



Community perception, vulnerability, and coping strategies to cyclone-induced disasters: A case study of two coastal settlements in Ganjam district of Odisha, India

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Abstract

The people of coastal Odisha have been constant victims of frequent natural hazards, such as floods and cyclones. The socio-economic condition and the coping strategies adopted by local communities define the degree of a place's vulnerability to a particular disaster. Therefore, the purpose of this study is to conduct a comparative analysis of two coastal settlements to identify the major factors of vulnerability and assess vulnerability levels across households. The study also emphasizes people's perceptions of natural disasters and their risks. It focuses on the role of local communities in mitigating the adverse effects of natural hazards, particularly floods and cyclones, by adopting various coping strategies. The present research is based on the collection of primary data from 400 households through an interview schedule survey, 12 key informant interviews, and 7 focus group discussions in two coastal settlements in the Ganjam district. The correlation coefficients derived from vulnerability indices for the components of exposure, sensitivity, and adaptive capacity indicate that sensitivity and adaptive capacity are the primary determinants of vulnerability in both study sites. The key informants suggest that people should be provided with greater flexibility in their livelihoods and coping strategies by arranging alternative income sources. The most important coping strategy adopted by the local communities is the help and cooperation they receive from their neighbours, as well as the social linkages and bonds they share, which are crucial during rescue and evacuation processes. The local community's active participation in forming and implementing government policies will surely help build knowledge capacity to improve adaptation strategies for people in vulnerable communities.

Keywords: Cyclone vulnerability; coastal Odisha; community perception; disaster risk reduction; coping strategies; adaptive capacity; household vulnerability; coastal settlements; Ganjam district; cyclone-induced disasters

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1 Introduction

Among the catastrophic events occurring worldwide, cyclones are considered the most devastating atmospheric disasters when measured by intensity and area of impact (Needham et al., 2015). India is no different from the global scenario in terms of hazardous events such as cyclones, floods, and landslides. The east coast of India experiences frequent cyclonic storms originating over the Bay of Bengal between June and August each year (Selva et al., 2025).

The Odisha coast, situated in the eastern part of India and owing to its proximity to and exposure to the Bay of

Bengal, is highly prone to frequent natural disasters such as cyclones, floods, and storm surges (Panda et al., 2026). The India Meteorological Department (IMD) reports on cyclone landfalls over the last 130 years show that coastal Odisha has experienced the highest number of cyclones among the three states on India's east coast (Behera and Jally, 2026). Cyclonic storms have emerged as the most destructive natural calamity, causing severe damage to the state's economy and immense misery on its people (Mishra et al., 2023).

Due to the frequent occurrence of catastrophic events and their proximity to the Bay of Bengal, coupled with their

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restricted capacity to manage the adverse impacts of natural calamities, coastal communities are exceedingly vulnerable to such disasters (Bahinipati, 2014). The risks faced by individuals are invariably dependent on households' coping capacity, which is influenced by their livelihoods and income levels. The frequent occurrence of natural hazards disrupts people's livelihoods, thereby decreasing households' income-generating capacity (Patel et al., 2019). Although a decrease in income temporarily affects people experiencing poverty, in the long run, they are trapped in debt or loans borrowed from neighbours or small banks, pushing them into a poverty trap (Padhan and Madheswaran, 2023).

The vulnerability of a place to any natural hazard depends not only on its exposure to hazards of a place to any natural hazard but also on its economic context and capacity for response and recovery after experiencing such hazards. Vulnerability, once considered a static concept of a place or population, is now understood as a dynamic state arising from the interplay of exposure, sensitivity, and adaptability (Bankoff, 2003; Gallopín, 2006; Smit and Wandel, 2006). Socio-economic characteristics are widely recognized as important determinants of people's perception of hazard, vulnerability, and adaptive capacity, particularly in developing regions where households differ considerably in their access to resources and livelihood opportunities. For instance, the study by Cruz-Bello and Alfie-Cohen (2022) shows that perceptions of flood impacts in South Mexico City were not quantitatively associated with socioeconomic characteristics; rather, the community's collective experience and memories play an important role in shaping community responses. In contrast, Adisa (2019) demonstrated that socioeconomic and demographic factors contribute to differential vulnerability among older people in Nigeria. Indicators related to exposure, sensitivity, and adaptive capacity; housing conditions; education; unemployment; dependence on natural resources; impacts of cyclones and floods; shelter availability; and post-disaster support are key contributors to socio-economic vulnerability in coastal Odisha (Yadav and Barve, 2017). A recent study by Mandal and Dey (2022) in the Jagatsinghpur district found variations in terms of coastal vulnerability when combining socioeconomic characteristics and local perceptions.

Risk perception, experience, and local knowledge are important aspects of community vulnerability and preparedness. Choudhury et al. (2021) have demonstrated that indigenous and local knowledge, social learning, institutions, and power dynamics contribute to community resilience against cyclones. It is thus evident that risk perception is socially embedded rather than being determined by the physical characteristics of a hazard. Communities living along the coast of Odisha, with experience in extreme environments, will also be a factor in how they interpret warning signs, assess their potential consequences, and decide whether to evacuate or stay.

The literature shows that coping and adaptation are highly correlated with livelihood and household factors. Coping can occur before, during, and after a disaster and may include structural adjustments, preparation, borrowing, migration, livelihood diversification, and external assistance. Structural adjustment and reconstruction of homes

have been cited by Mohapatra et al. (2022) as adaptation strategies in rural areas of eastern India before disasters. In contrast, borrowing and seasonal migration have been shown by Padhan and Madheswaran (2023) to be adaptation strategies after disasters among poorer and middle-income families in the coastal areas of Odisha. Similarly, Patnaik et al. (2016) found that rural coastal families in Odisha use location- and household-specific coping strategies to address climatic shocks. A more recent study of households living in cyclone-prone areas of the eastern coast of India has found that livelihood diversification, household factors, and risk attitude affect the selection of coping and adaptation strategies (Sen et al., 2023a). This implies that households facing the same cyclones can be vulnerable to varying degrees, depending on livelihood dependence, household assets, and alternative income sources.

In addition to household endowments, social capital, community networks, and institutional support play important roles in building disaster resilience. Social interactions in neighbourhoods can enable information exchange, evacuation, rescue, and recovery activities in situations where such services are lacking or difficult to access. For example, in communities affected by cyclones in Bangladesh, social capital facilitates evacuation, and help from the neighbourhood can be essential, especially for vulnerable communities (Shoji and Murata, 2021; Quader et al., 2025). Community coping ability depends partly on the institutions' capabilities and their interaction with the community. For example, Munsaka et al. (2021), in their study of Cyclone Idai in Zimbabwe, have shown the consequences of poor disaster management systems. In Odisha, Panda et al. (2025) have noted the significance of community involvement, institutional assistance, and livelihood security in responding to Cyclone Phailin. These studies altogether indicated that resilience has emerged through relationships among households, communities and institutions.

Therefore, the important gap is not about the absence of village-level research but the limited integration of these dimensions within comparative micro-level studies of contrasting settlements exposed to the same regional cyclone hazard. This is especially true in Ganjam, where communities near the sea and those farther inland may experience the same cyclones but have unique levels of dependence on their livelihoods, socioeconomic conditions, exposure, and ability to cope. The present study addresses this gap by comparatively examining Arjyapalli and New Baxipalli, focusing on community perception, socioeconomic vulnerability, previous experience, livelihood characteristics, coping strategies, social linkages, and institutional support.

The perception of the local community and its capacity to adapt to the adverse effects of natural hazards are important components of disaster risk reduction, which are mainly influenced by the socio-economic and demographic characteristics of the people (Mohapatra et al., 2022). Although many studies have previously examined the vulnerability and resilience of communities based on social, environmental, cultural, economic, and historical factors, there has been little assessment at the household level regarding the subjective analysis of indigenous knowledge and perceptions, which are crucial for their ability to adapt and cope

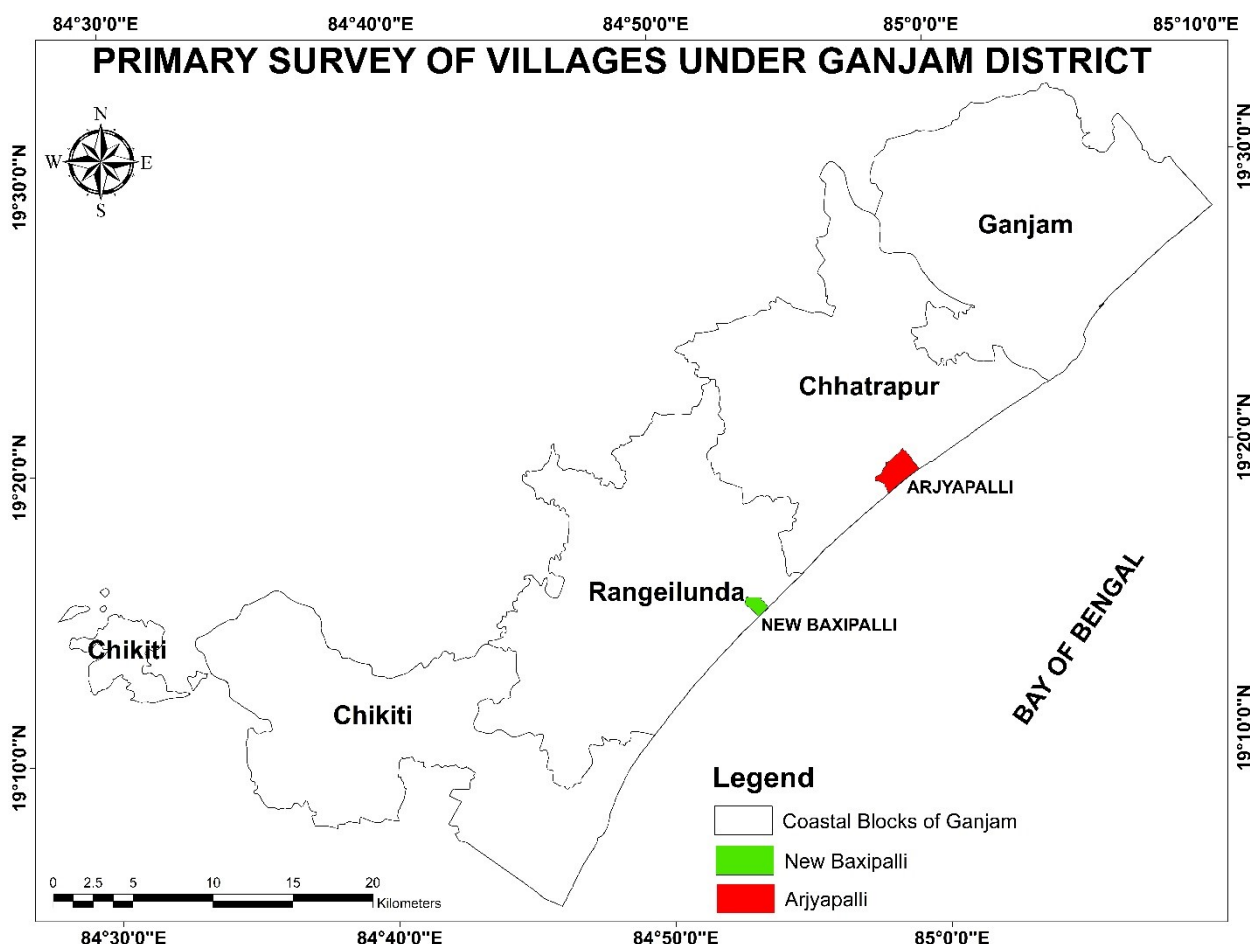


Fig. 1. Sample sites selected for field survey.

with threats from natural disasters. Therefore, the main objective of the present study is to conduct a comparative analysis of the level of vulnerability based on the demographic and socio-economic parameters of two settlements, to explore the perceptions of local communities regarding the occurrence of cyclone-induced disasters and their impact on various socio-economic aspects, and to examine the coping strategies these communities adopt for disaster risk reduction. Hence, the major research questions about the present study are as follows.

1. What are the major socio-economic components that determine the level of vulnerability?
2. What is the level of the community's perception of the occurrence of natural hazards and their effects on various socio-economic aspects?
3. How do the communities cope with or adapt to the cyclone-induced hazards in the pre-disaster and post-disaster scenarios?

2 Methodology

2.1 Study area

The present study is based on two coastal settlements, namely Arjyapalli and New Baxipalli, which are located to the north and south of the Gopalpur coast in the Ganjam

district of Odisha (Fig. 1). Since major cyclones have affected the Ganjam district near the Gopalpur coast, the neighbouring villages have experienced greater impacts than in other areas. According to the District Disaster Management Plan-2019 published by the district administration of Ganjam, Arjyapalli falls under a very highly vulnerable zone to both cyclones and floods. At the same time, New Baxipalli is highly prone to cyclone disasters.

Arjyapalli is, in fact, a small census town with more than 2,000 households living very close to the sea coast, where the majority are engaged in fishing. Arjyapalli comprises two coastal villages: Bada Aryapalli and Sana Arjyapalli. Bada Aryapalli is located on the edge of the seashore, while Sana Aryapalli is located to the northwest of Bada Aryapalli. However, the census town has a population of more than 11,000. The Bada Arjyapalli is located very close to Gopalpur Ports Limited. The Indian Rare Earths Limited (IREL), situated near the village of Matikhalo, is just 2 km away from Arjyapalli census town. The census town is only 7 km away from Chatrapur, the district headquarters of Ganjam.

The second sample site is New Baxipalli, located south of Gopalpur NAC, less than 1 kilometre from the sea. The people in this village engage in agricultural and allied activities, as well as fishing, which is the community's primary occupation. It has a population of more than 3,700 and 820 families.

Table 1. Approach of the Field Survey.

Name of the village/ census town	Sample size	Time Period of the study	Prime aspects of data collection	Methods of data collection
Arjyapalli	250	Nov 2021	Socio-economic aspects	Scheduled survey through stratified random sampling
New Baxipalli	150		Impact of natural hazards on different socio-economic aspects	
Arjyapalli	Key informant interview (8)	Dec 2021	Perception of the natural hazards	Key informant interview & Focus group discussions
New Baxipalli	Key informant interview (4) Total focus group 7		Coping strategies adopted by the local community	

2.2 Data Collection

To obtain data on people's socio-economic status and the impact of natural hazards on various socio-economic aspects, an intensive field survey was conducted using a household interview schedule. Information on community perceptions and coping strategies in pre- and post-disaster scenarios was collected through key informant interviews and focus group discussions. The field survey was conducted in two villages highly exposed to the Bay of Bengal. Hence, both qualitative and quantitative data were collected for the present study. Some verbatim notes and narratives from the key informants were also used to support the findings. The field survey has been conducted in two different villages that are highly exposed to the Bay of Bengal. Information from these two villages was collected in two phases. Table 1 presents an outline of the study's approach.

A pilot field survey was first conducted with 20 households in September 2021 to test the interview schedule before the final survey in November 2021, with verbal consent obtained from the head of the village and the respondents. The stratified random sampling method was used to select households, with samples randomly drawn from all sections of the villages with different socio-economic statuses, based on information collected from the village head, ensuring that the data would represent the entire population. As the Arjyapalli census town constitutes more than 2000 households, 250 households, i.e., more than 14 percent of the total households, were chosen for the survey. Similarly, 150 respondents were randomly selected in the New Baxipalli village, which has more than 820 households. Cross-checking socio-economic data collected through the interview schedule against projected estimates based on the Census of India 2011 data reveals that the collected primary data is reliable.

2.2.1 Key informant interviews

A total of 12 key informant interviews were conducted across both villages, with 8 key informants from Arjyapalli census town and 4 from New Baxipalli village. The key informant interviews included targeted respondents such as the village heads, shopkeepers from the village squares, Angan-

wadi workers, differently abled individuals, widows, socially and economically deprived individuals, and single-member households (Fig. 2(a) & (b)).

2.2.2 Focus Group Discussions

Seven focus group discussions were conducted, comprising 72 participants from both villages, to collect information on the communities' perceptions and coping capacity in response to the impact of natural hazards. Each group comprises 8 to 12 people purposively selected from public places, with knowledge and experience. The focus group discussions included participants from the fishing community, the Women Self-Help Groups (WSHGs), daily-wage labourers, residents of the rehabilitated colonies near the villages, and attendees of public gatherings at community centres, such as Kothaghara, village pandals like Chandini, and temple *mandaps*. Each discussion lasts approximately 1.5–2 hours (Fig. 2(c)). Field notes were prepared from these discussions, and then key notes were interpreted in this paper.

2.3 Ethical Considerations

From the pilot survey through the final survey, ethical principles were upheld by obtaining verbal consent from the Sarpanch, the head of the Gram Panchayat, or the Sabhapati, the head of the village, for each respondent before conducting the scheduled household survey. Similarly, participants in the FGDs and key informants were well informed about the purpose of the interviews, and the interviews and discussions were conducted without hampering their livelihood activities. The participants were also informed about the voluntary nature of their participation and their right to withdraw from the study at any stage without consequence. The individual identity and personal information shared by the respondents were kept confidential and anonymized during data analysis and interpretation.

2.4 Conceptual framework

The conceptual framework for the present study is derived from the Sixth Assessment Report of the Intergovern-



Fig. 2. A woman from a single-person household was interviewed as a key informant in Arjyapalli census town. (b) Interview with an older adult in New Baxipalli village. (c) Group discussion with the local communities in Arjyapalli census town.

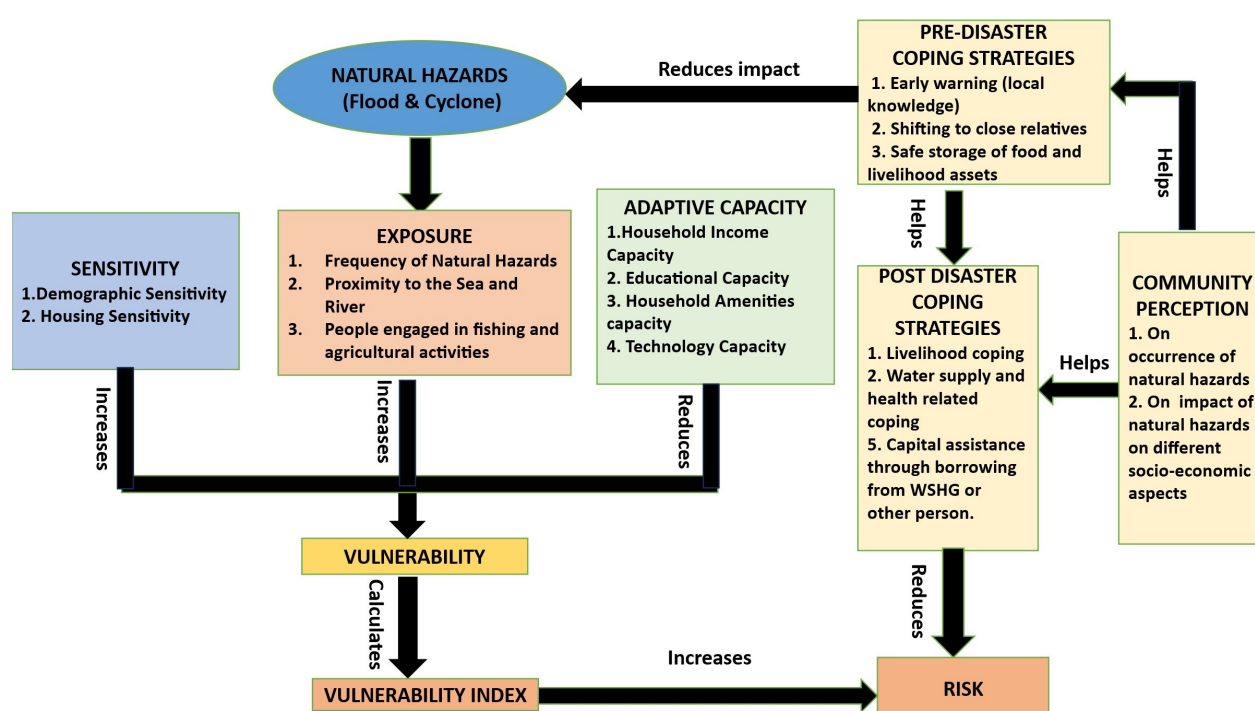


Fig. 3. Conceptual framework showing vulnerability assessment and disaster risk reduction through pre-disaster and post-disaster coping strategies influenced by community perception for the present study (based on IPCC, 2022).

mental Panel on Climate Change (IPCC, 2022), which describes the linkages and interactions among climate, ecosystems, and human society, with risk a function of natural hazards, exposure, and vulnerability. Adaptation plays a key role in reducing both exposure and sensitivity to natural hazards. Adaptive capacity can be regarded as an opposing force to exposure and sensitivity. Vulnerability is influenced by the degree of exposure of socio-physical features, the sensitivity of a particular place, and the adaptive capacity of its people (Lanlan et al., 2024). Therefore, vulnerability is a function of exposure, sensitivity, and adaptive capacity, and it can be expressed using the formula: $Vulnerability = (Exposure + Sensitivity) - Adaptive Capacity$ (IPCC, 2022) (Fig. 3).

Major components were derived from the determinants of vulnerability, which include exposure, sensitivity, and adaptive capacity. Then, various proxy indicators were selected from these components to assess the socio-economic vulnerability of both villages (Table 2). The higher the vulnerability index value, the greater the risk to the household. Pre-disaster coping strategies help reduce the impact of natural hazards, particularly at lower intensity levels, while post-disaster coping strategies help reduce community risk. The community's perceptions of the occurrence and impact of natural hazards guide the identification of pre- and post-disaster strategies for disaster risk reduction. The socio-economic conditions of coastal communities determine how well households can cope with the effects of natural

Table 2. Description of determinants of vulnerability, major components, with their proxy indicators.

Determinants of Vulnerability	Components	Proxy Indicators	Relation with vulnerability
Exposure	Frequency of hazard	Frequency of cyclones in the last 30 years	+
		Frequency of floods in the last 30 years	+
	Proximity to the water body	Distance from the sea coast (200 meters)	+
		Distance from the nearest river (12 km)	+
	Outdoor economic activities	Number of people engaged in fishing activities	+
		Number of people engaged in agricultural activities	+
		Number of people engaged in daily wage labourers	+
Sensitivity	Demographic sensitivity	Number of disabled persons	+
		Number of old-age persons	+
		Number of children (0–6) in the family	+
		number of female populations in the family	+
	Housing sensitivity	Temporary structured (made of mud, bamboo & straw) houses	+
		Semi-permanent structured (made of tin, bamboo and brick) houses	+
Adaptive Capacity	Income capacity	Family income per month	–
	Educational capacity	Total literates	–
		Total female literates	–
		Total number of graduates	–
	Household amenities capacity	Toilet facility in the house premises	–
		Bathroom facility in the house premises	–
		Drinking water facility from tap water	–
		Kitchen facility inside the house	–
	Technology capacity	Availability of a smartphone with internet facility	–
		Availability of Television in the house	–
		Availability of Radio in the house	–

(+) The sign indicates that vulnerability increases as the variable's value increases. In contrast, the (–) sign indicates a decrease in vulnerability as the variable increases.

hazards. Improvements in households' socio-economic conditions make them more resilient to natural hazards (Mid-delanis et al., 2025).

Exposure to natural hazards is determined by the extent to which households are exposed to them (Gallopín, 2006). To calculate household exposure, it is essential to study the frequency of natural hazards in the study villages. The location of the settlements with respect to the sea and river also determines the exposure to floods and cyclones. Households located in proximity to the sea and river are likely to be more affected than those located away from the sea (Sen et al., 2023). People engaged in fishing activities in the deep seas are expected to be more exposed to cyclones than those working in plants and buildings.

Sensitivity is the extent to which a community, structure, or asset is affected, either positively or negatively, by extreme climatic events (Li et al., 2024). The demographic sensitivity includes vulnerable groups such as children un-

der 6, older adults over 60, people with disabilities, and the number of females in the family (Hofflinger et al., 2019). At the household level, sensitivity is determined with greater specificity for individuals rather than for the community or a group of people. The types of houses, with respect to their structure and composition, also play a major role in determining vulnerability in coastal areas (Highfield et al., 2014). The temporary house structures built with mud, bamboo, and straw are most vulnerable to cyclones and floods, followed by the semi-permanent house structures made up of tin, bamboo, and brick. Permanent housing types built of brick and concrete are the least vulnerable (Siddique et al., 2024).

Adaptive capacity is the ability of a household to manage the potential losses from the natural hazards (Andrijevic et al., 2023). Adaptive capacity, in other words, refers to the strong resource base of a household, which depends on multiple factors such as financial resources, education, and

Table 3. Pearson's correlation between determinants and major components of vulnerability for households of New Baxipalli village.

	Exposure	Demographic Sensitivity	Housing Sensitivity	Income Capacity	Educational Capacity	Household Amenities Capacity	Technology Capacity	Vulnerability
Exposure	1							
Demographic Sensitivity	0.309***	1						
Housing Sensitivity	0.016	0.124	1					
Income Capacity	0.291***	0.081	0.504***	1				
Educational Capacity	−0.035	−0.256	0.305***	0.372***	1			
Household Amenities capacity	0.237***	0.040	0.644***	0.854***	0.436***	1		
Technology Capacity	0.093	0.179**	0.753***	0.517***	0.345***	0.603***	1	
Vulnerability	0.449***	0.317***	0.769***	0.799***	0.479***	0.855***	0.774***	1

***P < 0.01 and **P < 0.05.

household assets; these factors directly or indirectly help reduce the impact of natural hazards and provide households with the ability to withstand adverse effects in both pre-disaster and post-disaster scenarios (Chapagain et al., 2025). The adaptive capacity components considered for the present study include income capacity, educational capacity, household amenities, and household asset capacity. Households with higher income and education levels will have a greater capacity to cope with the damage caused by natural hazards (Khan et al., 2022). Household amenities such as a tap water drinking facility, a toilet and bathroom facility, and a kitchen facility within the household premises make households less exposed and therefore less vulnerable to extreme climatic conditions (Lloyd et al., 2022). The availability of technology, such as televisions and smartphones, helps people obtain information on measures to take before and after cyclones or floods (Lai et al., 2018).

2.5 Calculation of vulnerability Index

The indicators can be analysed in two ways: either by assigning equal weights to each indicator or by assigning different weights based on expert judgement. But for the present study, equal weights have been assigned to each indicator to assess the degree of correlation between the variables and the extent to which they influence vulnerability levels. Before calculating the vulnerability index, all the variables were first normalized to unit-free values. But before normalization, it is necessary to identify the functional relationship between the proxy indicators and the vulnerability.

Two types of functional relationships exist between the variables and vulnerability. In the case of a direct (positive) relationship, vulnerability increases as the value of the variables increases. The formula applied for normalization of the variables in a direct relationship is as follows:

$$x_{ij} = \frac{X_{ij} - \text{Min}\{X_{ij}\}}{\text{Max}\{X_{ij}\} - \text{Min}\{X_{ij}\}}$$

where, x_{ij} is the normalized value of indicator j corresponding to respondent i , X_{ij} represents the actual value of indicator j corresponding to respondent i , and $\text{Max}\{X_{ij}\}$ and $\text{Min}\{X_{ij}\}$ manifests the maximum and minimum actual values of indicator j for respondent i , respectively.

In the second functional relationship, as the values of the variables increase, the level of vulnerability decreases. Hence, there exists an indirect relationship (negative) be-

tween the variables and vulnerability. For this, the normalization has been done by the following formula:

$$y_{ij} = \frac{\text{Max}_i\{X_{ij}\} - X_{ij}}{\text{Max}_i\{X_{ij}\} - \text{Min}_i\{X_{ij}\}}$$

The normalized values of all the variables lie between 0 and 1. The value 1 represents the household with the maximum value, and 0 represents the household with the minimum value. The relationships among 23 variables and their impact on vulnerability levels are shown in Table 2. After obtaining the normalised values of the variables, the vulnerability indices have been calculated by employing the following formula:

$$VI = \frac{\sum_{i=1}^n x_{ij}w_{ij}}{n}$$

where, $x_{ij}w_{ij}$ is the product of the normalized value and the weighted value of natural variables, and n represents number of variables.

Two correlation matrices have been prepared separately for each settlement, using households as the unit of analysis and based on indices of exposure, sensitivity, adaptive capacity, and vulnerability. The vulnerability indices have been prepared at the household level for all the components with a sample size of 250 households for Arjyapalli census town and 150 households for New Baxipalli village. Similarly, the standard deviation (SD) for all the major determinants of vulnerability has been calculated from the indexes of exposure, sensitivity, adaptive capacity and vulnerability.

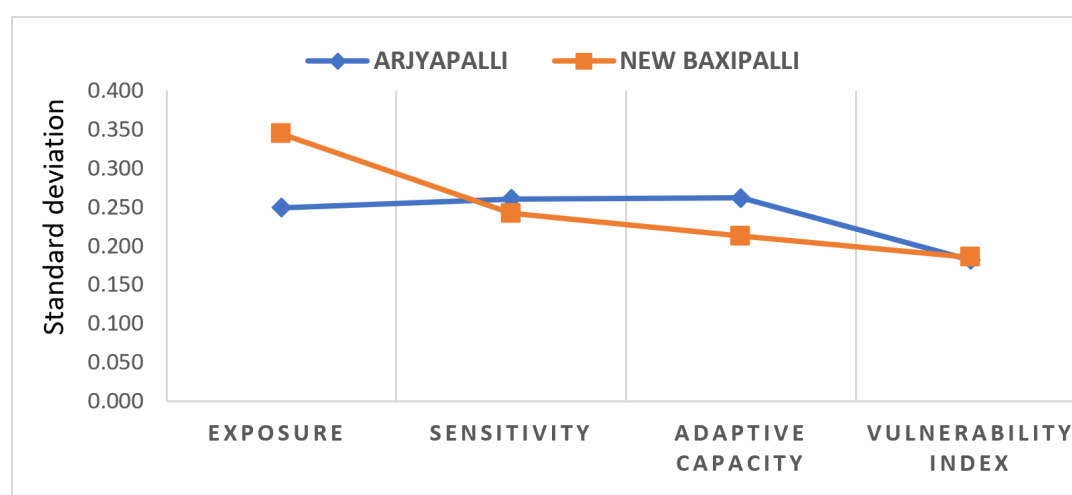
3 Results and Discussion

The correlation coefficients for all vulnerability components have been calculated using Pearson's correlation for both Arjyapalli and New Baxipalli. The correlation coefficient values between the vulnerability index and the major components of the determinants of vulnerability for New Baxipalli (Table 3) indicate strong positive correlations with housing sensitivity (0.769), income capacity (0.799), household amenities (0.855), and technology capacity (0.774). In contrast, moderate correlations are found for the components of exposure (0.449), educational capacity (0.479), and demographic sensitivity (0.317). The coefficients for these components are significant at the 1% level. The positive values of all components not only indicate their degree of influence on vulnerability levels but also reveal that house

Table 4. Pearson's correlation between determinants and major components of vulnerability for households of Arjyapalli census town.

	Exposure	Demographic Sensitivity	Housing Sensitivity	Income Capacity	Educational Capacity	Household Amenities capacity	Technology Capacity	Vulnerability
Exposure	1							
Demographic Sensitivity	0.073	1						
Housing Sensitivity	−0.136	−0.182	1					
Income Capacity	−0.328	−0.124	0.453***	1				
Educational Capacity	−0.469	−0.525	0.353***	0.589***	1			
Household Amenities Capacity	−0.287	−0.245	0.596***	0.823***	0.641***	1		
Technology Capacity	−0.140	−0.193	0.613***	0.481***	0.461***	0.711***	1	
Vulnerability	−0.116	−0.043	0.797***	0.764***	0.530***	0.875***	0.820***	1

***P < 0.01.

**Fig. 4.** Standard deviation shown for different determinants of vulnerability for both Arjyapalli and New Baxipalli village.

type and household income, along with household amenities and household assets, are the major determinants of vulnerability.

For the Arjyapalli census town (Table 4), strong positive correlations were found for the components of housing sensitivity (0.797), income capacity (0.764), household amenities (0.855), and technology capacity (0.820). Therefore, a similar picture was found in both villages with respect to the components of adaptive capacity. But the major differences were observed for exposure (−0.116) and demographic sensitivity (−0.043). The coefficients of correlation indicate that the relationships between vulnerability and exposure, and between vulnerability and demographic sensitivity, are not statistically significant for the Arjyapalli census town.

The value of the standard deviation (SD) derived for all the determinants of vulnerability and the vulnerability index shows that the standard deviation (0.344) found in the case of exposure for New Baxipalli is much higher than that of the Arjyapalli census town (0.249) (Fig. 4). It indicates the heterogeneity in the exposure variables in New Baxipalli village. But in the Arjyapalli census town, adaptive capacity, with an SD of 0.262, was higher than in New Baxipalli, indicating greater variation in adaptive capacity variables. The SD value of the sensitivity index for both villages is nearly equal, indicating similar variations in demographic and housing sensitivity. For both settlements, the SD of the vulnerability index was nearly equal, with a very small variation of 0.003.

The lowest vulnerability index in the case of the Arjyapalli census town (0.133) is higher than that of the New Baxipalli village (0.075), indicating the higher vulnerability of the households in the category of 'very low' vulnerability. Coincidentally, the highest vulnerability index for both villages is equal, i.e., 0.816, implying that both places are equally vulnerable at the highest level. The vulnerability index represented in Figs. 5 and 6 shows that more than 20% of the households in Arjyapalli census town are very highly vulnerable as compared to Baxipalli village (12.5%). But in the 'high vulnerability' category, New Baxipalli (10.00%) has almost doubled the percentage of households compared to Arjyapalli census town (5.02%). In the 'medium' category of vulnerability, New Baxipalli has a higher percentage of households (35.0%) compared to Arjyapalli census town (27.20%).

4 Community perception on the occurrence and impact of natural hazards

The second objective of this study is to ascertain the community's perception of the occurrence of natural hazards and their effects on various socio-economic aspects. The study of community perception is crucial, as it provides insight into how people manage danger and how individuals react to the varied threats that arise in their vicinity (Shaw et al., 2014). This section provides a brief overview of a community's assessment of the hazards they have encountered, as well as the extent of their impact on socio-

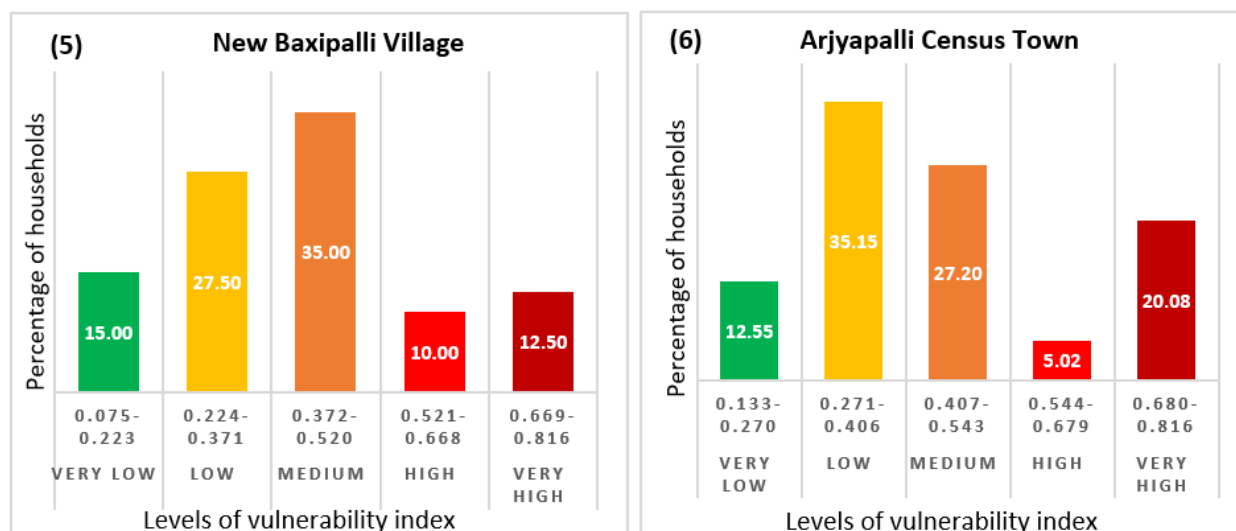


Fig. 5 and 6. Percentage of households vulnerable to various levels of vulnerability with a range of vulnerability indices.



Fig. 7. A coastal road was washed away at the sea coast near Arjyapalli census town. (b) The marine police station standing on the verge of the sea coast at Arjyapalli census town, indicating the future threat to the settlements.

economic elements and individuals. It is important to note that a community's vulnerability to hazards is influenced by the frequency and intensity of those hazards (Schneiderbauer and Ehrlich, 2004). The identification of diverse coping mechanisms employed by a community in response to various coastal hazards has been achieved by first understanding their perceptions.

4.1 Perception of the local community about the occurrence of natural hazards and their level of impact

The key informant interviews conducted on the experiences of respondents regarding the occurrence and intensity of natural hazards over the last 30 years indicate that the majority of the respondents have experienced three major cyclones since 1999 (specifically, the super cyclone in 1999, Phailin in 2013 and Titli in 2018), with the super cyclone of 1999 causing the most damage, followed by Phailin and Titli. The people attribute these cyclones to the “will of

God.” The local people believe that God is the creator of this universe and the destroyer of it.

As per the statement given by a key informant, AG of Bada Arjyapalli village, “Because of the frequent occurrence of cyclones as well as a series of low depressions, we have been used to these natural phenomena over the years. Therefore, we are always prepared to face the occurrence of natural hazards, but we want immediate action from the government to provide financial help to recover our losses from the cyclones”

4.2 Perception about the Impact on livelihood and livelihood assets

Cyclones and cyclonic disturbances have the greatest impact on fishing communities compared with other occupations. Despite early warnings about cyclones, deep-sea fishermen often remain unaware of cyclonic disturbances in the Bay of Bengal, putting their lives at risk. According to key

informants, many fishermen lost their lives in the super cyclone of 1999 while fishing in the deep sea at the time of the disaster.

Many fishing communities have either lost or sustained damage to their fishing trawlers, boats, and nets due to high-tide waters during cyclonic disturbances. During the super cyclone in 1999, all fishing communities suspended their livelihoods for nearly two to three months after losing their fishing equipment. Although the extent of damage was reduced during Cyclone Phailin in 2013, people were still unable to fish for almost 15 days due to persistent weather disturbances, including heavy rainfall, low-pressure systems, and windstorms.

The major concern of the fishing community of the Arjyapalli census town is the coastal erosion caused by the cyclonic storms and high tides (Fig. 7(a) & (b)). In particular, smaller fishing communities are highly affected by the narrowing of the coast due to coastal erosion, as they lack sufficient space to harbour their boats and carry out post-fishing activities along the coast. Due to rapid coastal erosion from high-tide water, the distance between the village and the seashore has now been reduced to less than 300 meters, posing major threats to both the fishing community and the village as a whole.

4.3 Perception about the impact on housing structures and household assets

The majority of the houses built with thatch, bamboo, and mud were completely damaged during Super Cyclone 1999 and during *Phailin* in 2013. The loss of assets mainly includes the loss of their cycles and cooking utensils. The Super Cyclone in 1999 either partially or completely damaged all types of houses except concrete ones. The construction of more concrete and asbestos houses increased significantly after *Phailin* in 2013, reducing the percentage of damaged houses to less than 25% of the total.

4.4 Perception about the impact on sanitation, health and education

The availability of drinking water facilities has become the primary concern during and after disasters. The cyclones disrupted electricity, cutting off tap water and forcing people to use bore wells and other wells to obtain drinking water. The contamination of well water (meant for drinking) with floodwater led to waterborne diseases such as jaundice and diarrhoea in the aftermath of the cyclones. The most vulnerable sections of the population are the children and older adults; they are affected by the sanitation problem and suffer from mild fever and other waterborne diseases. During and after the cyclones, the school buildings were used as temporary shelters, preventing children from receiving an education for 15 to 20 days during *Phailin* in 2013. The situation deteriorated further during the super cyclone, as schools remained closed for nearly 2 to 3 months due to significant damage to school buildings with tin and asbestos roofs.

4.5 Perception about the impact on transport and communication

There is a high likelihood that road and rail connectivity will be damaged during and after natural hazards, such as floods and heavy rains (Koks et al., 2019). Continued heavy rainfall damaged both the metalled and unmetalled roads along these coastal villages. The scarcity of daily-use goods and vegetables was widespread for nearly a month due to disruptions in road communication caused by damage to small bridges and culverts. The people experienced a disruption in phone connectivity for nearly 15 days during *Phailin*.

5 Pre-disaster and post-disaster coping strategies adopted by local communities

The village communities adopt no specific formal coping strategies. But informally, the community members had developed the family preparedness plans that cover the collection and sharing of emergency contact information within the family members, conducting village meetings, home evacuation procedures, shifting of livestock to safer places, safe storage of food and water, assembling household assets inside the houses and covering them with polythene sheets for minimal loss of these assets. The major pre-disaster measures taken by the local communities are as follows.

5.1 Indigenous knowledge on early warning indications

The fishing communities of the study village generally use local knowledge systems, such as sudden shifts in wind direction, changes in wind temperature, and unusual sea behaviour, as major coping strategies to alert themselves and return to the coast well before cyclones arrive. In particular, fishermen in deep-sea regions rely on this type of indigenous knowledge before the government announces cyclone warnings through print, electronic, or social media. Informal discussions in public places, such as fishing net repair sheds and village mandaps (Fig. 8), where the community gathers to repair their nets or relax in the afternoon, serve as major sources of information for sharing details about cyclone arrivals, including their intensity and potential impact.



Fig. 8. Fishing net repair sheds act as the centre of sharing information on cyclone-induced hazards among the fishing community at Arjyapalli Census Town.



Fig. 9. (a). Safe storage of fishing boats in the harbour, an artificial pond connecting to the sea with a narrow passage of water (b). Safekeeping of fishing nets by tying them to the concrete poles near the fishing harbour (c)—a conventional method used to process raw fish and store them for future use in New Baxipalli village.

5.2 Home evacuation coping strategies

The evacuation measures were implemented strictly by the government so that no individual was left behind in the villages. But some families move to the homes of their close relatives in low-hazard-intensity areas before the government's evacuation measures are implemented. In addition to the precautionary measures taken by individual households, the government, with active participation from local communities, plays a major role in relocating people to multipurpose cyclone shelters in nearby areas.

According to a statement made by CHB, a widow from Bada Arjapalli who has a 14-year-old disabled son, she said, “*It is very difficult for me to make necessary arrangements for shifting with my son with disability whenever it is required to evacuate the houses in the pre-disaster period; how will I handle all these difficulties without the support of a male family member?*”

5.3 Safe storage of livelihood assets and food storage coping strategies

Households prioritise the safe storage of food grains to prevent damage from floods or cyclones. For this purpose, they use large tin containers to store food grains. Most households also store dry fish (Fig. 9(c)), locally called ‘*sukhua*’, in small containers or polythene bags for use during the off-fishing season or fishing ban, which occurs due to the formation of low depressions in the Bay of Bengal. After hearing the announcement about the upcoming cyclonic disturbances, the respondents from the fishing community keep their fishing equipment in safer places, i.e., in the fishing harbours. The fishing harbours are artificial ponds created by the fishing community, where seawater intrusion is less likely (Fig. 9(a)). To store fishing nets, the fishing community used the concrete poles near the fishing harbour. Some households with kutcha houses use the community shelters in the village to store their fishing nets (Fig. 9(b)).

5.4 Occupational or livelihood-related coping methods

Regarding livelihood or income sources, individuals predominantly engaged in fishing use their accumulated savings from high-revenue fishing seasons as a coping mechanism. Individuals lacking funds or property typically seek financial assistance from family, neighbours, or WSHGs estab-

lished within the local community. Nevertheless, the majority of these families and neighbours also face similar socio-economic turmoil. Certain fishing communities transition their livelihoods from fishing to working as daily-wage labourers in civil construction, or migrate to other regions such as Kerala, Chennai, and Bangalore to generate income by engaging in fishing, civil construction, and small-scale industries. Approximately 55% of households participate in alternative employment activities during the post-disaster rehabilitation phase.

5.5 Water supply and health-related coping methods

An immediate issue that arose following the storm was the shortage of potable water in the villages. To address this problem, over half of the families, specifically 52% of the villagers, need to travel considerable distances to obtain water from neighbouring villages. Typically, the male individual transports potable water from neighbouring villages in small plastic containers. 20% of the homes lack a viable strategy to ensure access to potable water. In cyclone-prone areas, it is usual for people to store pure drinking water in advance of potential threats. Additionally, they often utilise water purification powders, such as bleaching powder, to ensure the water is safe for consumption. In the aftermath of the disaster, some residents use heated water for drinking. To combat waterborne infections, sick individuals receive pills provided by the Government of Odisha through Asha *didis* or Anganwadi workers.

6 Conclusion

This study sought to investigate the socioeconomic determinants of vulnerability in coastal Odisha. Due to the selected sites' proximity to the Bay of Bengal, the components of exposure and sensitivity play a major role in determining vulnerability levels. However, the components of adaptive capacity have minimal effect on vulnerability. The sensitivity and adaptive capacity of the people, including households' socio-economic standards, are primarily influenced by socio-economic indicators such as demographic characteristics, house type, income level, household amenities, and households' technological capacity, all of which significantly affect vulnerability levels. Although both villages are highly vulnerable to cyclones, the degree of household vulnerability to cyclones varies between them.

The local community believes that individuals should have greater flexibility in livelihood options better to mitigate vulnerability to natural disasters in coastal settlements. Organising alternative sources of income could prevent forced or unwanted migration to regions outside the state. The major threat to the fishing community of Arjyapalli census town is the advancing seawater towards the village settlement due to rapid coastal erosion, which may increase the long-term risk of land loss and damage to the village's settlement infrastructure in the Bay of Bengal in the near future. Baxipali village, situated 1.5 km farther from the sea coast, is less vulnerable than Arjyapalli. Continuous coastal erosion and frequent cyclonic activity indicate that Odisha's coastal area is inherently susceptible to natural disasters, and complete avoidance of this vulnerability is impossible. However, the extent of susceptibility can be minimised, and its impact on the population could be mitigated by enhancing scientific and advanced coping mechanisms through community participation.

The vulnerability assessment of the exposure, sensitivity, and adaptive capacity components helps identify the socio-economic resilience of the fishing community at the household level by addressing the root causes of problems related to the high sensitivity of demographic characteristics, housing infrastructure, and household economic capabilities. The impact of hazards on demographic and socio-economic characteristics may not return to their original state due to the post-disaster coping strategies implemented at the household level; however, these strategies can be transformed into a strong resource base that enables the community to recover even more effectively than before, given the appropriate capital and technological inputs (Padhan and Madheswaran, 2023).

7 Limitations

Although many studies have previously focused on vulnerability analysis at the district, block, and village levels in coastal Odisha, this is one of the first attempts to assess household vulnerability in two specific settlements. Therefore, many challenges have been encountered in adapting the exposure variables, such as measuring the minimum distance of households from the sea and to the nearest river. Similarly, some important socio-economic factors, such as the availability of medical, educational, and banking facilities, could not be incorporated into the components of adaptive capacity, as they are common to all households.

In addition to these constraints, the most important limitation of the present study is that mapping vulnerability levels may not be feasible because the vulnerability indices were calculated at the household level. This study extensively discussed various topics, but it did not adequately address some of the most vulnerable groups, such as pregnant women and individuals with disabilities.

8 Recommendations

Regular and frequent inspections of hazard-related infrastructure and risk-reducing training activities conducted by ground-level officials would certainly reduce the effects

of natural hazards. The financial assistance provided to the smaller fishing community for the loss of their boats and nets is minimal and therefore requires additional government support to revive their livelihood activities. Immediate construction of a guard wall along the coast of Arjyapalli census town is essential to protect the locality from submergence caused by seawater intrusion. Although the state government's role in reducing vulnerability has been highly appreciated at the national and international levels, more community-level initiatives are still needed, with maximum involvement of the local community in reducing the risks of cyclone-induced natural hazards.

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Conflict of Interest

The authors declare that there is no known conflict of interest associated with this publication.

Data Availability

The primary data is kept confidential and, therefore, unavailable in the public domain.

Credit Statement

Sudhir Kumar Behera: Conceptualisation, data Collection and processing, methodology development, manuscript writing, reference management. **Sujit Kumar Jally:** Supervision, technical inputs, review, editing and writing. **Sibabrata Das:** Review and overall supervision of manuscript writing.

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