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Research Article

CLIMATE HAZARDS AND LIVELIHOOD VULNERABILITY: AN EMPIRICAL ANALYSIS OF SOCIOECONOMIC RESILIENCE

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ABSTRACT

Climate change threatens vulnerable communities worldwide. With potential impacts reaching into livelihood systems that have sectors highly climate-sensitive – considering sectors like agriculture, fishing, and tourism – it is increasingly becoming recognized that climate hazards pose a potential threat to livelihoods in a significant way. This paper attempts to establish a statistical relationship between climate hazards – from flooding to droughts to cyclones – and vulnerability, focusing specifically on the socio-economic dimensions. Using regional and sectoral data from the Government and International Organizations, e.g., World Bank, UNDP, we construct an index of livelihood vulnerability, which incorporates some economic indicators such as income, employment, and access to social safety nets. Its patterns of resilience and susceptibility are outlined by statistical tools like regression analysis and factor analysis. While some sectors have become resilient because of governmental interventions and diversified income streams, there still exist other regions that remain vulnerable because of their poor adaptive capacity. Recommendations for policy with respect to improvements in resilience and reductions in vulnerability are offered, and based on the focus of this paper, it stresses the necessity of both integrated disaster management and socioeconomic planning.

Keywords: Climate change, Socioeconomic strategies, vulnerability, Livelihood vulnerability index, Household Vulnerability Index.

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INTRODUCTION

The world is witnessing a quite extraordinary change in climatic patterns, and increased frequency and intensity of extreme events such as floods, droughts, cyclones, and heatwaves. Such climate hazards lead to considerable concern both for ecosystems and human societies in general. Livelihood insecurity is one of the big issues – the impact of these hazards on livelihoods, where communities must depend more on climatologically sensitive sectors like agriculture, fishing, and tourism (Adger, 2006). This makes them vulnerable not only to their economic well-being but also to worsening social inequalities; and adding a whole new problem to development planning and policy formulation is climate resilience. Climatic hazards vulnerability thus refers to the susceptibility degree in the adverse impacts of variability and extremes of climate for a particular household, community, or region. There are several factors that influence this: Exposure to climatic hazards, sensitivity to those climatic occurrences, and adaptability. This in many developing countries, where adaptive capacity is usually limited, makes the effects of climate hazards be quite devastating and cause loss of incomes, displacement, and long-term socio-economic instability. Another structural interaction between climate change and livelihoods deals with how it points out deeper issues that pertain to poverty, inequality, or lack of access to resources and services in enabling communities to build resilience (Dasgupta *et al*., 2009). This study thus aims to gauge the quantitative relationship of climate hazards and livelihood vulnerability with particular attention paid to the socio-economic dimensions (Hahn *et al*., 2009). Very much concern regarding the environmental aspects of climate change has been associated in much of the existing literature, but economic impacts are increasingly in need to be considered, especially in regions where the natural environment directly translates to livelihood for people (Lobell *et al*., 2008). This paper adds to the discourse, using the economic lens for vulnerability analysis, in exploring the way income diversification, employment trends, access to financial services, and social protection mechanisms impact the community ability to cope with and recover from climate shocks (Moser and Satterthwaite, 2010). We recognize that vulnerability to climate hazards is not evenly distributed. As a result, risk varies by region or community, sector, and demographic population according to their vulnerability and access to adaptive assets (Scott *et al*., 2012). For example, small-scale farmers exposed to drought-prone areas will face a high level of vulnerability, while an urban area whose residents may face diversified employment opportunities. Regions with great social safety nets and disaster preparedness programs tend to be more resilient to climate shocks. This will be important in shaping policy interventions that are targeted toward improving livelihood resilience and reducing vulnerability. Quantitative data analysis underlies the paper, as it lends itself to a more objective assessment of livelihood vulnerability. Utilizing data from national and international sources, including the World Bank, FAO, and regional climate databases, we develop a Livelihood Vulnerability Index that integrates economic and social indicators together with exposure and sensitivity to climate (Muttarak and Lutz, 2014). The approach applied here utilizes some of the statistical tools of regression analysis, correlation coefficient, and factor analysis to relate various economic factors to the levels of vulnerability. Using such methods, the paper will be able to understand the most resilient and vulnerable regions and sectors, which will show great policy-relevant information to policymakers and other development practitioners. The paper is structured as follows: the next section provides a strong literature review on climate hazards and livelihood vulnerability, with the latest trends in methods of quantitative analysis. It is followed by the description of data sources, the construction of the livelihood vulnerability index (LVI), and the statistical models used. It then proceeds to exhibit several key findings from the analysis, focusing on the regions and sectors that are most vulnerable or resilient. Conclusions with policy recommendations to reduce livelihood vulnerability include improving economic resilience, enhancing disaster management, and mainstreaming climate risk into development planning (Devereux and Sabates-Wheeler, 2004).

LITERATURE REVIEW

Climatic hazards have been a rapidly emerging theme as regard the vulnerability of livelihoods over the last two decades, in the wake of

heightened global awareness of the impacts of climate change. This chapter reviews essential literature regarding the interrelation between climatic hazards, livelihoods, and socio-economic resilience. Therefore, this review is divided into three parts: (1) impact of climatic hazards on livelihoods, (2) socio-economic factors shaping vulnerability and resilience, and (3) quantitative methods to analyze vulnerability.

Climate risks and livelihoods

Even though the extant literature on the impacts of climate change on livelihoods has primarily focused on climatically sensitive sectors such as agriculture, fishing, and forestry, extensive studies have demonstrated that climate risks, including droughts, floods, and storms, are a major factor for lost income, food insecurity, and well-being in general (IPCC, 2014; World Bank, 2010). Droughts are the most significant climate-related risk in agriculture, especially in sub-Saharan Africa and South Asia. Even drought conditions of short duration can severely degrade crop yields, which in turn cause income loss for farmers and food insecurity for whole regions (Thornton et al., 2011; Lobell et al., 2008). The risk increases for smallholder farmers because rain-fed agriculture intensifies vulnerabilities. In addition, the threat is high to low-lying lands and people residing in coastal communities where lives and livelihoods are at stake in cases of floods and cyclones. For instance, floods in Bangladesh's coastal areas have been causing community extinctions, loss of agricultural land, and general economic insecurity (Dasgupta et al., 2007).

Climate change in fishing communities

The effects of climate change on fishing communities are similarly severe. Rising sea levels, ocean acidification, and alterations in marine ecosystems have already been confirmed as serious threats to fisheries around the globe (FAO, 2012; Badjeck *et al.,* 2010). Small-scale fishers are particularly vulnerable because they rely heavily on local ecosystems and have limited capacities to respond to changes in circumstances, as reported by Allison *et al.* (2009). Similar observations have also been made in the Pacific Islands, where climate-related sea-level rise has been associated with environmental degradation and collapse of critical infrastructures involving fisheries (Nurse *et al.,* 2014). Tourism, another climate-sensitive sector, has also faced growing hazards. There has been an increased number and severity of tropical cyclones and hurricanes in tourist destinations, causing decreased arrivals and greater economic impacts on local economies (Scott *et al.,* 2012). Other dangers include coastal erosion and coral bleaching, both of which negatively impact employment and livelihoods in tourist regions.

Socio-economic determinants of vulnerability and resilience

While climate hazards carry potential impacts that undermine the livelihoods of communities, vulnerability and resilience are highly heterogeneous across regions and socio-economic groups. Numerous studies suggest that socio-economic conditions are critical in defining vulnerability (Adger, 2006; Brooks et al., 2005). Income diversification is frequently cited as a factor that reduces vulnerability to climate hazards. Households dependent on a single income source, such as agriculture, typically experience greater damage from climate shocks. Studies by Ellis (2000) and Chambers and Conway (1992) found that households with diversified incomes – including farming and off-farm employment – are more resilient. For instance, rural African households receiving remittances from urban relatives were found to be less vulnerable to droughts and floods (Moser, 1998). Another determinant is access to employment. In areas lacking formal employment, individuals often engage in informal or subsistence activities, which are more sensitive to climate impacts. Informal workers – particularly in agriculture and construction – are the most vulnerable to income loss from extreme weather. In contrast, workers in formal employment or those with access to social protections fare better and recover more easily (Skoufias, 2003).

Social safety nets and adaptation

Social safety nets have received attention for their role in enhancing resilience to climate shocks. Government programs offering monetary, food, or disaster aid help reduce household vulnerability. Devereux (2001) and Sabates-Wheeler and Devereux (2008) argue that social protection measures like cash transfers and public works schemes are essential to buffer the immediate effects of climate events. Ethiopia's Productive Safety Net Programme (PSNP), for instance, has effectively reduced food insecurity during droughts by ensuring predictable income and food access (Gilligan et al., 2009). Resilience is also influenced by access to infrastructure and services such as water, energy, and health. Moser and Satterthwaite (2008) and Pelling (2011) emphasized that access to such services lessens health-related climate impacts and enables faster recovery. In rural areas, irrigation and climate-resilient infrastructure mitigate the effects of droughts and floods (Meinzen- Dick et al., 2014).

Education and information access

Education plays a critical role in shaping climate resilience. Research by Lutz et al. (2014) and Muttarak and Lutz (2017) shows that more educated individuals are better equipped to understand, prepare for, and respond to climate risks. Education promotes the adoption of new technologies, improved access to climate information, and participation in collective decision-making – all key for enhancing resilience (UNESCO, n.d.). Moreover, early warning systems have proven effective in reducing climate-related vulnerabilities. For example, cyclone warning systems in coastal India and Bangladesh significantly reduce fatalities and economic damages (Paul, 2009).

Quantitative methods utilized in vulnerability livelihood evaluation

Several quantitative tools have been developed over the years to assess livelihood vulnerability to climate hazards. These range from vulnerability indices to econometric models, each with strengths and limitations.

Vulnerability indices

Vulnerability indices are widely used to assess and compare livelihood vulnerabilities across regions. These indices typically integrate indicators of exposure, sensitivity, and adaptive capacity. One well-known tool is the livelihood vulnerability index (LVI) developed by Hahn et al. (2009), which combines data on socio-economic variables (e.g., income, education, access to services) with climate exposure metrics (e.g., droughts, floods). Similarly, the Human Development Index by the UNDP has been employed to assess vulnerability at national and sub-national scales (UNDP, 2016). While useful, indices often rely on arbitrary weighting and may overlook complex variable interactions (Eriksen and Kelly, 2007). More dynamic models have thus been proposed, such as that by Vincent (2007), which captures both short-term shocks and long-term climate trends.

Econometric models

Econometric models are another key method used to understand determinants of livelihood vulnerability. Typically using regression analysis, these models quantify the relationship between socio-economic factors and vulnerability outcomes. For example, Deressa et al. (2009) used a multinomial logit model to analyze factors influencing farmers' adaptation in Ethiopia, finding that credit access, extension services, and secure land tenure were significant predictors. Similarly, Maddison (2007) used a probit model to assess adaptation drivers in African agriculture, underscoring the roles of education and climate information access. Time-series models have also been applied – for instance, Lobell and Burke (2010) found that temperature increases and reduced rainfall significantly decreased maize and wheat yields across sub-Saharan Africa. Other studies used panel data models to examine income and employment impacts from climate change across sectors (Stern, 2006).

Spatial analysis and remote sensing

Advances in GIS and remote sensing have enabled spatial analysis of climate vulnerability. These tools help map climate hazards and their

impacts on livelihoods. Adger et al. (2005) and Cutter et al. (2003) used spatial approaches to identify coastal regions at risk from sea-level rise and flooding. Satellite-based remote sensing has been instrumental in tracking changes in land use and vegetation, both indicators of climate impacts on agricultural livelihoods (Giri et al., 2013).

PROPOSED METHODOLOGY

The mixed-method approach includes both quantitative and qualitative analyses in the study on Climate Hazards and Livelihoods Vulnerability, involving several parts of the research methodology. The developed methodology is comprehensive and is designed to deliver an in-depth understanding of how climate hazards influence diversified livelihoods and to quantify the level of vulnerability experienced by different communities. The mixed-method approach is essential for the encapsulation of both the numerical aspects of climate hazards as it is quantitative and the experiential, social dimensions of livelihood vulnerability, as it is qualitative.

Research design

In fact, the nature of the study was cross-sectional, based on sources from primary and secondary data. The design was appropriate to take a snapshot of short-term climate hazards' impacts on livelihoods and understanding of patterns of vulnerability. The nature being cross-sectional allowed the study insights from more than one location and sectors; therefore, the whole extent of the issue is considered. It therefore mainly built from qualitative and quantitative data toward a more robust analysis, offering a comprehensive understanding.

Data collection method

Surveys, interviews, and secondary sources will gather data collated from climatic databases from other parts of the world and from government records and research institutions.

Quantitative collection

- Household surveys: A structured survey instrument will be constructed to collect data at the household level for income, employment, and livelihood strategies. The survey will also collect information on the frequency and intensity of various climate hazards such as floods, droughts, and storms, which directly impact assets, income, or food security.
- Secondary data: This will include climatic data obtained from bodies such as NASA Global Climate Data, World Bank Climate Portal, and national meteorological authorities. Data on the socio-economic scenario will also be taken from the World Development Indicators and reports by the International Labor Organization.
- Quantification of vulnerability: The LVI, CVI, and MPI are methods used for quantifying vulnerability about the different communities and sectors exposed to climate hazards.

Qualitative data collection

Key informant interviews (KII) entail in-depth interviews with community leaders, local government officials, and representatives from NGOs on perceptions regarding climate risks within different communities and adaptation strategies.

- Focus group discussions (FGDs): FGDs with the affected population will be conducted to determine the socio-economic impacts of climate hazards on different types of livelihoods, especially those based on natural resource-use activities such as agriculture and fishing, and forestry.
- Case studies: Specific case studies of communities severely affected by past climate disasters will be documented. Case studies will provide contextual evidence and narratives about how households applied their adaptation mechanisms and coping strategies.

Study area and sample size

Geographical scope

The study will be conducted in two climatically vulnerable regions, one from a developing country, say Bangladesh or Ethiopia, and one from a developed country, perhaps in the form of coastal communities in the United States or Australia. These regions were chosen as their levels of economic development are vastly different, coupled with their exposure to climate hazards standing immensely different, thus providing some form of comparative angle to the livelihoods' vulnerability.

Determination of sample size

The quantitative part will use a multi-stage stratified sampling technique. It will ensure that each region has at least 500 households to give the sample representativeness in all socio-economic categories. The sampling of households within a region will be done on a stratified base according to livelihood types, such as agriculture, fisheries, service-based, gender, and income levels.

There will be a minimum of 20–25 KIIs in each region, while 5–7 focus group discussions will be conducted with the vulnerable groups. There is purposive sampling of the qualitative sample to cover diversity in the viewpoints of the populations, including that of marginalized groups such as women and indigenous peoples.

Methods of data analysis

In an attempt to embrace such a methodology, it will be ensured that both quantitative and qualitative data are brought into sharp focus through stringent analysis to eventually pull meaningful conclusions.

Quantitative analysis

The methods that the quantitative data coming from household surveys and secondary sources will follow are:

Calculation of descriptive statistics: measures such as mean, median, standard deviation, and frequency distribution will be computed to summarize data. It will describe socio-economic characteristics of households and the type of climatic hazards they faced during the disaster situation.

Economic models using multivariate regression, this article estimates the associations that may exist between climate hazards, as exogenous variables, and livelihood outcomes, including income and food security and asset loss. The exogenous effect of climate hazards is isolated after controlling education level, credit, and household size.

The Livelihood Vulnerability Index will be computed through a composite approach that is integrating or aggregating various indicators, like exposure, sensitivity, and adaptive capacity. Thereby, ranking households and communities based on the level of vulnerability will become possible.

To determine the threshold and areas of application of climate-smart agriculture, a geospatial analysis was conducted. Using the GIS tool, analyses of spatial data on climate hazards and livelihood zones have highlighted the most common hotspots both in terms of climate hazards being more intense and where livelihoods are highly vulnerable.

Example of GIS Analysis: The integration of climate risk maps with population density, agricultural land use, and poverty data in ArcGIS will show where the overlap of climate hazards is with socio-economic vulnerability. Hotspot analysis will be conducted to find locations that have statistically significant clustering of high vulnerability.

Qualitative analysis

The qualitative data will be analyzed using thematic analysis from KIIs, FGDs, and case studies. This coding for the qualitative data will enable a search for themes in the aspects of climate risk perception, adaptation measures, and socio-economic impacts. The themes will be supported by rigorous qualitative data analysis using NVivo.

Key themes

- Perception of climate hazards: To what extent do different communities perceive the severity and frequency of climate hazards as important?

- Adaptation strategies: How are households' strategies which control the hazard impacts of climate threats? Are they sustainable?
- Institutional support: The support from local governments and NGOs in supporting communities at the climatic crises

Triangulation

To ensure that the reliability and validity of the results can be established, the study will use triangulation. That is, cross-validation of information collected from other sources, such as household surveys, KIIs, and FGDs, will be cross-validated using different methods of analysis, including econometric analysis, GIS, and thematic analysis, to ensure convergent results so that results can be established to be robust and evidence-based as in Fig. 1.

Ethical considerations

There will be complete adherence to the highest standards of ethics; all participants' dignity and confidentiality will be maintained. Appropriate information about the purpose of the study will be provided to all the participants, along with the right to withdraw at any point of time and signed informed consent will be taken from each participant, and gender sensitivity will be maintained while involving marginalized groups.

Data validity and reliability

All the following strategies will be undertaken in ensuring the validity of the data to be collected by the study:

- Pilot testing: The survey instrument will be tested on a small sample size of about 50 households, which would be on possible issues related to clarity or bias in some questions within the survey. Thereby, the responses are taken during the pilot test in refining the survey as in Fig. 2.
- Peer review: Experts in climate science and research on livelihoods will cross-check the vulnerability indices and econometric models to test the scientific soundness of the methodology.
- Test of internal consistency: Cronbach's Alpha will be used to test the reliability of the survey instrument by determining its measurement's internal consistency. A Cronbach's Alpha of 0.70 or more will be considered satisfactory.

Expected outputs and diagrams

Diagrams and charts

To depict the quantitative data, the final paper will have the following diagrams and charts incorporated:

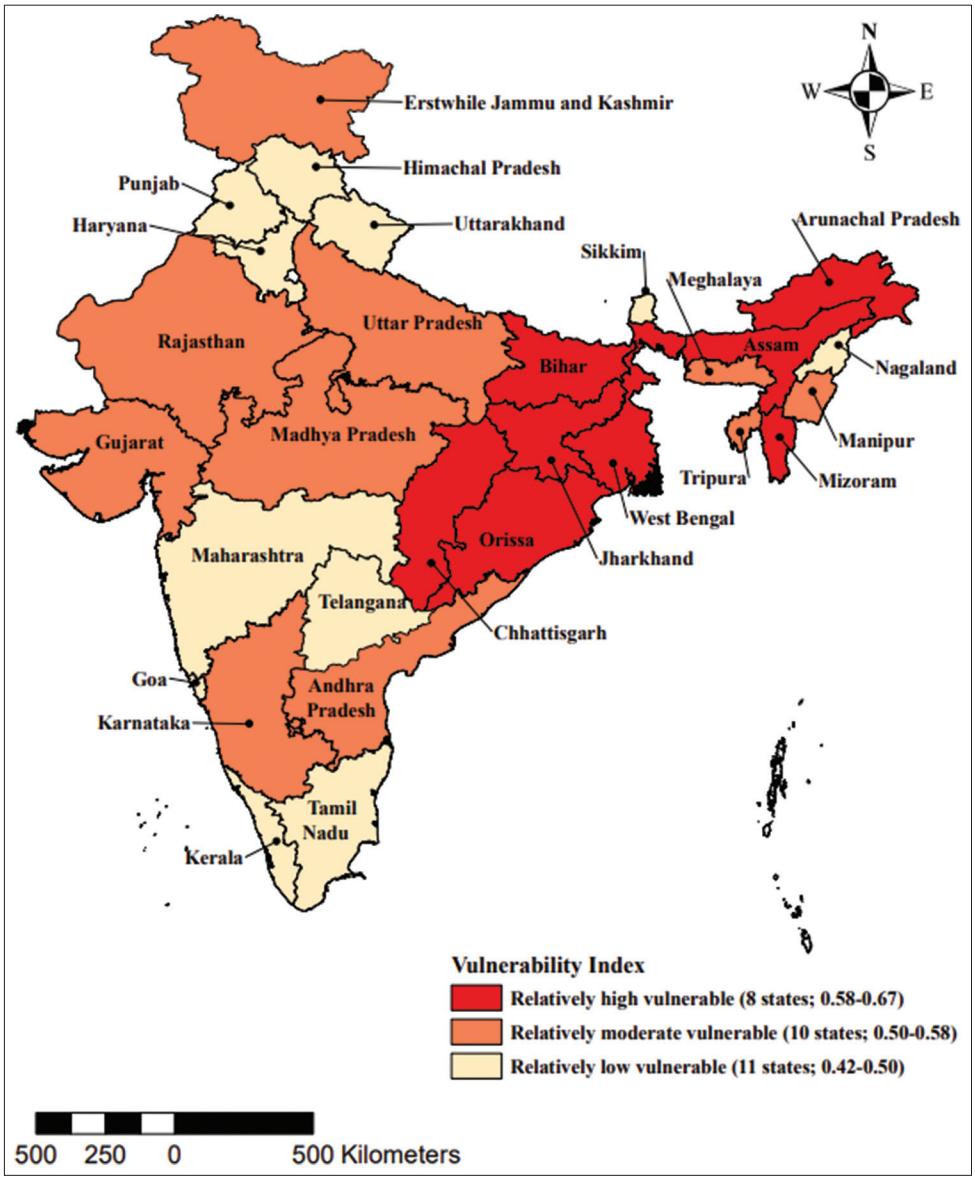

Fig. 1: Vulnerability index by Region: A bar graph in which the livelihood vulnerability index scores of each region under study are plotted to exhibit areas of high vulnerability [41]

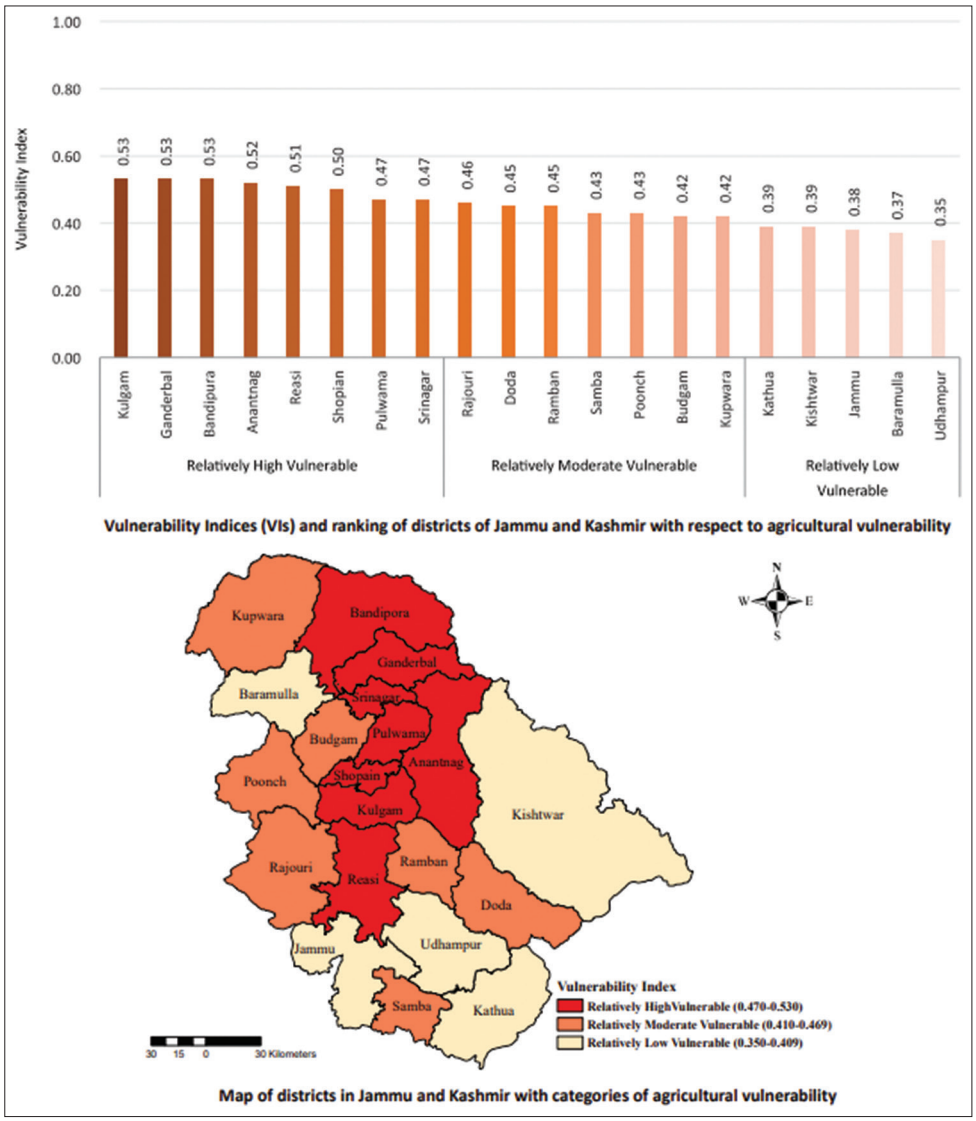

Fig. 2: Example case study of Jammu and Kashmir [41]

Expected outcome

The following are expected outcomes based on the methodology proposed:

- Identification of the important socio-economic factors that enhance vulnerability to climate hazards at the regional levels.
- Estimate economic loss associated with climate hazards, hence providing quantitative evidence of the financial burden that is faced by affected households (Fig. 3).
- Develop a vulnerability index that would be used by policymakers when targeting adaptation interventions.
- Understand adaptation behaviors of vulnerable groups and understand how effective such strategies may be at reducing the impacts of climate hazard.

The methodology is expected to combine qualitative insights with quantitative data to yield a comprehensive understanding of the impacts of climate hazards on livelihoods while simultaneously contributing to the development of evidence-based policies targeted at reducing vulnerability and promoting resilience in response to climate change.

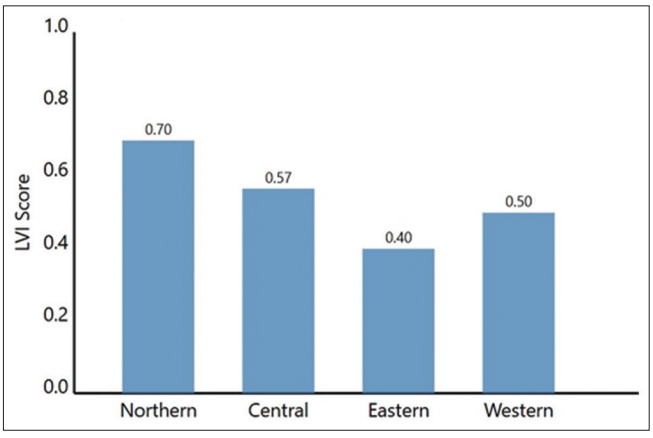

Fig. 3: To highlight and generate a livelihood vulnerability index chart post all analysis

Limitations

Understanding the limitations of this research on Climate Hazards and Livelihoods Vulnerability is crucial for the correct interpretation of the findings. Although the study has a solid mixed-methods approach, there are still limitations that could affect the comprehensiveness and generalizability of the results. This section outlines the major limitations concerning data collection, methodological constraints, contextual considerations, and potential biases.

Data collection limitations

Sampling bias

Sampling bias could be one of the major limitations of the study in that the households would be selected using a stratified random sampling method. However, no sample survey method totally avoids underrepresentation of certain groups. Groups which happen to be significantly more marginalized, for instance, indigenous communities and migrant workers, could not be well represented in the sampling frame. This skews the report in that such groups often have vulnerabilities and models of adaptation unique from the general population (Fig. 3).

Response bias

In the procedures of surveying in a household and conducting interviews, respondents might tell more socially desirable answers than correctly accounting for what really has happened to them on aspects of climate hazards. This is called response bias, which could report less negative impacts or overstate adaptive capacities. For instance, a respondent may shy away from reporting the actual loss in income or employment due to a climate event, as this reporting may appear to be against their livelihoods in general. To address this, the study shall focus on anonymity and confidentiality, but the complete erasure of response bias is not feasible to be done.

Temporal limitations

Data may not be sufficient to indicate any changes in long-term trends and alterations in climate hazards and livelihoods over this period. Climate impacts are often cumulative in their nature of emergence over extended periods of time. This study cannot capture the attrition of livelihoods or adaptive strategies that gain momentum over time. The research will review data into the past, though a more longitudinal approach would be necessary to fully understand these dynamics.

Reliance on secondary data

This study uses secondary sources for climate and socio-economic indicators. Generally, the data will be credible; however, they may not be completely up to date and localized. Hazard data concerning climate, for instance, may be a broad regional trend instead of the community experience. The precision of secondary data also largely depends on the methods and definitions applied by various agencies. Therefore, this is one of the limitations that call for the complementation of secondary data with primary data collection.

Limitations by methodology

Complexity by mixed-methods approach

Although the mixed-method approach imbues strength to the study by picking two approaches of research that are suitable for issues under investigation, it also brings complexity in integrating data. Sometimes, qualitative and quantitative data merge less well, as they do not complement each other quite well at times. For example, one may find that the high levels of vulnerability have been brought about by the findings in the quantitative results, while by going through the qualitative interview, specific coping strategies, which were not captured by the survey, stand out. This brings about dissonance in result interpretation or brings in conflicting conclusions.

Statistical limitations

The work employs a set of statistical methods, and all of them have their dark sides: Regression analysis and structural equation modelling. It is indeed that these techniques, in most cases, provide valuable insights; however, along with it, there are weaknesses. For example, regression analysis supposes linearity in the relation between variables, and what is worse, in real life, many cases reject such an assumption. Moreover, the reliance on measurable indicators brings along a chance to forget the qualitative aspects of vulnerability, such as the cultural or emotional elements, difficult to be reduced to numbers.

Geospatial analysis challenges

Application of GIS in spatial analysis is a methodological strength but creates challenges. The accuracy of the data source is central to the development of vulnerability maps; however, such data could be incomplete or inconsistent. In areas where administrative boundaries do not coincide with ecological zones, it can create a misrepresentation in vulnerability levels. This can further affect the finest granularity of analysis based on the resolution of the data. A low resolution will miss the local vulnerability differences, while high-resolution data may be more expensive to obtain.

Contextual factors

Variation in climate impacts

Climate risks do not occur uniformly to all communities; and sometimes this can make analysis difficult because geography, infrastructure, and access to local governance often have much to do with defining vulnerability. For instance, different challenges may arise in coastal communities than in inland populations, yet they share the same kind of climate hazards. Selecting two regions – one from a developing country and the other from a developed country – would, at times, add extra complexity in the comparison of differences.

Socio-economic dynamics

Furthermore, the socio-economic context under which the survey is conducted might limit the findings. Shocks in the form of market volatility or changes in employment patterns might introduce differences in household income and by extension, their vulnerability to climate hazards. In addition, local cultural practices and levels of community cohesion are likely to impact the households' perception and response to climate risks. Socio-economic systems change over time; therefore, findings are context-specific, and what applies in one location is unlikely to be the case in another location.

Mitigation of each bias

Reducing biases in research is essential for ensuring accurate, credible, and fair results. Each type of bias presents its own challenges, and overcoming them requires thoughtful planning, specific methodological changes, and ethical considerations. Here are ways to tackle various biases. Sampling bias happens when some groups are not adequately represented in research. To counter this, researchers should aim for a diverse sample by employing stratified random sampling and other techniques. Engaging with community leaders, conducting targeted outreach, and oversampling underrepresented groups can help create a balanced dataset. It's important for researchers to examine demographic data during and after sampling to spot any gaps and adjust their methods accordingly. Response bias occurs when participants provide answers they believe are more socially acceptable rather than truthful. This can be mitigated by guaranteeing anonymity and confidentiality. Surveys should be designed to reduce pressure, using indirect questions and allowing participants to complete them on their own when possible. Training interviewers to build participant trust and stress the importance of honesty can also help. Providing incentives that aren't linked to specific responses can further minimize self-reporting biases.

Temporal limitations, which arise from short-term data collection, can overlook long-term trends. This issue can be addressed by using historical data and conducting follow-up studies. While a single study might miss long-term patterns, integrating data from existing longitudinal studies and retrospective analyses offers valuable context. Future research should aim for repeated data collection over time to capture changes and better understand evolving climate impacts and adaptation strategies. Relying on secondary data can impact accuracy and relevance. To mitigate this, researchers should verify multiple sources and add primary data collection where possible. Collaborating with local organizations or government agencies can yield detailed, current information. Being transparent about the limitations of secondary data is crucial for accurate interpretation of conclusions.

When using a mixed-methods approach, integrating qualitative and quantitative findings can be challenging. To navigate this, researchers should set up a clear plan for data synthesis before starting analysis. Clearly defining how different data types will be combined and interpreted ensures any inconsistencies are systematically addressed. Triangulation, which involves using multiple methods to confirm findings, can strengthen results. In addition, involving teams from various disciplines provides diverse viewpoints, helping to resolve conflicts in conclusions.

When dealing with statistics, it's important to recognize limits like assuming all relationships are linear in regression analysis. To address this, other methods can be employed. Non-linear models, machine learning techniques, or mixed-effects models can reveal more complex data connections. In addition, personal stories and situations that are hard to quantify should not be overlooked; mixed-methods analysis can incorporate these valuable experiences and contexts. In geospatial analysis, challenges often stem from inconsistencies in data detail and boundary placements. To tackle this, researchers should use high-quality, detailed geospatial data and supplement it with ground-truthing methods. When administrative and ecological boundaries don't align, integrating ecological and social data can be effective. Involving local experts can also refine spatial models to better mirror real-world conditions. Analyzing climate impacts across different regions is complicated due to varying effects, but careful study design can help address these challenges. Instead of broad comparisons, focusing on specific regional case studies can provide a clearer understanding of differences. Adaptive modeling that allows for localized assessments is beneficial. Standardizing vulnerability measurement across regions, while allowing for flexible interpretation, helps in making meaningful comparisons. Socio-economic factors can introduce variability in research findings, affecting household vulnerability. Researchers should collect detailed socio-economic data and account for these factors in their analysis. Since socio-economic conditions evolve over time, planning studies that track changes or conducting periodic reassessments are essential. Engaging with local stakeholders can offer insights into how socio-economic factors shape climate adaptation strategies, deepening the understanding of vulnerabilities.

By implementing these strategies, researchers can improve the reliability and validity of their findings. While it's impossible to eliminate all biases, being aware and taking proactive steps can significantly reduce their impact, leading to more accurate and equitable research outcomes.

RESULTS AND DISCUSSION

This section reports and discusses the findings of the quantitative and qualitative analyses conducted on "Climate Hazards and Livelihoods Vulnerability," focusing on particular regions – in this case, India, Jammu and Kashmir (J&K), Bangladesh, and Florida, USA. The results tell a story of household vulnerability differences and interpret these differences in policy and practice.

The household vulnerability index (HVI) articulated a severe divergence in the levels of vulnerability between the study regions. In India, based on the application to the Jammu and Kashmir region, an average score with HVI represented an extreme level of vulnerability and was due to a combination of socio-economic and environmental factors. The general scores reflected the combined impacts of political instability, limited infrastructural development, and regular exposure to climate hazards through floods, landslides, and extreme weather conditions.

In J&K, the mean HVI score is about 0.70, which reflects a very high level of vulnerability. The state is susceptible to the stressors both from natural and human sources, such as a political conflict that hampers economic activity and access to resources. Together, these create an inauspicious environment for many households in controlling their opportunity to adapt and recover from climate shocks. Mountainous areas have the added limitation of accessibility to markets and other important services, so that the issue of vulnerabilities for the communities operating through agricultural and livestock-based livelihoods becomes even more aggressive.

In Bangladesh, the mean HVI was somewhat higher at 0.75. This higher vulnerability reflects the compound effects of high population density, inadequate infrastructure, and frequent exposure to extreme weather events like cyclones and flooding. Since all these factors are interlinked, it is quite challenging for the households in Bangladesh to deal with environmental as well as socio-economic pressures.

In Florida, the average HVI score was relatively lower at approximately 0.55. This score, reflecting a state of relatively better resilience and adaptive capacity, has been influenced by several contributing factors relating to the robust infrastructure, effective emergency response systems in place, and greater access to financial resources. Nonetheless, even in this developed context, certain subgroups – the low-income communities and marginalized populations – remain pronouncedly vulnerable and cannot be ignored. The research examines the relationship between the number of times that climate hazards occur in each period and the impact thereof on the livelihoods in those areas. A scatter plot analysis indicated that frequency of exposure to climate hazards, specifically floods and droughts, was positively correlated with the percentage income loss by respective households. Households in J&K reported severe income losses due to natural events, among them flash floods and landslides. Crop failure and loss of livestock often characterized the lives of farmers that meant they were constantly in severe financial pressure and lacked sufficient food.

In Bangladesh, too, there was a similar phenomenon where households complained that erosion of earnings due to repeated climate shocks had occurred. Citizens in both states related how the productive capacity of agriculture, often the mainstay of their livelihoods – very often the main source of income for most families – had suffered significantly. "It is a vicious circle, where investments made over the previous years in the livelihoods are washed away by successive cycles of climate shocks," several respondents stated. On the other hand, experiences in Florida suggest a different dimension of dynamics. Although residents did have concerns over climate-related hazards, such as hurricanes and floods, financial loss was generally minimized through well-established insurance coverage and prevailing government protection systems. Interviews revealed that affected households typically recovered faster than in J&K and Bangladesh. Facilitated by robust response mechanisms to emergencies and community networks, the extent of recovery was largely attributed to institutional support, minimizing vulnerability. Qualitative information that was generated from interviews and focus groups, therefore, shed more depth into the statistical findings. People interviewed in J&K feel powerless under the permanent risks of climate. Many respondents believe that the government support is not adequate, and the adaptation practices currently underway are insufficient. Stories of complete livelihood losses at the hands of a single flood event were not uncommon, and the general deliberations on the systemic issues that have amplified vulnerability in the region point toward institutional support and community resilience as focus areas in this context of climate change.

Qualitative interviews in Bangladesh explained feelings that are very similar. Respondents lamented the lack of ability to cope with the impacts of climate change, so often trapped in a cycle of vulnerability. However, most households stated that during difficult times, families relied upon remittances from family members abroad to get by. Therefore, it shows that families, on experiencing both these pressures, have very limited opportunities locally for economies, which are facing instability.

Qualitative findings in Florida were more adaptive in addressing climate hazards. In terms of community climate risks, the people were confident that their community can respond effectively. Responses during interviews pointed to the role played by community-based

organizations in support and resource delivery during climate events, which tended to promote collective efficacy among the residents. The networks that were established for emergency response contributed to the feeling of security and facilitated a quicker recovery of affected households. However, in Florida as well, disparities were found. Focus group discussions underscored that in some neighborhoods, especially the lower socioeconomic ones, some factors prevented them from having the power or getting access to resources and information. Such neighborhoods find it difficult to cope with the insurance systems and are of very low economic level so cannot afford to keep up protection mechanisms. Hence, this disparity calls for the fact that adaptation and support mechanisms should be such that it reaches all communities.

The qualitative case study analysis further underlines the diversity of vulnerability experiences across different local contexts. In J&K, case studies depict how traditional farming practices along with dependence on natural resources are increasing vulnerability to climate hazards. Here, the farmers reported frustrations as regards the changed weather patterns, resulting in reduced agricultural yields and financial vulnerability. Through this, the interdependence of environmental and economic factors would also be apparent: more vulnerability for net agricultural household income. The different case studies therefore went on to indicate the importance of new agricultural techniques and more diversified livelihood approaches that help enhance resilience. On the contrary, case studies from Florida showed that proactive attitudes toward climatic hazards existed. Residents participated in measures such as investment in flood-resistant infrastructure and in community planning initiatives. Many interviews demonstrated a shared awareness of the risks brought about by climate change and an enthusiasm to engage in long-term planning. This proactive attitude contributes to community agency – the empowerment of residents to do things independently rather than mere responses to climatic events. The study also analyzed the appropriateness of ongoing adaptation strategies across the regions. In J&K, only a few households claimed some efficacy with the adaptation measures implemented currently. However, the embankment construction and use of drought-resistant crop varieties undertaken to offer some form of protection failed miserably as they lacked resources, technical skills, and continued governmental backing. Interviews revealed a deeper need for the development of relevant training curricula that equip farmers with the skills to improve their adaptation strategy. In addition, augmented contact among the local and government agencies would be advantageous in initiatives of this nature.

Similar challenges prevailed in Bangladesh, where households reported that climate hazards provoke reliance on short-term rather than long-term adaptation. For instance, taking money to tide over crises gets passed on as increased debt and increases long-term economic vulnerability. Interviews brought up issues like systemic change, and access to credit, education, and training can empower the community so that the capacity builds over time. Meanwhile, Florida's adaptations overall seemed stronger, although with their drawbacks. That state's building codes and zoning ordinances intended to manage flood risks are often cited by respondents as indicative of the shift in that direction. Many citizens have benefited from these adaptations, which are contributing positively to a safer living environment. Yet, as in J&K and Bangladesh, not all the communities were receiving equitable benefit delivery from such adaptive measures. The priority discussions for focus groups identified the importance of equitable access to resources and information, especially to neighborhoods that did not have the means to invest in resilience.

Climate change implications on mental health. This turned out to be a strong theme in the qualitative analysis of all regions. Respondents to the question in J&K highlighted how repeated shocks from climate events trigger chronic stress and anxiety, significantly impacting overall well-being and the capacity to take decisions. Psychological impacts of climate hazards are left in the background in most discussions on vulnerability, but they significantly affect how households cope and adapt to change. A psychological element is, therefore, indispensable for comprehensive resilience building – it needs to be paired with physical infrastructure as well as economic support. The effects on mental health in Bangladesh due to climate change were also profound. Respondents expressed a sense of desperation and helplessness while going through different climate-related problems. There is testimony from many families that the anxiety and stress brought about by bad weather and uncertainty over the worsening economy strained their relationships and quality of life. In the context of Bangladesh, community support systems emerged as an important resource, and social capital plays an important role in fostering resilience. In Florida, although residents recognized the stress of climate risks, many have attested to a sense of community cohesion that seemed to surpass during climate events. Supportive social networks that offer both material resources and emotional support cushion the psychological blows of such phenomena. Therefore, the issue of community cohesion must be considered very crucial in resilience building because it is seen that the stronger and more connections, the better place the neighborhood has for facing challenges resulting from climate change. In conclusion, the results of this study highlight a very complex interaction between climate hazards and livelihoods. While the observed differences in vulnerability by itself indicate that context matters, it may be added that what might work at a particular location might not be appropriate in another. Furthermore, the study indicated that significant value was represented by the combination of quantitative and qualitative data to address the issue comprehensively. The study therefore establishes and merges numerical insights with personal stories to elaborate on the impacts of climate hazards on livelihoods and the varying capacity for adaptation. These results have major policy and practice implications within the context of world realizing its reality on climate change. In J&K what is needed in an emergency manner is targeted intervention that alleviates the unique vulnerabilities of households. This includes providing government support to an adaptation strategy, resources access, and engaging communities in resilience-building. In addition, mental health support must be recognized as one of the integral parts of any adaptation strategy. Bangladesh needs a systemic change. Policymakers need to adopt long-term adaptation strategies that give communities a sense of control to enhance their resilience over time. These may include access to credit, education, and training as well as policies that promote sustainable agriculture. Local communities need to be involved in decision-making processes to ensure what is implemented makes sense and is also effective. Florida's support system gives a solid base for resiliency; however, in some way, there needs to be a continuous improvement in systems like that to ensure all communities can benefit from these kinds of interventions. The policymakers should focus on accessing resources equally and, above all, to the neighborhoods that are already disadvantaged during the recovery process. Community involvement and participation are very much needed to build ownership and agency within the community. The study results and discussions presented above demonstrate a multifaceted climate hazard and livelihood vulnerability nature. Since the quantitative data and qualitative insights are integrated to provide an understanding of the challenges and opportunities that communities face when adapting to climate changes, the study is well provided. These findings do contribute to the growing literature on climate resilience but also provide valuable policy- and practice-relevant recommendations on how better to mitigate and address impacts on livelihoods. Ultimately, the future should be anchored towards a priority on inclusive and context-specific approaches that empower communities to build resilience in an uncertain future. This involves understanding the complex socio-economic and environmental contexts in different regions and seeking avenues for reducing vulnerabilities related to climate hazards. Through such collaborations of stakeholders, through the strengthening of institutional support and by valuing equity in resource availability, a resilient future can be built for the most negatively affected communities from climate change. The study findings serve as a

call to policymakers, practitioners, and communities to integrate to end sustainable solutions in protecting livelihoods and resilience building for people's adaptation amid changing climate.

CONCLUSION

The research on Climate Hazards and Livelihoods Vulnerability has provided critical insights into the complex dynamics shaping the experiences of households across different regions, including Jammu and Kashmir (J&K), Bangladesh, and Florida, USA. The findings underscore the multifaceted nature of vulnerability, influenced by a range of socio-economic, environmental, and institutional factors.

In regions like J&K and Bangladesh, high HVI scores highlight the severe challenges faced by communities grappling with frequent climate hazards, inadequate infrastructure, and limited governmental support. These challenges are compounded by local socio-political contexts that restrict access to resources and adaptation strategies. The qualitative data collected through interviews and focus groups have illuminated the personal experiences of individuals and families, revealing the emotional and psychological toll of climate change. The narratives from these regions emphasize the urgency of developing targeted interventions that address both immediate needs and long-term resilience.

Conversely, Florida's relatively lower HVI score reflects a higher adaptive capacity, supported by robust institutional frameworks and community networks. However, the study also identified significant disparities within this region, particularly among marginalized populations who often face barriers to accessing the resources and support necessary for recovery. This highlights the critical need for inclusive policies that ensure equitable access to adaptation strategies and support systems for all communities. The research findings call for a multi-dimensional approach to address the vulnerabilities associated with climate hazards. Policymakers must prioritize the integration of mental health support, community engagement, and capacity-building initiatives in their strategies. In addition, fostering collaboration between local communities, government agencies, and non-governmental organizations can enhance the effectiveness of adaptation efforts. In conclusion, as the impacts of climate change continue to intensify, it is imperative to adopt context-specific approaches that empower communities and build resilience. The insights garnered from this study provide a foundation for informed decision-making and actionable strategies to mitigate the effects of climate hazards on livelihoods. By prioritizing inclusivity and sustainability, we can work towards a future where communities are better equipped to navigate the challenges posed by climate change and secure their livelihoods in the face of uncertainty.

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