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Systematic Review

Ecology, equity and adaptation: a systematic review of climate-change and tribal solutions in North-East India (2015 to 2025)

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ABSTRACT

The tribal populations of Northeast India are found in ecologically sensitive, biodiversity-rich areas which are highly susceptible to the effects of climate change, such as changes in monsoon patterns, deforestation, crop damage, food insecurity, and health problems. The tribal populations have their own indigenous knowledge systems that are essential for their survival and management of their environment. However, the rapidly increasing effects of climate change are a major challenge. This systematic review compiled research studies published between 2015 and 2025 on the effects of climate change on tribal communities in North East India, including adaptive measures, indigenous practices, and policy recommendations. Using the PRISMA guidelines, a systematic search was conducted to identify relevant studies from the ScienceDirect database. After screening 421 studies using the title and abstract method, 21 studies were identified that specifically addressed the effects of climate change and adaptation measures in these communities. The findings validated the existence of significant impacts of climate change, encompassing heightened vulnerability of forests, threats to conventional agroforestry practices, alterations in resource availability, and jeopardies to livelihoods. Although indigenous knowledge sets the baseline for resilience, the increasing rate of climate change necessitates the combination of traditional knowledge with modern scientific approaches to ensure long-term ecological equity and sustainability in the region.

Keywords: Climate change adaptation, Tribal communities, North-east India, Indigenous knowledge, Food security, Ecological vulnerability

INTRODUCTION

North East India, encompassing parts of the Himalayan and Indo-Burma biodiversity hotspots, is home to numerous tribal communities whose cultures and livelihoods are intrinsically linked to the region's rich yet ecologically sensitive environment. These communities rely heavily on forests, diverse agricultural practices (including traditional shifting cultivation or Jhum), and water resources, stewarding them through generations of accumulated knowledge.[1,2] However, this region is experiencing pronounced effects of climate change, including shifts in monsoon patterns, temperature increases, greater frequency of extreme weather events like forest fires, forest degradation, disruptions to agriculture leading to crop loss and food insecurity, and associated health risks.[3,5-8] The complex interplay of factors like dam construction can further exacerbate vulnerabilities in riverine communities.[9]

Although tribal communities have historically been able to adapt thanks to complex indigenous knowledge systems (IKS) and ecological stewardship practices, the unmatched speed and size of modern climate change offer new difficulties that challenge conventional coping strategies.[7,10] Effective, fair climate action depends on a clear awareness of the particular effects experienced by these communities, their adaptive responses (informed by IKS), and the terrain of suggested remedies.

This systematic review synthesizes research published between 2015 and 2025 to address this knowledge gap. The specific objectives of this study were (a) to determine the recorded effects of climate change on the communities and environment of North East India; (b) to examine the adaptive measures and indigenous knowledge used by the communities to deal with climate variability and change; and (c) to list the solutions and recommendations put forward to address the challenges and improve community resilience.

METHODS

This review followed the principles of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. An initial search was conducted in the ScienceDirect database using the following search terms: [‘climate change’ and (‘Indian tribe’ or tribal or ‘indigenous community’) and India and (solution or mitigation or adaptation or resilience)]. The search was limited to research papers and open-access publications with publication dates between January 2015 and April 2025. The initial search yielded 422 records (n=422)

After the removal of duplicates, 421 unique records were obtained. The records were filtered based on title and abstract searches for relevance to the topic of climate change impacts and adaptation among the tribal communities of North East India. The full text of the potentially relevant articles identified during the screening process was obtained and evaluated for eligibility based on the inclusion criteria (421). Studies were excluded if they did not meet all criteria upon full-text review (e.g., publication date outside 2015 to 2025, lack of focus on tribal communities or climate change/adaptation, wrong study type, wrong study population) (Studies excluded=400).

This led to the selection of the final 21 studies that satisfied all the inclusion criteria. These studies comprise the basis of this systematic review. Statistical analysis was not possible in this qualitative synthesis of literature.

PRISMA flow

Inclusion criteria

The inclusion criteria for the studies were: (a) publication between January 2015 and April 2025, (b) studies conducted in the context of tribal communities in North East India, (c) studies that specifically discussed the impacts of climate change and/or adaptation measures (including indigenous knowledge components), and (d) studies that were primary research articles, reviews, or policy analyses related to the topic.

Data extraction

The key data was extracted from the 21 studies that met the criteria and compiled, with emphasis on the study aim, impact findings, recorded adaptation measures, indigenous knowledge component, and implications.

Synthesis and thematic analysis

A thematic synthesis method was used to analyze the data. Themes emerging from the data on impacts, adaptation, indigenous knowledge, and policy were identified. In addition, the number of studies that contained discussion on adaptive measures, indigenous knowledge and practices, and policy options was counted.

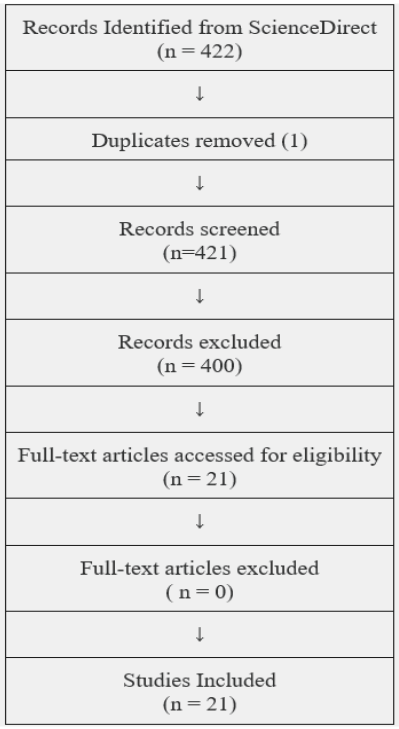

Figure 1: PRISMA flow.

RESULTS

The results of the synthesis of the 21 identified studies showed important outcomes related to the effects of climate change, adaptation, and policy requirements for the tribal regions of North East India. Notably, the discussion on adaptation strategies and policy requirements was common in the overwhelming majority of studies (20 out of 21), while indigenous knowledge was a focus in more than half of the studies (12 out of 21).

Climate change impacts

The susceptibility of key ecosystems has been a recurring finding in the literature. Forest vulnerability studies, especially in the Himalayan regions such as Nagaland, have pointed to the susceptibility of particular types of forests as highly vulnerable, and this has serious implications for ecosystem services that are essential to the tribal population.[11]

Climate change also leads to forest fragmentation and the susceptibility of forests to forest fires.[3,5,6] Agro-ecosystems, including Jhum and agro-forestry systems (AFS) in states such as Mizoram and Tripura, are threatened by changes in climate patterns, which in turn affect crop production, diversity, and water availability.[7,10,12]

Riverine populations are doubly vulnerable due to the effects of climate change and the construction of dams.[9] Climate change affects the availability of key biological resources such as bamboo and various non-timber forest products, including medicinal plants, which are essential for both livelihood and subsistence purposes.[1,2,13] The functional character and vulnerability of resources such as bamboo shoots may also be affected.[14,15]

Adaptive strategies and resilience (discussed in 20 studies)

Adaptation by land-use change, such as a shift from shifting cultivation to other forms of agroforestry, the use of soil moisture conservation methods, modifying upland crop production on slopes, and incorporating other methods such as rice-fish polyculture, were also prominent.[7,10,12,16] Community-based forest management and the factors that contribute to forest fragmentation are important approaches to forest conservation and adaptation.[6,11] Conservation of wildlife also helps maintain ecosystem health.[17,18] Exploring the use of alternative or complementary livelihood strategies, sometimes involving wild bioresources, can also reduce reliance on climate-sensitive economic sectors.[1] Harvesting and management practices for sustainable use of resources such as bamboo and the use of locally adapted species (such as Arenga obtusifolia for 'Tassey' bamboo) can be considered effective adaptation strategies that are grounded in local knowledge.[13,19] Appropriate processing of resources such as bamboo shoots is also important for food security.[15] IKS/TEK was often cited as a key basis for local adaptation.

This includes extensive knowledge of local biodiversity, traditional resource management regulations, ethno-botanical knowledge of medicinal plants, climate observation expertise, water conservation techniques, and culturally rooted practices such as the use of particular plants (e.g., Arenga) for food security in times of drought.[1,2,19] Local knowledge of environmental change, ecosystem services, and disservices (e.g., for bamboo or wildlife) is essential for the design of acceptable and effective interventions.[13,17] Indigenous knowledge also questions the external framework of carbon datafication.[20] This review has emphasized that indigenous knowledge practices for the environment are often inextricably linked with cultural identity and social bonding, thus underlining the importance of culturally informed approaches.[19]

Policy solutions and recommendations (discussed in 20 studies)

There was a clear consensus on the need for comprehensive and localized vulnerability analysis (ecological as well as socio-economic) to form a basis for adaptation planning and policy development.[10,11] It is important to identify 'hotspots' of vulnerability.[4,11] Building the capacity of local governance institutions (both formal and traditional) is considered essential for the implementation and maintenance of adaptation and conservation actions.[11,18]

The policies need to address complex local dynamics, such as conflict impacting conservation.[21]

And there was a clear consensus on the need to bridge IKS/TEK with scientific research to co-produce knowledge and develop comprehensive adaptation strategies.[19,20]

Policies should address climate-resilient agriculture, sustainable agroforestry systems, value chains for local products, and livelihood diversification, including integrated systems such as aquaculture.[1,7,10,12,16] Apart from these, improving WASH is also essential.[8]

The critical evaluation of external interventions, such as carbon market mechanisms or datafication projects, was suggested to ensure alignment with community rights and epistemologies, and to ensure that they bring actual benefits without further marginalization.[20]

Table 1: Prevalence of key themes across studies.

Theme	Number of studies (out of 21)	Percentage (%)
Climate change impacts	21	100
Adaptive strategies	20	95.2
Policy solutions	20	95.2
Indigenous knowledge and practices	12	57.1

Table 2: Climate change impacts on ecosystems and resources.

Impact category	Specific impacts	Affected regions/systems	Key references
Ecosystem Vulnerability	Forest fragmentation, increased forest fire risk, vulnerability of mixed moist deciduous forests	Himalayan areas (e.g., Nagaland), forests	Meru et al, Mahapatra et al, Sagar et al, Sarkar et al, Talukdar et al[3,4,6,11]
	Altered climate patterns affecting crop yields, diversity, and water availability	Agroecosystems (Jhum, AFS in Mizoram, Tripura)	Mathur et al, Schröder et al, Thangjam et al[7,10,12]
	Compounded risks from climate change and infrastructure (e.g., dams)	Riverine communities	Rampini et al[9]
Resource Availability	Reduced availability of bamboo and NTFPs (e.g., medicinal plants)	Forests, tribal livelihoods	Chaudhury et al, Sailo et al, Singh et al[1,2,13]
	Affected functional profile and safety of resources (e.g., bamboo shoots)	Food security systems	Sadananda et al, Singhal et al[14,15]
Socio-economic Stress	Increased livelihood insecurity, disparities in WASH access	Tribal communities	Thangjam et al, Biswas et al[8,10]

Table 3: Adaptive strategies and resilience measures.

Strategy category	Specific Measures	Examples/Systems	Key References
Resource management	Sustainable harvesting, use of resilient species (e.g., Arenga obtusifolia), proper processing of bamboo shoots	Bamboo, Tassey, food security systems	Akhtar et al, Sailo et al, Singhal et al[2,15,19]
Livelihood diversification	Alternative/supplementary livelihoods based on wild bioresources	NTFPs, bamboo-based products	Chaudhury et al[1]
Agricultural and forestry adjustments	Transition from shifting cultivation to AFS, soil moisture conservation, rice-fish co-culture	Jhum, AFS in Mizoram/Tripura, rice-fish systems	Mathur et al, Thangjam et al, Schröder et al, Samaddar et al
	Community-based forest management, addressing fragmentation	Forests in Himalayan areas	Mahapatra et al, Meru & et al
	Wildlife conservation for ecosystem health	Forest ecosystems	Jyrwa et al

Table 4: Role of indigenous knowledge and practices.

Aspect	Description	Examples	Key References
Foundation for adaptation	Deep knowledge of biodiversity, resource management rules, ethnobotanical knowledge, climate observation, water conservation	Biodiversity management, use of Arenga for food security	Chaudhury et al, Singh et al, Akhtar et al
Community perspectives	Local perceptions of environmental change, ecosystem services/disservices	Bamboo, wildlife perceptions	Jyrwa et al, Sailo et al.
Cultural heritage	Practices tied to cultural identity and social cohesion	Environmentally embedded cultural practices	Akhtar et al

Table 5: Policy solutions and recommendations.

Recommendation category	Specific recommendations	Focus areas	Key references
Context-specific planning	Localized vulnerability assessments, identification of vulnerability hotspots	Ecological/socio-economic baselines, forest fire risks	Pandey et al, Thangjam et al, Sarkar et al
Institutional strengthening	Empower local governance (formal/traditional), navigate local dynamics	Adaptation and conservation measures	Pandey et al, Talukdar et al, Dutta et al
Knowledge integration	Bridge IKS/TEK with scientific research for co-produced adaptation strategies	Holistic adaptation strategies	Akhtar et al. (2024), Pongen (2023)[20]
Supporting resilient livelihoods	Promote climate-resilient agriculture, sustainable AFS, value chains, WASH access	Agriculture, aquaculture, local products	Schröder et al, Bhattacharya et al, Chaudhury et al. (2021), Biswas et al. (2024)
Ethical considerations	Evaluate external interventions (e.g., carbon markets) for community alignment	Community rights, epistemologies	Pongen (2023)[20]

DISCUSSION

This systematic review, which encompasses 21 studies between 2015 and 2025, reaffirms the pressing impact of climate change on the tribal populations of North East India. The results emphasize the susceptibility of the region's distinct ecosystems and the resultant threats to the livelihoods and well-being of the communities, as observed in other indigenous lands worldwide.[10,11]

The fact that the use of adaptive strategies is prevalent in almost all studies (20/21) indicates the active measures being taken by the communities to cope with changes in the environment. These strategies vary from modifying agricultural and forestry patterns to the development of new livelihoods, often based on indigenous resources and ingenuity.[1,7,12] Notably, indigenous knowledge, explored in more than half of the studies (12/21), not only serves as a means of adaptation but also represents a living and thriving body of knowledge that sustains observation, interpretation, and response to environmental variability.[2,13,19]

The prominent focus on policy solutions and recommendations in the literature (20/21 studies) also highlights the understanding that community actions alone may not be sufficient in the face of the magnitude of climate change. There is a definite need for supportive policies that are context-specific, participatory, and draw upon existing local knowledge systems.[10,11] The emphasis on the need to integrate IKS with scientific knowledge also reflects a shift towards more inclusive and perhaps more effective adaptation planning. However, the critical analysis of efforts such as carbon datafication also emphasizes the need to ensure that climate actions are equitable and respect indigenous rights and worldviews.[20] Conservation policies also need to be aware of local socio-political contexts, including conflict.[21]

The results are a strong indication that a multi-faceted approach is necessary to improve the resilience of tribal communities in North East India.

Limitations

Firstly, the search was limited to a single database-ScienceDirect-which, although comprehensive, may not have included relevant studies published in other academic sites, regional journals, or grey literature such as government publications and local institutional publications. Secondly, the inclusion criteria further narrowed the review to English-language articles. The studies included in the review also differed widely in terms of methodological approaches, scope, and regional focus, making it difficult to compare and possibly influencing the consistency of synthesized findings. In addition, due to the predominantly qualitative and descriptive nature of the existing data, a quantitative meta-analysis was not feasible. A further significant limitation is that the disaggregated data for particular tribal groups or sub-regions in North East India is not presented, which would make it difficult to present location-specific recommendations. Finally, while every effort was made to follow a structured and transparent review process according to PRISMA

guidelines, a certain degree of subjectivity in the screening, coding, and interpretation process is inevitable and may have affected the final analysis.

CONCLUSION

Climate change is a challenging phenomenon for the tribal population and ecosystems of North East India. This review brings together evidence that shows the serious effects of climate change on forests, agriculture, and livelihoods from 2015 to 2025. The review also emphasizes the widespread use of adaptation measures by the population, which are largely influenced by indigenous knowledge systems. Adaptation measures require strong policy support that is location-specific, participatory, and builds on local institutions and effectively combines traditional ecological knowledge with scientific knowledge. The climate change vulnerability of the tribal population of North East India is important not only for the well-being of the population but also for the conservation of this globally significant biodiversity hotspots. Future research should prioritize longitudinal studies on adaptation effectiveness and collaborative knowledge co-production.

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