P-ISSN: 2618-0723
E-ISSN: 2618-0731

Extension Journal

NAAS Rating: 5.04
www.extensionjournal.com

International Journal of Agriculture Extension and Social Development

Volume 8; Issue 3; March 2025; Page No. 346-353

Received: 02-01-2025
Accepted: 05-02-2025

Indexed Journal
Peer Reviewed Journal

Mapping climate vulnerability in Meghalaya: A three-tiered analysis at district, block, and village levels

[1] N Uttam Singh, [2] N Laitonjam, [3] PM Sharma, [4] Wanbiang Dkhar, [5] BP Singh, [6] SB Singh, [7] A Roy, [8] Krishnappa Rangappa, [9] D Chakraborty, [10] Anjoo Yumnam, [11] Pampi Paul, [12] Kamni P Biam, [13]HRC Gowda and [14]VK Mishra

[1] Senior Scientist (Agricultural Statistics) ICAR Research Complex for NEH Region, Meghalaya,

[2] YP II, ICAR Research Complex for NEH Region, Meghalaya, India

[3] Project Associate, ICAR Research Complex for NEH Region, Meghalaya, India

[4] Project Assistant, ICAR Research Complex for NEH Region, Meghalaya, India

[5] Principal Scientist (Agricultural Extension) ICAR Research Complex for NEH Region, Meghalaya, India

[6] Principal Scientist (Agricultural Economics) ICAR Research Complex for NEH Region, Meghalaya, India

[7] Senior Scientist (Agricultural Economics) ICAR Research Complex for NEH Region, Meghalaya, India

[8] Senior Scientist (Crop Physiology) ICAR Research Complex for NEH Region, Meghalaya, India

[9] Scientist (Agricultural Meteorology) ICAR Research Complex for NEH Region, Meghalaya, India

[10] Scientist (Agricultural Economics), ICAR Research Complex for NEH Region, Meghalaya, India

[11] Scientist (Agricultural Extension), ICAR Research Complex for NEH Region, Meghalaya, India

[12] Scientist (Agricultural Extension), ICAR Research Complex for NEH Region, Meghalaya, India

[13] Scientist (Agricultural Economics), ICAR Research Complex for NEH Region, Meghalaya, India

[14] Director, ICAR Research Complex for NEH Region, Meghalaya, India

DOI: https://www.doi.org/10.33545/26180723.2025.v8.i3e.1721

Corresponding Author: N Laitonjam

Abstract
The study examines climate change vulnerability in Meghalaya at the district, block, and village levels using the IPCC 2014 framework. A vulnerability index is applied to categorize areas into different vulnerability levels, from very low to very high. At the district level, the analysis identifies notable regional variations in vulnerability, with South Garo Hills and West Khasi Hills classified as very high vulnerability, while several other districts-including East Khasi Hills, South West Garo Hills, East Jaintia Hills, Ri Bhoi, North Garo Hills, West Garo Hills, and East Garo Hills-fall within the high vulnerability category (72.73%). On the block level, a substantial proportion (69.57%) of blocks in Meghalaya are highly vulnerable, with 21.74% falling into the very high vulnerability category. This detailed assessment underscores the urgent need for focused climate adaptation strategies, particularly in high and very high vulnerability areas, to effectively address climate-related risks.

Keywords: Vulnerability, climate change, sensitivity, adaptive capacity

Introduction

The study is conducted in Meghalaya, a state located in the Northeastern (NE) part of India. Situated between 24°57′ to 26°10′ N and 89°46′ to 92°53′ E, Meghalaya covers an area of approximately 22,429 km². The state's temperature ranges from 2°C to 35°C and it receives the highest rainfall in the country. Meghalaya is home to Mawsynram and Cherrapunjee, which are among the wettest places on Earth. Over the past 35 years, Cherrapunjee has averaged 11,952 mm (470 inches) of rainfall annually, with some years recording even higher amounts. The economy of Meghalaya is primarily agrarian, with agriculture contributing 22% to the Gross State Domestic Product (GSDP). About 80% of the state's population relies directly or indirectly on agriculture, and the sector plays a key role in employment and income generation. Despite this, the Net Cropped Area represents only 9.76% of the state's total geographical area.

Additionally, the state is highly vulnerable to climate change impacts and has recently experienced extreme weather events. It is prone to floods and soil erosion, which make the agricultural sector particularly susceptible to damage. Out of the seven NE states, Assam and Meghalaya with 32% rainfall deficit seems to have suffered the most from rainfall deficit and high temperature during 2006 monsoon season while the remaining states experienced 25% rainfall deficit during the period (Das *et al.*, 2010) [3]. During end of July 2009, most of the NE states are affected by drought like situation. Manipur, Nagaland, Meghalaya witnessed severe meteorological drought while other states have recorded moderate drought. Till July, 20, 2009 Manipur recorded 67% rainfall deficiency followed by Nagaland (-63), Meghalaya (-56), Assam (-34), Mizoram (-32), Tripura (-31) and Arunachal Pradesh (-29) (Times of India, 22 July, 2009). Analysis of long-term temperature data for the NE region points to a distinctly rising trend in surface air temperatures. The annual mean maximum temperatures rise at the rate of 0.11°C per decade while the annual mean temperatures increased at the rate of 0.04°C per decade (Das 2004) [4].

Climate change in Meghalaya has already led to more frequent and intense weather extremes, including floods, landslides, and severe droughts, which disrupt local agriculture, damage infrastructure, and increase vulnerability among rural communities. These changes are expected to further exacerbate existing socio-economic challenges, threatening food security and increasing risks to health, water resources, and biodiversity. While a number of studies have explored climate vulnerability in India, there is a significant gap in region-specific, comprehensive assessments that focus on the district, block and village levels. Moreover, previous research on vulnerability in NE India and Meghalaya has been largely confined to specific pockets within the region. For example, Thong *et al.* (2022) [20] and Thangjam *et al.* (2023) [19] assessed socio-economic vulnerability among shifting cultivators (Jhumias) in three districts of Mizoram. Similarly, Devi *et al.* (2022) [5] examined farmers' resilience to climate change across three districts: East Siang (Arunachal Pradesh), Bishnupur (Manipur), and East Khasi Hills (Meghalaya). Dubey (2022) [6] focused on livelihood vulnerability in three villages-Thoubal Khunou (Manipur), Iewrynghep (Meghalaya), and Hari-II (Arunachal Pradesh). Although these studies provide valuable insights, they are limited to specific districts and villages, lacking a comprehensive, region-wide perspective. IIT Guwahati and IIT Mandi (2019) study district level vulnerability in Indian Himalayan region lacking an in-depth analysis of block level and district level vulnerability assessment of the region. In 2018-19, [11] the Meghalaya Climate Change Centre (MCCC) conducted a district-level vulnerability assessment (MCCC, 2019) [12], but this analysis was limited to only seven of the state's districts, even though Meghalaya now comprises eleven districts. Additionally, the MCCC (2021) [13] also evaluated block-level vulnerability in Meghalaya limited to 39 blocks, however the sate now comprise of 46 blocks. Moreover, the data used for this assessment primarily relied on the 2011 Census, which is outdated. Some of the data used were from 2019-2020, creating a discrepancy in timeframes and potentially affecting the consistency and relevance of the findings. To address these challenges, this study aims to provide a comprehensive analysis of climate vulnerability at the district (11nos.), block (46 nos.), and village (5997 nos.) levels in Meghalaya.

Materials and Methods

Data used: Spatial secondary data for the year 2020 were obtained from the Ministry of Rural Development, Government of India. The dataset encompassed approximately 180 parameters at the village level. Among these parameters, suitable sub-indicators related to adaptive capacity and sensitivity were identified through exploratory factor analysis. The data for the identified sub-indicators were subsequently cleaned and tested using descriptive statistics for further analysis.

Identification of Indicators

Sensitivity and adaptive capacity, as defined in the IPCC 2014 framework, are two critical components of vulnerability. Sub-indicators were initially identified using Exploratory Factor Analysis (EFA). To further validate the factor structure of these observed variables, Confirmatory Factor Analysis (CFA) was subsequently employed. However, the results of the CFA indicated that it was not feasible to incorporate the identified sub-indicators effectively. Consequently, the identification of sub-indicators remained anchored to the findings from EFA.

Exploratory Factor Analysis (EFA)

Exploratory factor analysis (EFA) is one of a family of multivariate statistical methods that attempts to identify the smallest number of hypothetical constructs (also known as factors, dimensions, latent variables, synthetic variables, or internal attributes) that can explain the covariation observed among a set of measured variables (also called observed variables, manifest variables, effect indicators, reflective indicators, or surface attributes). That is, to identify the common factors that explain the order and structure among measured variables. In the social and behavioral sciences, factors are assumed to be unobservable characteristics of people, which are manifested in differences in the scores attained by those people on the measured variables (Tucker & MacCallum, 1997) [21].

The identified indicators will then be normalized so as to bring the values of the indicators within the comparable range (Nelson *et al.*, 2010; Gbetibouo and Ringler, 2009; Vincent, 2004) [8, 15, 22].

Normalization for positively related indicators

$$Z_i = (X_{ij} - \text{Min } X_{ij}) \div (\text{Max } X_{ij} - \text{Min } X_{ij}) \quad \text{……(i)}$$

Where, Z_i= Normalized value.

Normalization for negatively related indicators

$$Z_i = (\text{Max } X_{ij} - X_{ij}) \div (\text{Max } X_{ij} - \text{Min } X_{ij}) \quad \text{……(ii)}$$

Where, X_{ij} = observed value

Min X_{ij} = minimum of observed value

Max X_{ij} = maximum of observed value

In the next step, net weight should be assigned to the indicators. The earlier researchers followed equal weightage method (Vincent, 2004) [22]. One significant limitation of equal weighting method is the assumption that all indicators contribute equally to the outcome, which may not reflect the

reality of the situation being assessed. In many cases, certain indicators may have a disproportionately larger impact on vulnerability than others, leading to potential misrepresentation of the overall vulnerability profile (Greco *et al.*, 2018; Žurovec *et al.*, 2017) [9]. This oversimplification can result in inadequate responses to critical vulnerabilities that require targeted interventions (Stephan *et al.*, 2023) [18].
Another weighting method is expert's judgment (Vincent, 2007; Adger and Vincent, 2005) [1, 23] which is not an appropriate method and is often criticized for being too subjective. This method can lead to biases in the weight assigned to different indicators. Experts may have personal preferences or experiences that influence their assessments, resulting in inconsistent or skewed weight distributions across different experts (Hammitt and Zhang, 2012; Önkal *et al.*, 2009) [10].
Assigning weight using Principal Component Analysis (PCA) is also another method (Nelson *et al.*, 2010; Gbetibouo and Ringler, 2009) [8, 15]. One major disadvantage of PCA is that it transforms original variables into principal components, which can obscure the meaning of the weights assigned to each sub-indicators. Decision-makers may find it challenging to interpret these components in the context of the specific criteria being assessed, leading to difficulties in understanding the implications of the weightings (Okey 2018) [16]. Iyengar and Sudarshan's Method ensures that large variation in any one of the indicators does not dominate the contribution of other indicators (Anon, 2016) [2]. One of the primary advantages of this method is its ability to reflect the relative importance of different indicators (Mekonen & Berlie (2021) [14], Feyissa *et al.*, 2018) [7]. Hence, in the present paper, weight is assigned using Iyengar and Sudarshan's Method.
The unbiased weight will be calculated using the formula given below

$$W_j = \frac{c}{\sqrt{variance\ (xij)}} \quad \text{..........................(iii)}$$

Where w's ($0< w<1$ and $\sum_{j=1}^{k} wj = 1$) are weights. These weights are assumed to vary inversely with variance over regions in the respective indicators on vulnerability. 'c' is the normalizing constant such as

$$c = \frac{1}{\sum_{j=1}^{j=k} \frac{1}{\sqrt{variance\ (xij)}}}$$

$$F(z) = \frac{z^{a-1}(1-z)^{b-1}}{\beta(a,b)}, \quad 0< z < 1 \text{ and } a,b > 0$$

Where $\beta(a,b)$ is a beta function defined by

$$\beta(a,b) = \int_a^1 x^{a-1}(1-x)^{b-1}\,dx$$

Finally, vulnerability index for each household will be calculated using the formula

V = f (S, AC)

Where, V = Vulnerability index

S = Sensitivity index
AC = Adaptive capacity index

Functionally, vulnerability is directly related with sensitivity and inversely with adaptive capacity. In other words, vulnerability increased with increased in sensitivity and decreased in adaptive capacity.
A higher value of the vulnerability index indicates higher vulnerability, while lower value indicates lower vulnerability.

Range of Vulnerability index

The vulnerability index was classified into Very Low, Low, Medium, High, and Very High categories using the equal interval method. At the district level, the classification range was determined using the vulnerability index values of all districts. Similarly, for block and village levels, the ranges were calculated based on the vulnerability index values of each block and village, respectively.
The district level vulnerability profile for Meghalaya is presented in Figure 2. The state consists of 11 districts, which have been classified into five vulnerability categories: very low (0.0140-0.0143), low (0.0143-0.0146), medium (0.0146-0.0149), high (0.0149-0.0151), and very high (0.0151-0.0154) vulnerability.
About 72.73% of the districts (8 districts) exhibit high vulnerability, including East Khasi Hills, South West Garo Hills, East Jaintia Hills, Ri Bhoi, South West Khasi Hills, North Garo Hills, West Garo Hills, and East Garo Hills. West Jaintia Hills (9.09%) is classified under medium vulnerability, while South Garo Hills and West Khasi Hills (18.18%) are categorized as very high vulnerability, reflecting severe challenges in health, nutrition, and socio-economic resilience. The MCCC 2019 [12] report evaluated seven districts of Meghalaya based on climate vulnerability, categorizing five districts as high vulnerability and two districts, South Garo Hills and Ri Bhoi, as low vulnerability. The report also highlighted West Khasi Hills as the most vulnerable district among the seven, which aligns with the findings of the present study.
The variation in vulnerability rankings between the MCCC report and the current study can be attributed to differences in the indicators used for vulnerability assessment. The MCCC report primarily relied on socio-economic variables such as population density, poverty levels, literacy rates, food grain yield variability, forest area, and institutional factors like NREGS participation. In contrast, the present study incorporates a broader range of factors, including education, health sector performance, public services, agriculture and allied sectors, infrastructure and sanitation, water management, livelihoods, and handicrafts, to provide a more comprehensive assessment of development and vulnerability in the region.

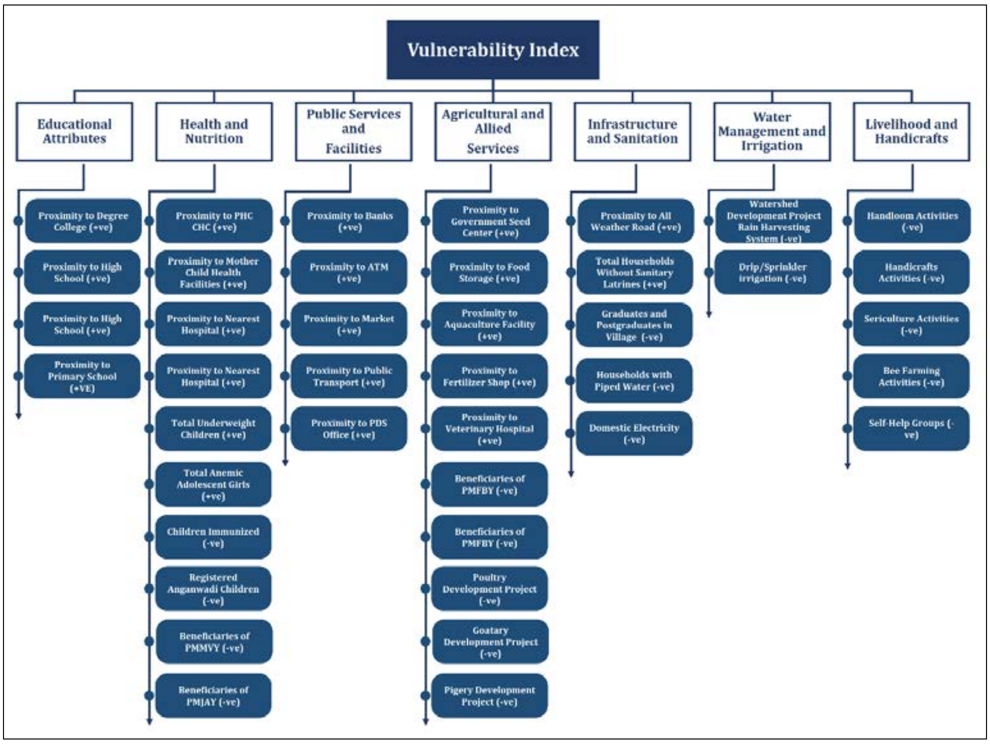

Fig 1: Vulnerability index indicators across socio-economic and infrastructure sectors in Meghalaya

Results and Discussion

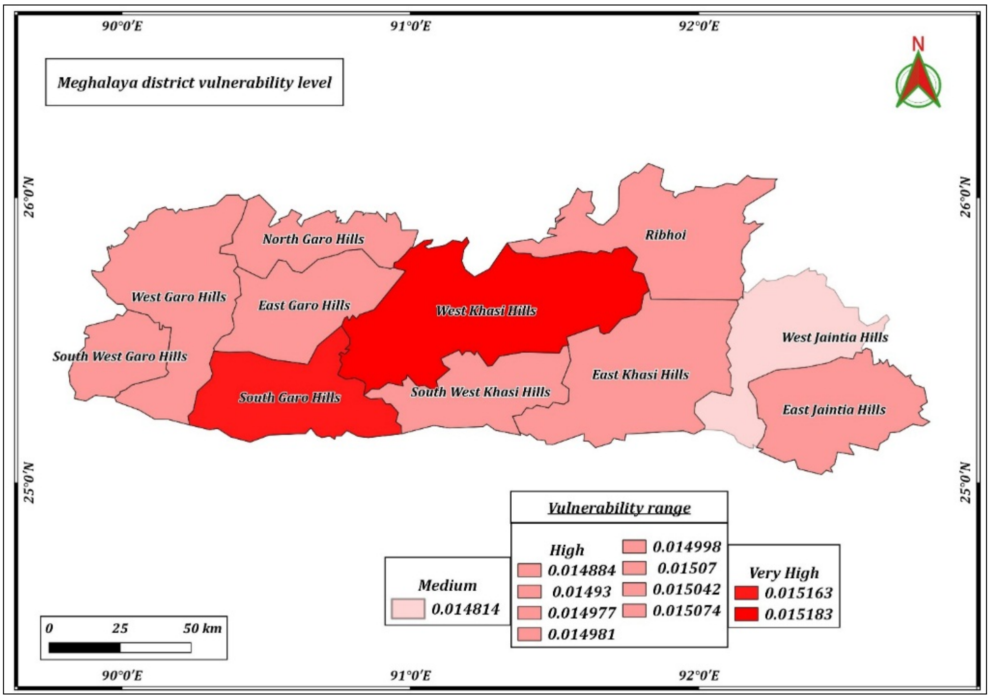

Fig 2: District level vulnerability profile in Meghalaya

Drivers of Vulnerability

A comprehensive understanding of vulnerability drivers is essential for formulating policies that promote sustainable development. By identifying these key factors, policymakers can design effective adaptation strategies that ensure sustainable resource management and resilience.

Figure 1 presents various indicators contributing to vulnerability across the eight states of NE India, categorized into eight domains: Health and Nutrition, Village Education and Infrastructure, Infrastructure and Sanitation, Agricultural and Allied, Water Management and Irrigation, Livelihood and Handicrafts, Educational Attributes, and Others. Each domain consists of multiple sub-indicators. The main drivers of vulnerability are identified based on the weight of each indicator (expressed as a percentage of the total). Only sub-indicators with a weight exceeding 1% are considered as major drivers, while the remaining sub-indicators are grouped under the category 'Others' (Fig-3).

Vulnerability in Meghalaya is predominantly influenced by health and nutrition factors, with the percentage of total anemic pregnant women standing at 11.49% (Figure 3). This is followed by 8.93% of registered Anganwadi children, 8.90% of beneficiaries of the Pradhan Mantri Matru Vandana Yojana (PMMVY), 4.92% of underweight children, and 4.16% of anemic adolescent girls. In addition to health and nutrition factors, other significant drivers of vulnerability include issues related to infrastructure and sanitation (10.16%), livelihood opportunities and handicrafts (9.24%), water management and irrigation (9.10%), agriculture and allied sectors (8.92%), and educational indicators (7.23%).

The high prevalence of anemia among pregnant women and adolescent girls in Meghalaya indicates a severe nutritional gap that contributes to health vulnerabilities. The registered Anganwadi children and underweight children also point to significant concerns regarding child nutrition and overall well-being. These health-related factors highlight the need for strengthened nutritional interventions and healthcare support. Furthermore, issues like infrastructure deficits, inadequate sanitation, and challenges in water management and irrigation further exacerbate vulnerability, potentially leading to a decrease in overall quality of life and productivity. The livelihood and agricultural sectors, crucial to the state's economy, also reflect vulnerabilities due to limited opportunities in handicrafts, lack of irrigation infrastructure, and challenges in the education system, which could affect future human capital development. Addressing these drivers is essential for improving resilience in Meghalaya's vulnerable populations.

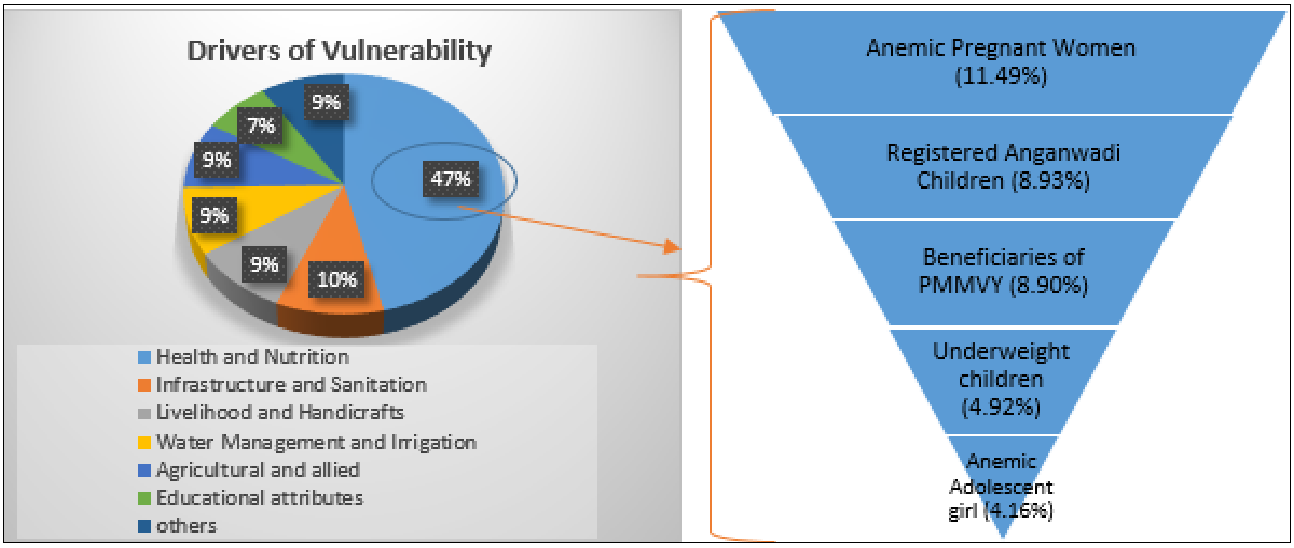

Fig 3: Major drivers of vulnerability in Meghalaya

Block-Level Vulnerability Analysis in Meghalay

In Meghalaya (46 blocks), majority of the blocks 69.57% (32 blocks) and 21.74% (10 blocks) were under the high and very high vulnerability category. This suggests that a substantial proportion of Meghalaya's blocks are facing significant challenges related to various socio-economic and environmental factors. Health and nutrition issues emerge as the primary drivers of vulnerability, with alarming rates of anemia among pregnant women, underweight children, and anemic adolescent girls. These health challenges are compounded by issues related to sanitation, water management, and inadequate livelihood opportunities (Figure 4).

The remaining 6.52% (Mawryngkneng, Mylliem and Amlarem block) and 2.17% (Mawpat block) were under medium and low vulnerability, respectively. The most vulnerable blocks were Mawshynrut, Rongara, Jirang, Dadenggiri, Nongstoin, Dalu, Gambegre, Baghmara, Chokpot, and Songsak. Similarly, the MCCC 2021[13] report identified Rongara, Jirang, Dadenggiri, Nongstoin, Dalu, Gambegre, and Chokpot blocks as the most vulnerable among the 39 blocks in Meghalaya. However, contrary to our findings, some blocks like Mawryngkhneng and Amlarem were categorized under very high vulnerability in the MCCC report, while our study classified them as low vulnerability. This discrepancy may be attributed to differences in the indicators used for vulnerability assessment, as discussed in the district-level vulnerability analysis.

Among the highly vulnerable blocks, Mawshynrut, Dadenggiri, Nongstoin, Dalu, and Gambegre are located in the West Khasi Hills district, while Rongara, Baghmara, and Chokpot are in the South Garo Hills district, making these two districts the most vulnerable in Meghalaya (Table 3 and Figure 6).

The fact that the majority of the blocks in these districts fall into the high and very high vulnerability categories highlights the need for urgent intervention. It also underscores the importance of addressing the underlying drivers of vulnerability, such as improving health services, providing better sanitation and water management systems, enhancing livelihood opportunities, and investing in education and agricultural development. Targeted interventions in these high-vulnerability blocks could help mitigate risks and improve resilience, particularly in the West Khasi Hills and South Garo Hills districts, which are the most affected.

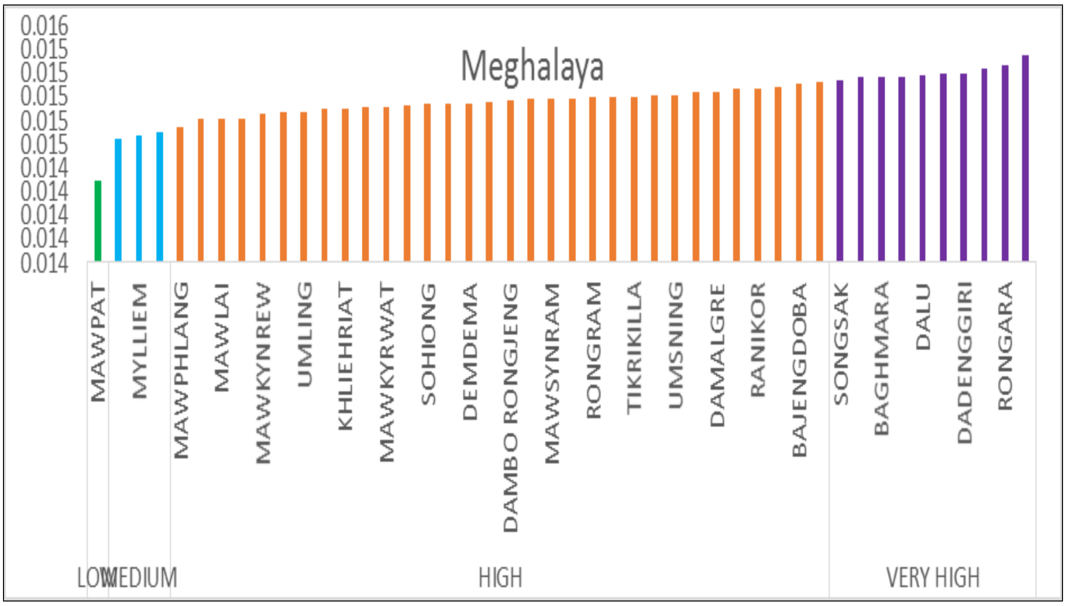

Fig 4: Block level vulnerability profile in meghalaya

Village level: The village-level vulnerability profile for Meghalaya is presented in Figure 5. The state consists of 5,997 villages, which have been classified into five vulnerability categories: very low (0.0109 - 0.0123), low (0.0123 - 0.0137), medium (0.0137 - 0.0151), high (0.0151 - 0.0165), and very high (0.0165- 0.0179) vulnerability. Among these, Nongmynsong village is the least vulnerable, while Mihmyntdu and Thadmuthlong villages, both falling into the "very high" vulnerability category, are the most vulnerable. A significant proportion of the villages (50.91%) fall under high vulnerability, followed by those in the medium vulnerability category (48.87%).

The majority of villages in Meghalaya are highly vulnerable, with almost half (50.91%) falling into the high vulnerability category. This suggests a pressing need for targeted interventions in these areas, particularly in terms of addressing factors contributing to high vulnerability. The relatively small percentage of villages classified as very low vulnerability indicates that there are few areas in the state that are comparatively resilient. This vulnerability distribution highlights the need for localized strategies to improve resilience, particularly in villages with high and very high vulnerability levels.

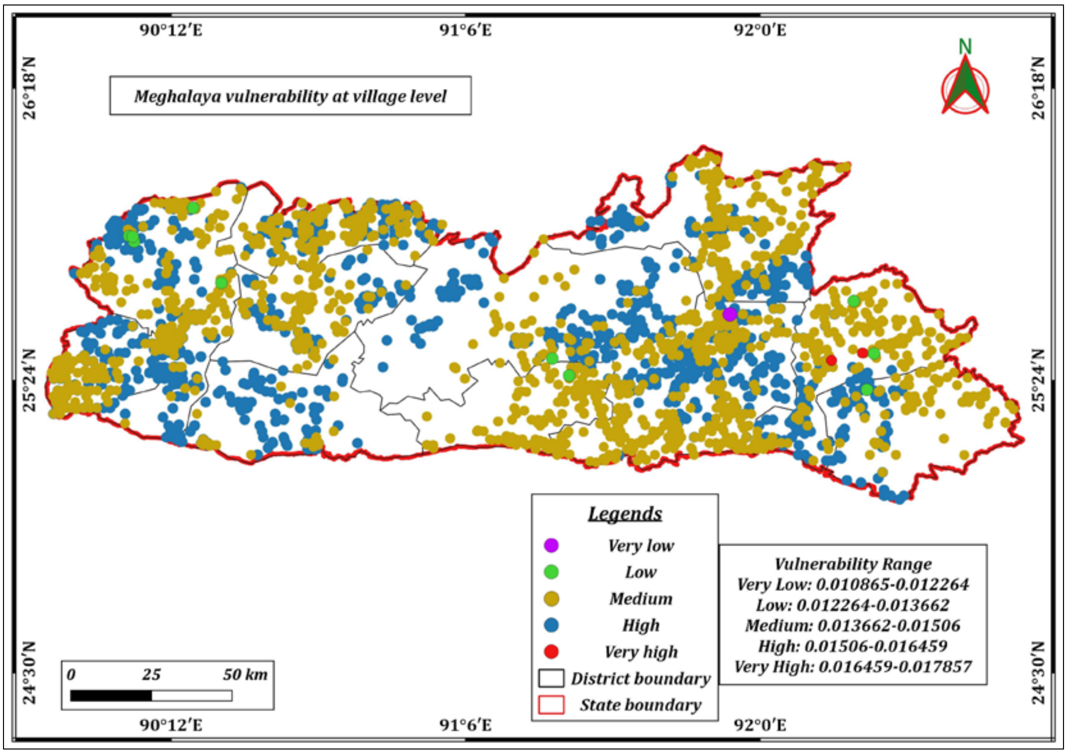

Fig 5: Village level vulnerability profile in Meghalaya

Conclusion

This study provides a comprehensive vulnerability assessment of Meghalaya, highlighting the critical socio-economic and environmental factors contributing to the region's overall vulnerability. The findings reveal that a significant proportion of districts, blocks, and villages in Meghalaya are highly vulnerable, with key drivers including health and nutrition challenges, inadequate infrastructure and sanitation, limited livelihood opportunities, and issues related to water management and irrigation. The prevalence of anemia among pregnant women and adolescent girls, along with high rates of underweight children, emphasizes the severe nutritional gaps contributing to health vulnerabilities in the state. The vulnerability rankings also reflect the broader structural weaknesses in infrastructure and public services, further exacerbating the socio-economic disparities within the state.

The results underscore the need for targeted interventions in the most vulnerable areas, particularly in the West Khasi Hills and South Garo Hills districts, which face the highest levels of vulnerability.

Policy Implications

1. Enhanced Health and Nutrition Programs: Given the significant health vulnerabilities, policies should prioritize improving maternal and child nutrition through strengthened healthcare services, nutritional interventions, and community health programs targeting anemia and malnutrition.
2. Improved Infrastructure and Sanitation: Addressing the deficits in infrastructure, particularly in sanitation and water management, is essential. Investments in rural infrastructure, including clean drinking water and waste management systems, should be a priority.
3. Livelihood and Employment Opportunities: Promoting sustainable livelihood options, particularly in agriculture and handicrafts, can reduce vulnerabilities related to poverty and economic insecurity. Fostering skill development programs and supporting local artisans would enhance economic resilience.
4. Targeted Adaptation Strategies: Based on block-level vulnerability assessments, targeted adaptation strategies should be developed that cater to the specific needs of highly vulnerable regions, focusing on health, education, and infrastructure.

By addressing these key areas, policymakers can reduce the vulnerability of Meghalaya’s population, enhance resilience, and ensure more sustainable development outcomes for the state’s most at-risk communities.

Acknowledgement

The study/work is supported by the Department of Science and Technology, Government of India through the National Mission for Sustaining Himalayan Ecosystem - Taskforce on Himalayan Agriculture. We are also thankful to ICAR Research Complex for NEH Region for providing the necessary support to conduct the study. The authors also extend their gratitude to the National Innovations in Climate Resilient Agriculture (NICRA) project of the Indian Council of Agricultural Research (ICAR) for their essential support in completing this study.

Reference

1. Adger WN, Vincent K. Uncertainty in adaptive capacity. Cr Geosci. 2005;337:399-410.
2. Anon. Quantitative assessment of Vulnerability to Climate Change: Computation of Vulnerability Indices. 2016. Available from: http://danida.vnu.edu.vn/cpis/files/Papers_on_CC/Vulnerability/Quantitative%20assessment%20of%20Vulnerability%20to%20Climate%20Change.pdf. Visited on 10 January 2025.
3. Das A, Ghosh PK, Choudhury BU, Patel DP, Munda GC, Ngachan SV, Chowdhury O. Climate change in North East India: Recent facts and events-Worry for agricultural management. In: Workshop Proceedings: Impact of Climate Change on Agriculture. 2010; ISPRS Archives XXXVIII-8/W3.
4. Das PJ. Rainfall regime of Northeast India: A hydro-meteorological study with special emphasis on the Brahmaputra Basin. 2004. Available from: http://hdl.handle.net/10603/68298. Visited on 11 January 2025.
5. Devi MV, Singh RJ, Chauhan JK, Marbaniang EK. Farmers' resilience to climate change in the North Eastern Hill Region of India. Indian Res J Ext Edu. 2022;22: December Special Issue.
6. Dubey P, Chaturvedi SS. Assessment of livelihood vulnerability to climate change: A study from Northeast India. J Himalayan Ecol Sustain Dev. 2022;17:1-16.
7. Feyissa G, Ayalew T, Teshome A. GIS-based quantification and mapping of climate change vulnerability hotspots in Addis Ababa. Geoenvironmental Disasters. 2018;5:10. doi:https://doi.org/10.1186/s40677-018-0106-4.
8. Gbetibouo GA, Ringler C. Mapping South African farming sector vulnerability to climate change and variability: A subnational assessment. In: Proceedings of the Amsterdam Conference on the Human Dimensions of Global Environmental Change. 2009. p. 1-28, December 2-4, Washington, USA.
9. Greco S, Rios ID, Siskos Y. On the methodological framework of composite indices: A review of the issues of weighting, aggregation, and robustness. Soc Indic Res. 2018;138:1031-1054. doi:https://doi.org/10.1007/s11205-017-1832-9.
10. Hammitt JK, Zhang H. Combining experts' judgments: Comparison of algorithmic methods using synthetic data. Risk Anal. 2012;32:1035-1048. doi:https://doi.org/10.1111/j.1539-6924.2012.01833.x.
11. Indian Institute of Technology Guwahati, Indian Institute of Technology Mandi, Indian Institute of Science Bangalore, Vardhan H, Sharma A. Climate vulnerability assessment for the Indian Himalayan Region using a common framework. 2018.
12. MCCC. Climate Vulnerability Assessment for Meghalaya using a Common Framework at District Level Assessment (2018-19). Report submitted by Meghalaya Climate Change Centre. 2019. Available from: https://meghalayaccc.org/reports/. Visited on 25 November 2024.
13. MCCC. Vulnerability Profile of Meghalaya: Block Level. Integrated Vulnerability Assessment. Report submitted by Meghalaya Climate Change Centre. 2021.

Available from: https://meghalayaccc.org/reports/.
14. Mekonen A, Berlie A. Rural households' livelihood vulnerability to climate variability and extremes: A livelihood zone-based approach in the Northeastern Highlands of Ethiopia. Ecol Process. 2021;10:1. doi:https://doi.org/10.1186/s13717-021-00313-5.
15. Nelson R, Kokic P, Crimp S, Martin P, Meinke H, Howden SM. The vulnerability of Australian rural communities to climate variability and change: Part II-integrating impacts with adaptive capacity. Environ Sci Policy. 2010;13:18-27.
16. Okey J. Loss of interpretability in principal component analysis: Implications for decision-making. J Appl Stat. 2018;45:456-467. doi:https://doi.org/10.1080/02664763.2018.1471234.
17. Onkal D, Lawrence M, Fildes R. The relative influence of advice from human experts and statistical methods on forecast adjustments. J Behav Decis Mak. 2009;22:394-410. doi:https://doi.org/10.1002/bdm.637.
18. Stephan A, Koller M, Riedel B. Assessing agriculture's vulnerability to drought in European pre-Alpine regions. Nat Hazards Earth Syst Sci. 2023;23:5-62. doi:https://doi.org/10.5194/nhess-23-45-2023.
19. Thangjam U, Thong P, Sahoo UK. Climate change threat on socio-economic condition of agroforestry managers: A vulnerability study in eastern Himalayan state of Mizoram, Northeast India. Clim Risk Manag. 2023;40:100519.
20. Thong P, Thangjam U, Sahoo UK, Pebam R. Socio-economic vulnerability assessment of shifting cultivators (Jhumias) amidst the changing climate in Mizoram, Northeast India. Appl Geogr. 2022;147:102790.
21. Tucker LR, MacCallum RC. Exploratory Factor Analysis. 1997. Available from: http://inis.jinr.ru/sl/M_Mathematics/MV_Probability/MVas_Applied%20statistics/Tucker%20L.R.,%20MacCallum%20R.C.%20Exploratory%20factor%20analysis%20(1997)(459s).pdf. Visited on 10 December 2024.
22. Vincent K. Creating an index of social vulnerability to climate change for Africa. Tyndall Center for Climate Change Research Working Paper 56. 2004; p. 1-50, August. Norwich.
23. Vincent K. Uncertainty in adaptive capacity and the importance of scale. Glob Environ Change. 2007;17:12-24.
24. Zurovec J, Skerlep M, Sumak B. Quantitative assessment of vulnerability to climate change in rural municipalities of Bosnia and Herzegovina. Sustainability. 2017;9:1208. doi:https://doi.org/10.3390/su9071208.