**Measuring Livelihood Vulnerability to Floods among Livestock rearers using a Composite Index in Odisha, India**

**ABSTRACT**

Frequent floods in Odisha have severely impacted agricultural livelihoods, particularly those of livestock-rearers. These disasters erode farmers’ investments, destroy crop fields, and reduce the availability of feed and fodder. Beyond crop loss, floods contaminate the environment, rivers, and drinking water, posing serious health risks to livestock. Prolonged exposure to floodwaters increases susceptibility to hoof and skin infections, while injuries from debris raise the risk of tetanus and toxin exposure. Outbreaks of multiple diseases among livestock during floods further threaten the livelihoods of rural households. In response to these challenges, the present study assessed the flood-induced vulnerability of livestock-rearers in Odisha using a Composite Livelihood Vulnerability to Flood Index (CLVFI). According to Odisha’s Disaster Management Plan (Animal Development Sector), 17 out of 30 districts are major flood-prone, while 13 are minor. For this study, one district from each category was randomly selected: Balasore (major) and Dhenkanal (minor). A random sample of 120 livestock-rearers was surveyed across the two districts. The findings revealed that livestock-rearers in Balasore exhibited lower adaptive capacity compared to those in Dhenkanal. Key factors such as income levels and cropping intensity were found to be more sensitive to flood exposure. Vulnerability was higher in villages farther from markets and veterinary centres. The study confirms a direct relationship between the severity of livelihood vulnerability and the degree of flood-proneness. These insights aim to support state and national agencies in agriculture, animal husbandry, and disaster management to design location-specific contingency plans for mitigating flood impacts effectively.

***Keywords:* Adaptive capacity, Flood-prone districts, Livelihood vulnerability, Livestock-rearers**

**Introduction**

Climate change has emerged as one of the most pressing global challenges, posing serious threats to ecosystems, livelihoods, and food systems. Although it is a global phenomenon, its impacts manifest differently across regions, depending on local ecological, socio-economic, and institutional factors (Piya et al., 2012). These regional disparities necessitate context-specific adaptation strategies and targeted development interventions. According to the Intergovernmental Panel on Climate Change (IPCC, 2001), vulnerability denotes the extent to which a system is exposed to, and incapable of coping with, the negative impacts of climate change. This vulnerability is influenced by the magnitude and frequency of climatic events such as floods-the extent of exposure, and the adaptive capacity of the affected systems. For livestock rearers, several socio-economic and environmental factors-such as poor access to technology, inadequate infrastructure, institutional limitations, and increasing anthropogenic pressure on natural ecosystems-exacerbate this vulnerability (Deressa et al., 2009; Rai & Singh, 2019). India has historically experienced recurrent floods due to its diverse climatic zones and variable rainfall patterns (Mishra et al., 2010). Odisha, one of India’s most flood-prone states, comprises 30 districts and has a 480 km long coastline along the Bay of Bengal. Several major perennial rivers, including the Mahanadi, Brahmani, Baitarani, Rushikulya, Budhabalanga, and Subarnarekha, flow through the state, making it highly susceptible to seasonal flooding. Livestock rearing forms an integral component of rural livelihoods in Odisha, where mixed crop-livestock farming is the predominant system practiced, especially by smallholders, marginal farmers, and landless households. However, recurring floods-often lasting 5 to 15 days in various coastal regions-result in widespread destruction of property, standing crops, and infrastructure, severely affecting the livelihood security of rural communities (Behera et al., 2020). Beyond crop loss, post-flood conditions also lead to water contamination and degraded environments. Livestock, more vulnerable than humans during and after flood events, often suffer significant losses, including death, injury, disease outbreaks, reduced productivity, and disrupted breeding cycles. These losses translate into substantial economic setbacks for farming households, particularly those dependent on livestock as a key livelihood asset (Patnaik & Narayanan, 2010). Despite the growing intensity and frequency of floods, there remains a lack of localized data on the extent of vulnerability faced by rural households-particularly livestock rearers. This information gap hinders the development of effective adaptation strategies and risk mitigation programmes (Sam et al., 2017). Micro-level vulnerability assessments are crucial for identifying the most at-risk populations and for understanding which livelihood resources are most impacted in specific regions. Such analyses are essential to design region-specific, evidence-based coping mechanisms and policy responses (Aryal et al., 2020). Considering these issues, the present study was conceptualized to address this gap by assessing the degree of flood-induced vulnerability among livestock-rearing households in Odisha. Specifically, this research aims to evaluate the extent and key determinants of vulnerability using a factor analysis approach, with the goal of contributing to improved disaster risk management and enhancing livelihood resilience in climate-sensitive regions.

**MATERIALS AND METHODS**

**Sampling plan**

To explore the vulnerability of livestock rearers, an exploratory research design was implemented in the state of Odisha. Two districts were randomly selected to reflect different levels of flood exposure Dhenkanal, representing areas with minor flooding, and Balasore, indicative of regions prone to major flooding. From each of these districts, two blocks were chosen at random: Odapada and Gondia from Dhenkanal, and Bhograi and Jaleswar from Balasore, making a total of four blocks. Subsequently, four villages were selected from each block, serving as the primary sampling units, resulting in a total of 16 villages. The respondents were defined as individuals who had been engaged in livestock rearing (cattle, buffalo, sheep, or goat) for at least 10 years. Lists of eligible livestock rearers were compiled for each village with support from the respective livestock enumerators. From these lists, 120 respondents (15 from each village) were selected using purposive sampling. Data collection was carried out through face-to-face interviews at the respondents’ residences, utilizing a structured and pre-tested interview schedule.

**Methods for measuring vulnerability to flood:**

Vulnerability is generally conceptualized from two major perspectives: biophysical vulnerability and social vulnerability. Biophysical vulnerability focuses on the immediate physical impacts resulting from a hazard event and is typically assessed by examining the extent of damage a system incurs upon exposure. In contrast, social vulnerability encompasses the socio-economic and institutional factors that determine a community’s ability to prepare for, respond to, and recover from such events (Nyong *et al*., 2008; Maiti *et al*., 2015). The present study adopts the social vulnerability framework to assess the susceptibility of livestock rearers.

**Construction of Composite Livelihood Vulnerability to Flood Index’ (CLVFI)**

**i) Collection of the vulnerability indicators**

**Exposure**

Exposure indicators play a vital role in assessing the nature, frequency, and severity of hazardous threats affecting vulnerable elements (Messner and Meyer, 2006). In this study, historical trends including variations in rainfall patterns and experiences with extreme flood events were employed as primary indicators of exposure. A detailed account of the specific household-level exposure indicators used in the analysis is presented in Table 1.

**Table 1: Indicators to measure exposure at household level (Refer Annexure-I for definition and details of each indicator)**

|  |  |
| --- | --- |
| **Sl. No.** | **Indicators of Exposure** |
| a. | Frequency of Flood |
| b. | Duration of flood |
| c. | Proximity of household to river(km) |
| d. | Incidence of Very Heavy Rainfall |

**Sensitivity**

Ideally, 'sensitivity' is best assessed through observable changes in income or livelihood that are directly attributable to climatic factors. However, such specific data were unavailable for this study. Therefore, following the approach of Deressa et al. (2008) and Maiti et al. (2014), we adopted the assumption that regions experiencing a higher frequency of climate extremes are likely to exhibit greater sensitivity, as reflected in yield losses and livelihood disruptions among rural populations. This assumption guided the present analysis. A total of five indicators were used to assess the degree of household sensitivity in the study area, as outlined in Table 2.

**Table 2: Indicators of sensitivity**

|  |  |
| --- | --- |
| **Sl. No.** | **Indicators of sensitivity** |
| a. | Cropping Intensity |
| b. | Proportion of income from livestock |
| c. | Proportion of income from agriculture |
| d. | Average lactation length |
| e. | Average daily milk productivity of livestock (kg) |

**Adaptive capacity**

Adaptive capacity in this study was conceptualized as the composite effect of five forms of livelihood capital: human, social, physical, natural, and economic capital. To assess adaptive capacity at the household level, a total of 21 indicators were identified, based on a review of relevant literature and inputs from expert consultations. The specific indicators used in the analysis are presented in Table 3.

**Table 3: Indicators for adaptive capacity**

|  |  |
| --- | --- |
| **Human capital** | |
| 1. Age of the household head | 2. Average age of the adult family members |
| 3. Family education status | 4. Sex ratio in the family |
| **Social capital** | |
| 5. Community participation | 6. Community cohesiveness |
| 7. Social migration | 8. Frequency of Extension contact |
| 9. Farmer to farmer extension | 10. Assistance from External Agency |
| 11. Social Participation | |
| **3. Physical and natural capital** | |
| 12. Herd-size | 13. Fodder availability sources |
| 14. Operational land-holding | 15. Sources of flood-related information |
| 16. Distance of the nearest market | 17. Distance of Veterinary Centre /Artificial Insemination (A.I) Centre |
| **4. Economic capital** | |
| 18. Annual income | 19. Proportion of household expenditure to the Livestock–rearing expenses |
| 20. Average standard number of milch animal | 21. Proportion of crossbred animals to Herd-size |

**ii. *Selection of the appropriate indicators***

The raw data for each indicator were normalized to standardize the values within a comparable range. Normalization was performed by subtracting the minimum observed value from each data point and then dividing by the range (maximum value minus minimum value), following the procedure recommended by Kaiser (1958) for assessing the suitability of indicators. This process is expressed as follows:

***iii. Testing of suitability of indicators***

Principal Component Analysis (PCA) was employed to identify significant indicators and exclude non-significant ones, as supported by Ravindranath et al. (2011) and Maiti *et al.* (2015). Following normalization, three separate factor analyses corresponding to adaptive capacity, exposure, and sensitivity were conducted using PCA for factor extraction and the Varimax method for factor rotation in SPSS version 20. For this study, a communality cutoff value of 0.45 was established. One adaptive capacity indicator, ‘community participation,’ was excluded due to a communality value below this threshold. The remaining indicators were retained for further analysis, including the assignment of weights. All indicators for exposure and sensitivity demonstrated communality values above the cutoff, and thus, none were excluded from their respective factor analysis models.

**iv) Assignment of weights to the indicators**

After identifying suitable indicators, PCA was performed again separately for the three main components of vulnerability: adaptive capacity, exposure, and sensitivity to obtain factor loadings and eigenvalues. Kaiser normalization was applied to identify initial eigenvalues greater than one. Components corresponding to the number of eigenvalues exceeding this threshold were extracted using the Varimax rotation method, as reflected in the rotated component matrix. Subsequently, the approach outlined by Feroz *et al*. (2010) and Maiti *et al*. (2015) was adopted to assign weights to the selected indicators.

**v)** **Calculation of Composite Livelihood Vulnerability to Flood Index (CLVFI)**

To construct indices for each component of vulnerability i.e., exposure, sensitivity, and adaptive capacity, the normalized indicators were multiplied by their respective assigned weights. These component indices were then used to compute the Composite Livelihood Vulnerability to Flood Index (CLVFI) at both the household and district levels, following the formula proposed by Maiti *et al*. (2014):

The resulting Livelihood Vulnerability Index (LVI) enables comparative analysis of vulnerability levels across households. A lower LVI score indicates higher vulnerability, as it reflects a situation where exposure and sensitivity surpass the household's capacity to adapt. Conversely, a higher score denotes relatively lower vulnerability. Negative index values signal that the combined impact of exposure and sensitivity exceeds adaptive capacity, suggesting a critical vulnerability scenario. It is important to emphasize that this index does not represent an absolute measure of vulnerability, but rather serves as a relative tool to compare the vulnerability status among the sampled districts and households.

**vi) Differential level of vulnerability of vulnerability among the sample households**

All sample households were classified into three distinct vulnerability levels: low, medium, and high based on their respective vulnerability index scores. The categorization was performed using the cumulative square root frequency method.

**RESULTS AND DISCUSSIONS**

**Indicator of adaptive capacity and their suitability & weightage**

The indicators of adaptive capacity were prioritized based on their respective weightage scores, with higher-weighted indicators considered relatively more influential determinants compared to those with lower weights. Principal Component Analysis (PCA) was employed both to assess the suitability of the indicators and to compute the weights for the 21 initially identified indicators relevant to the adaptive capacity of livestock-rearers in the study area. As shown in Table 4, one indicator ‘community participation’ was deemed non-significant due to its extraction (communality) value falling below the established cut-off threshold of 0.45. Consequently, this indicator was excluded from the final weightage calculation.

Among the remaining 20 indicators of adaptive capacity, the distance of the veterinary centre/artificial insemination centre from the household (in kilometres) emerged as the most influential factor, with a weightage score of 3.21. This was followed by annual income with a weightage of 3.20, distance to the nearest market (km) at 3.16, age of the respondent (years) at 3.07, and community cohesiveness at 3.05. These indicators were found to contribute most significantly to the overall adaptive capacity of livestock-rearers in the study area."

Several other indicators also played a significant role in determining the adaptive capacity of livestock-rearers. These included the average standard number of milch animals (2.78), herd size (2.72), number of sources of flood-related information (2.62), extension contact (2.54), social participation (2.53), sex ratio (2.53), availability of fodder sources (2.50), assistance received from external agencies (2.40), expenditure on livestock (2.39), average age of family members (2.30), incidence of social migration (2.23), proportion of crossbred animals in the herd (2.22), farmer-to-farmer extension (2.06), landholding size (1.97), and overall family education status (1.91).

**Table 4. Indicators of adaptive capacity and their suitability & weightage (n=120)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Indicators of**  **adaptive capacity** | | **1st Run of Factor analysis** | | **2nd Run of Factor analysis** | | **Weightage** |
| **Communalities** | | **Communalities** | |
| **Initial** | **Extraction** | **Initial** | **Extraction** |
| **Human Capital** | | | | | |  |
| i | Age of Respondent (years) | 1.00 | .670 | 1.00 | .692 | 3.07 |
| ii | Average age of family Members | 1.00 | .651 | 1.00 | .664 | 2.30 |
| iii | Family Education Status | 1.00 | .671 | 1.00 | .675 | 1.91 |
| iv | Sex ratio | 1.00 | .458 | 1.00 | .470 | 2.53 |
| **Social Capital** | | | | | | |
| i | Sum of community participation | 1.00 | .391\* |  | | |
| ii | Sum of community cohesiveness | 1.00 | .631 | 1.00 | .634 | 3.05 |
| iii | Social Migrated Days | 1.00 | .656 | 1.00 | .638 | 2.23 |
| iv | Frequency of Extension Contact | 1.00 | .490 | 1.00 | .532 | 2.54 |
| v | Farmer to farmer extension | 1.00 | .691 | 1.00 | .688 | 2.06 |
| vi | Assistance from External Agency | 1.00 | .559 | 1.00 | .587 | 2.40 |
| vii | Social Participation | 1.00 | .673 | 1.00 | .675 | 2.53 |
| **Physical and natural capital** | | | | | | |
| i | Herd-Size | 1.00 | .770 | 1.00 | .770 | 2.72 |
| ii | Number of Fodder Sources | 1.00 | .512 | 1.00 | .532 | 2.50 |
| iii | Operational land- Holding(hactre) | 1.00 | .642 | 1.00 | .646 | 1.97 |
| iv | Number of sources of flood-related information | 1.00 | .667 | 1.00 | .670 | 2.62 |
| v | Distance of market from Household (km) | 1.00 | .924 | 1.00 | .956 | 3.16 |
| vi | Distance of veterinary Centre/ Artificial Insemination Centre from household(km) | 1.00 | .936 | 1.00 | .966 | 3.21 |
| **Economic Capital** | | | | | | |
| i | Annual income(rupees) | 1.00 | .606 | 1.00 | .629 | 3.20 |
| ii | Proportion of household expenditure to livestock | 1.00 | .645 | 1.00 | .670 | 2.39 |
| iii | Average number of milch animal | 1.00 | .734 | 1.00 | .736 | 2.78 |
| iv | Proportion of crossbred to Herd Size | 1.00 | .568 | 1.00 | .581 | 2.22 |
| **\*Indicates extraction value was below cut-off value (0.45)** | | | | | | |

**Adaptive capacity to flood-induced livelihood vulnerability**

Table 5 presents the mean values of adaptive capacity and its constituent components at the household level among respondents in the study area. The results indicate that livestock-rearers from the minor flood-prone district (Dhenkanal) had a higher mean score (4.31 ± 0.12) in the human capital category compared to those from the major flood-prone district (Balasore), with mean of 3.95 ± 0.11. In terms of social capital, both districts showed comparable mean values, with Dhenkanal and Balasore having mean score value of 4.28 ± 0.22 and 4.83 ± 0.21, respectively. For physical and natural capital, the minor flood-prone district exhibited a higher mean value (6.34 ± 0.31), as well as in economic capital (5.12 ± 0.20), when compared to the major flood-prone district. At the state level, the overall mean scores of the adaptive capacity components across the study area were 4.13 ± 0.08 for human capital, 4.56 ± 0.15 for social capital, 5.88 ± 0.23 for physical and natural capital, and 4.63 ± 0.15 for economic capital.

**Table 5: Average Value of adaptive capacity and its components (n=120) (Mean ± S.E)**

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Minor**  **Flood-prone District**  **(Dhenkanal; n1=60)** | **Major**  **Food-prone District**  **(Balasore; n2=60)** | **Overall**  **(Odisha; n=120)** |
| Human capital | 4.31 ± 0.12 | 3.95 ± 0.11 | 4.13 ± 0.08 |
| Social capital | 4.28 ± 0.22 | 4.83 ± 0.21 | 4.56 ± 0.15 |
| Physical and natural capital | 6.34 ± 0.31 | 5.42 ± 0.23 | 5.88 ± 0.23 |
| Economic capital | 5.12 ± 0.20 | 4.14 ± 0.20 | 4.63 ± 0.15 |
| Adaptive capacity | 20.04 ± 0.46 | 18.34 ± 0.42 | 19.19 ± 0.36 |

**Fig 1: Radar Chart showing Indicators of Adaptive capacity against Flood (n=120)**

Livestock-rearers of the minor flood-prone district had a higher mean value of adaptive capacity (20.04 ± 0.46) than major flood-prone district (18.34 ± 0.42). Similarly, the adaptive capacity of the respondents of the overall study area was 19.19 ± 0.36.

**Indicators of exposure and their suitability & weightage**

There had been four (4) indicators for exposure identified to the flood-induced vulnerability among respondents of the study area. Principal Component Analysis was applied to these four indicators of exposure to test their suitability as well as to calculate weightage of each suitable indicator.

**Table 6: Determinants of exposure to the flood-driven vulnerability of study area (n=120)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Indicators of Exposure** | | **1st Run of Factor analysis** | | **Weightage** |
| **Communalities** | |
| **Initial** | **Extraction** |
| i. | Frequency of flood | 1.00 | .937 | 2.86 |
| ii. | Duration of flood | 1.00 | .753 | 2.48 |
| iii. | Proximity of household to river (km) | 1.00 | .824 | 2.78 |
| iv. | Incidence of Very Heavy Rainfall in mm (124.5-244.4) | 1.00 | .746 | 2.56 |

Results shown in the Table 6 indicated that among the four indicators, frequency of flood (2.86) had the highest influence to exposure followed by the proximity of household to the river in km (2.78), the incidence of very heavy rainfall in mm (2.56), duration of the flood (2.48).

**Indicators of sensitivity and their suitability &weightage**

Principal Component Analysis (PCA) was used to test the suitability as well as to calculate weightage of the six (6) identified indicators of sensitivity of livestock-rearers of the study area. Result portrayed in Table 7 explained that among these 6 indicators, proportion of income from agriculture (1.71) was the most sensitive indicators to flood-induced livelihood vulnerability followed by proportion of income from livestock (1.63), cropping intensity (1.39), average milk productivity of animal in kg (1.34), dependent ratio (1.30), average lactation period of the herd (1.15).

**Table 7: Determinants of sensitivity to flood-driven vulnerability of study area**

**(n=120)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Indicators of Sensitivity** | | **1st Run of Factor analysis** | | **Weightage** |
| **Communalities** | |
| **Initial** | **Extraction** |
| i. | Cropping Intensity | 1.00 | .667 | 1.39 |
| ii. | Proportion of Income from livestock | 1.00 | .798 | 1.63 |
| iii. | |  | | --- | | The proportion of income from agriculture | | 1.00 | .793 | 1.71 |
| iv. | |  | | --- | | Average Lactation period  (all animal) | | 1.00 | .506 | 1.15 |
| v. | |  | | --- | | Average daily milk production of animal ( kg ) | | 1.00 | .525 | 1.34 |
| vi. | Dependent Ratio | 1.00 | .744 | 1.30 |

**Vulnerability to flood among the livestock-rearers of the study area**

Data presented in Fig 2. indicated the average mean value for the adaptive capacity, exposure, and sensitivity of the study area, by calculating separately. The same table also indicated the overall vulnerability value, which was calculated as a function of adaptive capacity, exposure and sensitivity and finally, it was quantified by subtraction of sum of exposure and sensitivity from the adaptive capacity. The mean values of vulnerability and its components of livestock-rearers of the study area were explained in Fig.2

**Fig 2: Average value of vulnerability and its components in the study area (n=120)**

The livestock-rearers of the major flood-prone district had a higher degree of exposure (7.23 ± 0.16) than the livestock-rearers of the minor flood-prone district (3.67 ± 0.15) towards flood. Results also indicated that the degree of exposure differs among the two districts and increases with the increase in the degree of flood proneness. Similarly, mean exposure value of respondents of the overall study area was 5.45 ± 0.20. The livestock-rearers of the minor flood-prone district, major flood-prone district, and overall study area had sensitivity value 3.17 ± 0.05, 2.51 ± 0.06 and 2.84 ± 0.05 respectively.

Livelihood vulnerability of each household was calculated by subtracting the sum of exposure and sensitivity from adaptive capacity. The district having lower livelihood vulnerability value indicated that livestock-rearers of that district were more vulnerable. Therefore livestock-rearers of the major flood-prone district (Balasore) were more vulnerable than minor flood-prone district (Dhenkanal). It was found out that mean value of livelihood vulnerability of livestock-rearers of each district was positive and increased with increase in the degree of flood proneness. Livestock-rearers of the major flood-prone district had the lower adaptive capacity and higher exposure than the minor flood-prone district. This could be the reasons for the higher vulnerability of livestock-rearers of the major flood-prone district (Balasore) than the minor flood-prone district (Dhenkanal). Similarly, the average vulnerability value of respondents of the minor flood-prone district, major flood-prone district and overall study area was 13.20 ± 0.40, 8.60 ± 0.51 and 10.90 ± 0.44 respectively.

**Distribution of respondents of the study area as per their Vulnerability against Flood**

Fig 2. showed the distribution of respondents of the study area in three types of categories based on their vulnerability against flood. In the minor flood-prone district, majority of the respondents (60.00%) were less vulnerable against flood, because their adaptive capacity is higher than the combined effect of exposure and sensitivity to flooding and they have the ability to cope up the flood. Likewise, respondents (48.33%) of the major flood-prone district were highly vulnerable against flood because their adaptive capacity is not to such extent to cope up the effect of flood, because their adaptive capacity is higher than the combined effect of exposure and sensitivity to flooding. Likewise, 42.50 per cent of respondents on an overall basis were having a moderate level of vulnerability against flood.

**Fig 3: Distribution of the respondents as per their Vulnerability against Flood (n=120)**

**CONCLUSIONS**

The study concluded that the overall Livelihood Vulnerability Index (LVI) for livestock rearers was 10.90 ± 0.44. Among the indicators of adaptive capacity, the distance to the nearest veterinary or artificial insemination centre, annual income, distance to the nearest market, and age of the household head emerged as the most influential. The frequency of flood events was identified as the most critical exposure indicator, while the proportion of income derived from agriculture was the most sensitive indicator influencing flood-induced livelihood vulnerability. In the minor flood-prone district, a majority of respondents (60.00%) were classified as less vulnerable, whereas in the major flood-prone district, nearly half (48.33%) were categorized as highly vulnerable. Across the overall study area, 42.50% of respondents experienced a moderate level of vulnerability. The findings reinforce the notion that adaptive capacity is directly linked to enhanced resilience within agro-ecosystems. Therefore, it is imperative for research and development departments in Odisha to address these issues through targeted interventions such as capacity-building programs, flood management workshops, and the promotion of innovative approaches like farmer-to-farmer extension systems to strengthen the adaptive capacity of livestock-rearing communities.

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