Kendrapada district Siali and Nolia Sahi in Jagatsinghpur district Puri-Konark Marine Drive and Arakhkuda in Puri district Podampeta and Ramyapatna in Ganjam district.
- The state should use the experience gained from the construction of the geo-tube wall at Pentha village in Raj Nagar block of Kendrapada district and the saline embankment constructed in different parts of all six coastal districts.

3. Massive afforestation along the coast is another measure for mitigating cyclone vulnerability. While doing afforestation, it has to be kept in mind the tree that is more resistant to high-speed wind namely Neem, Karanja, Baula, Jamun, Khaira, Arjun, Ashok, Harida, Bahada, Shisu, Champa and Dimiri.

4. Reviving the littoral zone (About 3 KM from the coast) would provide Nature – Based Solution (NBS) for mitigating cyclones and enhancing livelihoods. It includes the revival of mangroves, Casurina trees in sandy soil and If the overall socio-ecological vulnerability is compared district-wise, Puri was most vulnerable whereas Jagatsinghpur was the least vulnerable. Component-wise analysis revealed that Puri was the most vulnerable in the bio-physical component whereas Bhadrak was most vulnerable in the socio-economic component. Puri was the most vulnerable in the built-environment component whereas Kendrapada was the most vulnerable in institutional component.

5. Block level analysis revealed that Kakatpur in Puri districts, and Erasama and Balikuda in Jagatsinghpur districts were the least vulnerable whereas Krushna Prasad block in Puri district and Balasore Sadar block in Baleshwar district were the most vulnerable blocks.

6. The majority of people depend on climate-sensitive sectors which is popularly known in Oriya as "Pana (beetle leaf), Mina (Fish) and dhana (Rice)". There are two associated problems with these three livelihoods. These are highly climate-sensitive sectors and secondly, it does not provide livelihoods for the entire family throughout the year. This needs to be strengthened by making sectoral plans for agriculture, horticulture and fisheries to make these sectors climate-resilient and provide sustainable livelihoods.

particularly on these climate-sensitive sectors. It affects standing crops, winter vegetables, aquaculture, and particularly prawn farming. Therefore, there should be a plan for addressing climate-sensitive sectors like agriculture, horticulture and pisciculture.

8. There is a need for developing more fishing harbours in the state and bigger mechanized boats to go for deep sea fishing. There is an urgent need to augment cold storage facilities to support fishing activities. As the state lacks these facilities, family members of these communities migrate to other coastal states like Andhra Pradesh, Tamil Nadu and Kerala to work in the fishing and other sectors. Though, Odisha State Fisheries Policy-2015 duly acknowledge the need for strengthening various fishing infrastructures and making them more effective, there has been a collaboration between the Fisheries and Animal Resources Development Departments, the Government of Odisha and The World Fish, Malaysia, the progress has been observed are very low.

9. As far as Multi-purpose Cyclone Shelters (MCS) and Multi-purpose Flood Shelters (MFS) are concerned, the Odisha Government constructed various shelters over the years, but their utilization throughout the years has not been at a satisfactory level. There are certain cyclone shelters built by the Maharashtra Government in Jagatsinghpur district have been lying in a dilapidated condition. Similar is the condition of the

building constructed by the Red Cross Society. All of the above mentioned MCS needs to be revamped and made functional.

10. District and Block level analysis revealed that except the socio-economic indices, rest three sub-indices i.e., bio-physical, built-environment and institutional have a high positive correlation with the overall vulnerability and were also found to be highly significant at 1% level. On the other hand, it was found that the relationship between the socio-economic indices and the overall vulnerability was low and not significant. This might be due to high levels of socio-economic values in all the selected indicators and the least variations among all 22 blocks of all six coastal districts. This was reaffirmed by step-wise regression in which the socio-economic model was not found significant.

11. Step-wise regression analysis reveals that out of all eighteen indicators grouped under four variables, it was found that six indicators played a major role in deciding levels of the socio-ecological cyclone vulnerability with a high significance level (Significant at 1% level of significance). These six indicators are total area under mangrove forest, total forest cover, total length of coastline, cyclone shelter, drinking water facility, and density of population. Out of these six, three indicators belong to the bio-physical variables, two variables belong to the built environment and one indicator belongs to the socio-economic variable.

Not a single variable under institutional variables was found to be significant. This might be due to the least variations amongst all twenty-two blocks of six coastal districts

12. There is a need for making a balance between the mitigation and adaptation measures. Both efforts should continue simultaneously. Mitigation measures could be grouped as structural and non-structural. Structural measures are those measures which include Important mitigation measures are rejuvenating and enhancing forests including mangrove cover all along the entire coast, construction of coastal embankments, conversion of all kutcha houses to pucca houses, all-weather metalled roads to all the villages, disaster resilient electrical and telecommunication system.

13. Adaptation strategies will include the construction of cyclone-resistant buildings, the construction of more cyclone shelters, diversification of livelihood and climate-proofing of livelihood activities.

Methodological Lessons/ Innovations

The study regarding cyclone vulnerability characteristics facilitates a comprehensive approach to better understand the dynamic characteristics of cyclones and their complex interaction from various perspectives over Coastal Odisha.

It thus helps to provide sustainable cyclone mitigation measures. Step-wise regression analysis and a Confirmatory Factor Analysis helped in identifying the modelling of dependence structures of variables involving nonlinear interrelationships that played a major role in making the area in general and the households in Coastal Odisha vulnerable. Household-level analysis revealed that out of seven parameters, three parameters namely income and savings, community awareness and cohesiveness about cyclones and community-based preparation have significant relationships with strategies adopted for developing socio-ecological resilience.

Out of twenty-four indicators under five capitals, nine indicators were found significant. Out of these nine, six indicators were negatively significant effect whereas the other three indicators were positively significant effect. The factors having a significant negative impact on households of the coastal villages were health facilities during cyclones, lack of banking awareness, income constraints, lack of social cohesiveness, lack of diversified livelihood income source, lack of discussion platform, no savings for economic stability and strong organization.

Take Away for Policy Planners

The study revealed that there has been significant progress over the last twenty-three years (the 1999 Super Cyclone as the base year). About 10, 000 casualty in 1999 to almost zero casualty in 2021 (Cyclone Yaas) speaks a volume about the efforts made by the Odisha Government. There is a robust institutional arrangement from the State Headquarter up to the Cyclone Shelter level at the grassroots has earned appreciation from the United Nations. However, there are many areas of concern for making coastal Odisha a cyclone-resilient region in the country.

There are many indicators related to bio-physical, socio-economic, built-environment and institutional parameters needs to be strengthened. This is a continuous process in which the state has to critically analyse measures related to the readiness, responsiveness and revitalization of coastal communities. It would be possible when people's vulnerability is properly assessed and measures are properly executed, like robust mechanisms for 'Zero Casualty', the state should have a Vision Document for "resilient Coastal Communities. The Institutional arrangement has to be re-oriented to ensure local people's participation and bring development co-benefit.

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LIST OF ANNEXURES

HOUSEHOLD SCHEDULE

Disclaimer: Information obtained through this schedule will be kept confidential and it will not be used other than the Research Project

(A) GENERAL INFORMATION

Name	
Village	
District	
Social Group	GEN 2. OBC 3. SC 4. ST
Sex	Male 2. Female
Age (in years)	30-44 2. 45-59 3. 60 Above
Education	Illiterate 2. Primary 3. Matric 4. Higher Secondary1. Graduation 6. Post-Graduation 7. Others-Specify
Occupation	Government 2. Private 3. BusinessAgriculture/Fishery/Agricultural Labourer/Other allied activitiesSelf-Employed (Doctor/lawyer/engineer/ CA/others
Housing Type	1. Kutcha 2. Semi-Pucca 3. Pucca
Assets	1. Motorcycle 2. Car/Van 3. Tractor 4. Others

(B) RESILIENCE STRATEGIES - PRE, DURING AND POST CYCLONE

1. Who will you inform when you get information about the forthcoming cyclone?
1) Police 2) Fire & Emergency Services 3) Others_____
4) Ambulance Services 5) All of above
2. What are the major problems you face during Cyclones? _____
3. How do you manage during Cyclones? _____
4. Do you know Cyclone mock exercises? 1) Yes 2) No
5. If yes, are they conducted regularly? 1) Yes 2) No

Do you follow government guidelines and regulations for cyclones? 1) Yes 2) No

6. If No, why_____
7. To Whom you first go for help during cyclone _____
8. What measures are not available during cyclone that you feel can reduce the impact_____

9. What are the best methods of spreading mass general awareness at community level: -
1) Advertisement in electronic media 2) Advertisement in print media
3) Cable channels 4) Street shows. 5) Screening documentary on cable channels.
6) Any other (specify).
10. What role do you envisage for community before/during/after a cyclone? Elaborate briefly _____
_____
_____
11. What role do you envisage the District and State Disaster Management Authorities Should adopt to strengthen Community Based Cyclone Management?
_____
_____

(C) PARAMETERS OF SOCIO ECOLOGICAL RESILIENCE

Parameters	Variables	1	2	3
Proximity	Proximity to Sea	< 1 km	1-2 km	> 2 km
	Proximity to cyclone shelter	< 1 km	1-2 km	> 2 km
	Proximity to major Road	< 1 km	1-2 km	> 2 km
Accessibility	Transportation Availability	Poor	Moderate	Good
	Clean water access	Poor	Moderate	Good
	Health Service Access	Poor	Moderate	Good
	Internet Accessibility	Poor	Moderate	Good
Infrastructure	Effective Early Warning	low	Medium	High
	Evacuation plan	Low	Medium	High
	During Cyclone Support	Low	Medium	High
	Post Cyclone Support	Low	Medium	High
Income and Savings	Personal income (yearly)	< 1 lakh	1-3 lakh	>3 lakh
	Diverse income	1 source	2 sources	> 2 sources
	Savings	No Savings	<50,000	>50,000
Community Awareness and Cohesiveness about Cyclone	Cyclone Awareness	Poor	Moderate	Good
	Local knowledge	Poor	Moderate	Good
	Get help	Don't have	May be have	Certainly have
	Willing to help	Low	Medium	High
	Community Activities	Low	Medium	High
	Experience learning	Low	Medium	High
	Trust and hope among Community	Low	Medium	High
	Level of community connectivity	Low	Medium	High
Community based preparation	Level of preparation	Low	moderate	High
	Hazard Coping Plan	Don't Have	May be Have	Certainly Have
	Volunteer provision	Don't Have	Maybe have	Certainly Have
Community Participation	Decision making	Low	Medium	High
	Training Participation	Low	Medium	High
	Women Participation	Low	Medium	High

(D) RESILIENCE AND BARRIERS

Capitals	Barriers /Constrains in Resilience	Yes	No
Human Capital	Lack of execution of plan		
	Migration led labor scarcity		
	Lack of knowledge		
	Health Facility during cyclone		
Natural Capital	Cyclone frequency		
	Sea Proximity		
	Severity of cyclone damage		
Physical capital	Lack of institution to accurate dissemination of news		
	Lack of onset cyclone support		
	Effective Early Warning System		
	Proximity to cyclone shelter		
	Proximity to all weather roads		
Financial Capital	Income Constrains		
	Lack of diversified livelihood income source		
	No Savings for economic Stability		
	Loans		
	Lack of banking awareness		
	Absence of market for selling products		
Social Capital	Lack of strong organization		
	Lack of discussion platform		
	Lack of social cohesiveness		
	Lack of trust and hope as community among each other's.		
	Community participation (Training/ Experience)		
	Lack of community Institution and network		

(E) RESILIENCE CAPACITY RATING

Resilience Related Capacity	1	2	3	4	5
Absorptive Capacity- your household can bounce back from any challenge that life throws at it	Strongly Agree	Agree	Disagree	Strongly Disagree	Neither Agree nor Disagree
Adaptive Capacity - If threats to your household became more frequent and intense, you would still find a way to get by	Strongly Agree	Agree	Disagree	Strongly Disagree	Neither Agree nor Disagree
Anticipatory Capacity -Your household is fully prepared for any future disasters that may occur in your areas	Strongly Agree	Agree	Disagree	Strongly Disagree	Neither Agree nor Disagree

Transformative Capacity–During times of hardship, your household can change its primary income or source of livelihood if needed	Strongly Agree	Agree	Disagree	Strongly Disagree	Neither Agree nor Disagree
Financial Capital –During times of hardship, your household can access the financial support you need	Strongly Agree	Agree	Disagree	Strongly Disagree	Neither Agree nor Disagree
Social Capital – Your household can rely on the support of family and friends when you need help	Strongly Agree	Agree	Disagree	Strongly Disagree	Neither Agree nor Disagree
Political Capital –Your household can rely on support from politicians and government when you need help	Strongly Agree	Agree	Disagree	Strongly Disagree	Neither Agree nor Disagree
Learning – Your household has learned important lessons from past hardships that will help you better prepare for future threats	Strongly Agree	Agree	Disagree	Strongly Disagree	Neither Agree nor Disagree
Early Warning –Your household receives useful information warning you about future risks in advance	Strongly Agree	Agree	Disagree	Strongly Disagree	Neither Agree nor Disagree

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ABOUT CAP-RES PROJECT

"Climate Adaptive Planning for Resilience and Sustainable Development in Multi-Hazard Environment (CAP-RES)" aims at developing and implementing capacity building including a knowledge and training support system for wider use by related institutions and training centres across sectors and regions. The CAP-RES focuses on three specific regional contexts, i.e. Indian Himalaya Region (special reference to North East), Coastal region and Central-western region. Region specific climate-related hazard complex, including flood, drought, water scarcity, forest fire, cyclone/storm surge, coastal erosion, slope erosion/landslide, windstorms, heat wave, disease epidemics, industrial/chemical risks, etc.

CAP-RES aims at value-addition to programme sub-areas of the NKMCC by engaging with the institutions/research centres and network of experts, researchers and practitioners, across the following 5 key sub-sets of the project focus:

- Green Growth and Disaster Risk Reduction
- Resilient Agriculture Systems
- Public Health Resilience
- Climate Proofing Disaster Relief and Recovery
- Environmental Policy Instrument in Disaster Risk Reduction

SOME PUBLICATIONS UNDER CAP-RES

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