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Climate Change and Social Transformation: Challenges and Pathways - A Case Study of Bahraich District

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Abstract

Climate change poses unprecedented challenges to rural communities in the Global South, yet the social transformation pathways through which these communities navigate climate impacts remain inadequately understood. This paper examines the intersection of climate change and social transformation in Bahraich District, Uttar Pradesh, one of India's most climate-vulnerable regions. Drawing on empirical climate data spanning 1979–2025, hazard assessments, and a systematic review of community adaptation literature, the study addresses three research questions: (1) What specific climate changes has Bahraich experienced over the past four decades? (2) How are these changes driving social transformation across agricultural practices, livelihoods, and community structures? (3) What pathways exist for just and inclusive adaptation? The findings reveal that Bahraich has experienced a temperature increase of 0.9°C since 2010, a 54.2% reduction in annual rainfall, and a 43.3% worsening in climate severity scores, with drought expected every five years. These biophysical changes are catalyzing profound social transformations: agricultural system reorganization, livelihood diversification, migration pattern shifts, and emerging community-based adaptation strategies. Drawing on comparative insights from Nepal, Vietnam, Peru, and European case studies, the paper proposes an integrated framework for equitable climate transformation centred on four pillars: climate justice and equity, community resilience, participatory governance, and ethically deployed technological tools. The study contributes to scholarship on climate-induced social transformation while offering actionable recommendations for policymakers, practitioners, and researchers working in similar contexts across the Indo-Gangetic Plain.

Keywords: Climate change, social transformation, community adaptation, Bahraich, climate justice, participatory governance, rural livelihoods, Uttar Pradesh

1. Introduction

Climate change stands as one of the defining challenges of the twenty-first century, exerting profound and accelerating impacts on environmental, economic, and social systems worldwide (IPCC, 2021). While global discourses often focus on mitigation targets and technological solutions, the social dimensions of climate change—how communities experience, respond to, and are transformed by environmental disruption—remain inadequately integrated into both research and policy frameworks (Kalinowski, 2023). This gap is particularly acute in rural regions of the Global South, where agrarian livelihoods, informal institutions, and limited adaptive capacity intersect with intensifying climate hazards. Traditional climate

policy has largely prioritised measurable, technology-driven solutions. International agreements and national strategies emphasise carbon reduction targets, renewable energy application, and market-based instruments (Gills and Morgan, 2020). While these interventions are crucial for mitigating greenhouse gas emissions, they often marginalise the equally vital dimensions of social sustainability, including equity, justice, and community resilience (Ngcamu, 2023). Large-scale mitigation projects, ranging from hydropower dams to industrial afforestation schemes, frequently displace rural populations, devalue local knowledge systems, and reinforce existing power imbalances (Sovacool et al., 2017). Adaptation measures have similarly tended to prioritise infrastructure fixes over long-term capacity-building, leaving marginalised groups without the tools to shape their own climate futures. This paper addresses these gaps through a focused case study of Bahraich District in Uttar Pradesh, India. Bahraich presents a compelling site for investigating climate change and social transformation for several reasons. Located in the Terai region along the Indo-Nepal border, the district encompasses diverse ecosystems—from the Ghaghra River floodplains to forest-fringe villages—and supports a population heavily dependent on rain-fed agriculture, fisheries, and forest resources. Recent climate data paint a concerning picture: since 2010, temperatures have risen by 0.9°C, annual rainfall has declined by 54.2%, heatwave days have increased by 10.4 days annually, and the district now faces a "Very High" climate severity score of 71 out of 100 (AQI.in, 2025). Drought is projected to occur every five years (Think Hazard, 2025), while meteorological records confirm decades of warming trends and precipitation variability (meteoblue, 2025). These biophysical changes are not merely environmental phenomena; they are catalysts for deep social transformation. Agricultural systems that sustained communities for generations are becoming unviable. Livelihood patterns are shifting, with implications for migration, gender relations, and intergenerational knowledge transmission. Social institutions—from panchayats to kinship networks—are being tested by unprecedented pressures. Yet transformation is not simply imposed on passive communities; it is also actively negotiated, resisted, and shaped through local agency, indigenous knowledge, and emerging forms of collective action.

This study is guided by three interconnected research questions:

1. What specific climate changes has Bahraich District experienced over the past four decades, and how do these compare with broader regional trends?
2. How are these climate changes driving social transformation across agricultural practices, livelihood strategies, community institutions, and demographic patterns?
3. What pathways exist for just and inclusive adaptation that centre marginalised voices, build on local knowledge, and address structural inequalities?

To answer these questions, the paper adopts a multi-method approach combining secondary climate data analysis, systematic review of community adaptation literature, and comparative case analysis from similar contexts in South Asia and beyond. The study contributes to scholarship on climate-induced social transformation while offering actionable insights for policymakers, development practitioners, and researchers working in climate-vulnerable regions of the Indo-Gangetic Plain. The paper proceeds as follows. **Section 2** reviews the theoretical literature on climate change and social transformation, with particular attention to concepts of climate justice, community resilience, participatory governance, and the integration of technological and local knowledge systems. **Section 3** describes the study area and methodology. **Section 4** presents findings on climate trends in Bahraich and the emerging patterns of social transformation. **Section 5** discusses these findings in comparative perspective and proposes an integrated

framework for equitable climate transformation. **Section 6** concludes with policy recommendations and directions for future research.

2. Literature Review:

Climate Change, Social Transformation, and the Imperative for Justice-centred Approaches-

Climate Change as a Driver of Social Transformation: Social transformation refers to fundamental changes in the ways societies are organised, how livelihoods are pursued, how power is distributed, and how meaning is constructed. Climate change acts as a "threat multiplier" that accelerates existing social dynamics while creating novel pressures and possibilities (Adger et al., 2014). Unlike gradual environmental change, climate impacts often manifest through extreme events—floods, droughts, heatwaves—that disrupt established patterns and force adaptation, migration, or systemic reorganisation. Research on climate-induced social transformation has moved beyond simplistic vulnerability frameworks to recognise the agency of affected communities. As Adhikari et al. (2025) demonstrate in their study of Nepal's Madi region, communities facing climate disruption do not merely react; they actively experiment with new crop varieties, adjust planting seasons, develop water management techniques, and draw on indigenous knowledge to enhance resilience. This perspective challenges deterministic narratives that portray climate-vulnerable populations as passive victims, instead highlighting creativity, innovation, and the strategic deployment of local knowledge. However, transformation is never neutral. It produces winners and losers, creates new inequalities while potentially ameliorating others, and is shaped by existing power structures. The concept of "just transformation" has emerged to capture the normative dimension of these processes, insisting that how societies change in response to climate pressure matters as much as the fact of change itself (Newell and Mulvaney, 2013).

Climate Justice and the Marginalisation of Vulnerable Voices: Climate justice scholarship has fundamentally reshaped understanding of climate impacts and responses. Drawing on environmental justice traditions, this literature demonstrates that climate change disproportionately affects marginalised communities—the poor, women, indigenous peoples, ethnic minorities, and rural populations—while these same groups are systematically excluded from decision-making processes (Sultana, 2022). The reasons for this exclusion are multiple and mutually reinforcing. Institutional barriers, including formal decision-making procedures that privilege technical expertise over lived experience, systematically disadvantage communities without access to policy networks or scientific credentials (Ngcamu, 2023). Data inequities mean that climate modelling and risk assessments often lack the granularity to capture local realities, while indigenous and local knowledge systems are devalued or ignored (United Nations Climate Change Technology Executive Committee, 2024). Financial mechanisms channel resources to large-scale, quantifiable projects rather than participatory, community-led initiatives (Leshore and Minja, 2019). These patterns are evident across climate interventions. Sovacool et al. (2017) document how renewable energy projects, often framed as unambiguously beneficial, can displace communities, undermine local livelihoods, and concentrate benefits among elites. Hoicka et al. (2021) show that afforestation schemes frequently ignore customary land rights and local knowledge about ecosystem management. Nirmani (2025) demonstrates that adaptation funding tends to bypass women-led organisations, reinforcing gender inequalities even as it claims to address climate vulnerability. Addressing these injustices requires more than tokenistic consultation. It demands fundamental shifts in how climate problems are defined, who participates in defining them, and how solutions are designed and implemented.

As the Centre for Climate Justice (2025) argues, this means examining how status quo institutions—from property regimes to governance structures—accelerate ecological crisis and require fundamental reform.

Community Resilience and Adaptive Capacity: Community resilience has emerged as a central concept in climate adaptation discourse. Unlike engineering resilience, which emphasises return to equilibrium, social-ecological resilience focuses on the capacity of systems to absorb disturbance, reorganise, and maintain essential functions while adapting to changed conditions (Folke et al., 2010). Research identifies multiple determinants of community resilience. Social capital—networks of trust, reciprocity, and collective action—enables communities to mobilise resources, share information, and coordinate responses to climate shocks (Adger, 2003). Livelihood diversity spreads risk and provides options when particular activities become unviable. Access to information about climate risks and adaptation options enables informed decision-making. Flexible institutions that can learn from experience and adjust rules accordingly outperform rigid bureaucratic structures (Ostrom, 1990). The Madi region study exemplifies these dynamics. Facing unpredictable rainfall, increased temperatures, and flooding, farmers diversified crops, adjusted planting calendars, and developed collective water management arrangements (Adhikari et al., 2025). These strategies drew on indigenous knowledge while incorporating new information and techniques. Crucially, they emerged through community processes rather than being imposed externally. Yet resilience has limits. Some climate impacts may overwhelm even robust adaptive capacity, leading to transformation rather than adaptation. Migration, livelihood abandonment, and cultural disruption may become unavoidable. The distinction between adaptation (adjustment within existing systems) and transformation (fundamental system change) is therefore critical, though boundaries are often blurred in practice.

Participatory Governance and Community-Driven Solutions: The limitations of top-down climate governance have generated growing interest in participatory, community-driven approaches. Participatory action research frameworks demonstrate how involving affected communities in problem definition, data collection, and solution design produces more legitimate, effective, and sustainable outcomes (Reason and Bradbury, 2006). Case studies from diverse contexts illustrate the potential of participatory approaches. In Vietnam's Mekong Delta, the CS-MAP (Climate-Smart Mapping and Adaptation Planning) initiative engaged communities in participatory mapping to identify areas at risk from saltwater intrusion and plan informed relocations (Rodríguez Arrieta, 2025). Residents identified risks, discussed options, and validated maps before submission to authorities. This process strengthened community visibility in official decision-making and enabled negotiation with external actors. However, limitations persisted: inadequate financial support for relocation created debt burdens, and long-term resources for updating maps were lacking. In the Peruvian Andes, communities facing glacial retreat developed their own deliberative processes for deciding whether to relocate or adapt in place (Rodríguez Arrieta, 2025). Water Users' Associations convened assemblies where women farmers, young herders, and older adults participated alongside leaders. Popular communication networks—loudspeakers, radio messages, WhatsApp groups in Quechua—enabled widespread participation. Hand-painted maps on community building walls visualised risks and options. Yet community proposals were sometimes not incorporated into municipal planning, revealing that participation without formal recognition leaves implementation gaps.

European experiences with co-designing climate adaptation reinforce these lessons. Across four pilot regions, effective engagement required continuity to build trust and iterate, socio-culturally tailored formats, and facilitation that lowered participation barriers (Englund et al., 2026). Participants converged on recurrent solution typologies—inclusive risk communication, education and capacity-building,

workplace adaptations, accessible cooling and warning services—but insisted on context-specific design features shaped by local conditions. These cases yield consistent insights. Participation must be genuine, not tokenistic. It requires resources, time, and institutional flexibility. Community decisions need binding recognition, not merely consultation. And participatory processes must address internal community dynamics, including gender, age, and caste inequalities that can exclude marginalised voices even within apparently cohesive communities.

Integrating Technology and Local Knowledge: The relationship between technological innovation and local knowledge in climate adaptation is often framed as oppositional. Techno-centric approaches privilege expert systems, quantitative data, and standardised solutions, while community-based approaches emphasise local knowledge, qualitative understanding, and context-specific responses. Recent scholarship challenges this dichotomy, exploring how technologies can support—rather than supplant—grassroots action when guided by ethical design and co-creation (Arai et al., 2021). Participatory AI, GeoAI, big data, and remote sensing offer new possibilities for democratising climate governance (United Nations Climate Change Technology Executive Committee, 2024). Participatory mapping platforms enable communities to document local risks and resources. Early warning systems can be tailored to local communication preferences. Mobile technologies can disseminate climate information in accessible formats and languages. Citizen science initiatives engage communities in data collection while building scientific literacy.

However, digital technologies also carry risks. Without explicit attention to digital equity, they may widen existing divides, excluding those without connectivity, literacy, or technical skills (Zhao et al., 2023). Data generated through participatory processes may be appropriated by external actors without community benefit. Algorithmic systems may encode biases that disadvantage marginalised groups. The solution is not rejection of technology but its deliberate deployment within justice-centred frameworks that prioritise community control, transparency, and equitable access. Jack et al. (2024) demonstrate how integrating local knowledge with climate services can enhance adaptation outcomes when communities participate in tool design and retain ownership of their data. Jain et al. (2023) show that mobile applications for climate information are most effective when co-designed with users and delivered through trusted intermediaries. These approaches treat technology as a complement to, not substitute for, human relationships and local institutions.

Gaps and Contributions: This review reveals several gaps that the present study addresses. **First**, while community adaptation research has proliferated, relatively few studies focus on the Indo-Gangetic Plain, one of the world's most climate-vulnerable and population-dense regions. Bahraich District, with its diverse ecosystems and agrarian economy, offers a valuable case for understanding climate-induced social transformation in this context. **Second**, existing research often treats climate data and social analysis separately. This study integrates quantitative climate trend analysis with qualitative understanding of social transformation processes, enabling more nuanced conclusions about how biophysical changes translate into social outcomes. **Third**, the literature on participatory governance, while rich, provides limited guidance for operationalising justice-centred approaches in specific institutional contexts. By grounding analysis in Bahraich's particular conditions while drawing comparative insights from South Asia and beyond, this study contributes to bridging theory and practice.

3. Study Area and Methodology

Study Area: Bahraich District-

Bahraich District is located in the Terai region of Uttar Pradesh, India, bordering Nepal to the north. Situated between 27°20' and 28°25' North latitude and 81°05' and 82°10' East longitude, the district encompasses approximately 5,237 square kilometres. The Ghaghra River forms its western boundary, while numerous smaller rivers—including the Rapti, Saryu, and Suheli—traverse the district, creating extensive floodplains and wetlands. The district's population of approximately 3.5 million (2011 Census) is predominantly rural, with agriculture employing over 70% of the workforce. Principal crops include paddy, wheat, sugarcane, pulses, and oilseeds. The district also supports significant fisheries in its riverine areas and forest-based livelihoods in villages bordering the Katarniaghat Wildlife Sanctuary. Socially, the population includes diverse caste groups, with significant populations of Scheduled Castes and Other Backward Classes, as well as Muslim communities concentrated in urban areas and specific rural clusters. Bahraich's climate is subtropical monsoon, characterised by hot summers (April–June), a monsoon season (July–September), and cool winters (November–February). Average annual rainfall ranges from 1,000–1,200 mm, with substantial inter-annual variability. The district has historically faced flood risks from Himalayan-origin rivers, but drought has emerged as an increasing concern in recent decades.

Research Design: This study adopts a multi-method research design combining: (1) secondary analysis of climate data for Bahraich District; (2) systematic review of peer-reviewed literature on community adaptation to climate change; and (3) comparative case analysis drawing on studies from similar contexts in South Asia and beyond. This design is appropriate for several reasons. First, understanding climate-induced social transformation requires integrating biophysical and social data, which no single method can adequately capture. Second, the absence of primary field research (a limitation acknowledged below) necessitates careful triangulation of secondary sources. Third, comparative analysis enables identification of patterns that transcend local particularities while remaining attentive to context-specific dynamics.

Climate Data Sources and Analysis- Climate data for Bahraich District were drawn from three complementary sources:

1. **AQI.in Climate Change Severity Database:** Provides district-level analysis comparing 2010–2025 data with historical baselines, including temperature change, rainfall variation, humidity change, heatwave frequency, and composite severity scores.
2. **meteoblue Climate Change Data:** Based on ERA5 atmospheric reanalysis (1979–2021) from the European Centre for Medium-Range Weather Forecasts, providing temperature trends, precipitation trends, and monthly anomaly analysis with 30-kilometre spatial resolution.
3. **ThinkHazard Hazard Assessment:** Developed by the Global Facility for Disaster Reduction and Recovery, providing water scarcity hazard classification and climate change impact projections.

Data were extracted for Bahraich District and analysed to identify: (a) long-term trends in temperature and precipitation; (b) changes in extreme event frequency; (c) projected future hazards; and (d) composite measures of climate severity. Where multiple data sources covered the same parameters, cross-verification was conducted to assess consistency.

Systematic Review Protocol

The systematic review followed established guidelines (Higgins et al., 2022; Page et al., 2021) to ensure methodological rigour. The review focused on peer-reviewed literature published between 2015 and 2025, a period marked by the Paris Agreement and Sustainable Development Goals when social dimensions became central to climate governance.

Search Strategy: Five academic databases were searched: Science Direct, Springer Link, Scopus, Web of Science, and Google Scholar. Search strings combined terms related to climate change ("climate change" OR "global warming" OR "climate crisis"), community adaptation ("community adaptation" OR "community resilience" OR "local adaptation"), social transformation ("social transformation" OR "social change" OR "livelihood transition"), and geographic context ("South Asia" OR "India" OR "Indo-Gangetic Plain").

Inclusion Criteria: Studies were included if they: (a) were peer-reviewed journal articles, books, or book chapters; (b) addressed community-level climate adaptation or social transformation; (c) provided empirical evidence from the Global South; and (d) were published in English.

Exclusion Criteria: Studies were excluded if they: (a) focused exclusively on technical or economic modelling without social dimensions; (b) were editorials, commentaries, or opinion pieces without empirical grounding; or (c) addressed climate mitigation without adaptation or transformation dimensions.

Synthesis Approach: Thematic synthesis was employed to identify patterns across studies, with themes developed inductively through iterative reading and analysis. Particular attention was paid to: adaptation strategies, governance arrangements, knowledge systems, equity considerations, and transformation pathways.

Comparative Case Selection: Comparative cases were selected to illuminate different dimensions of climate-induced social transformation while maintaining relevance to Bahraich's context. Selection criteria included: **(a)** agrarian communities facing climate pressures; **(b)** documented community adaptation experiences; **(c)** availability of detailed case studies; and **(d)** geographic diversity within the Global South.

Three primary comparators were selected:

1. **Madi Region, Chitwan, Nepal:** A Terai region sharing ecological and agricultural characteristics with Bahraich, providing insights into community adaptation in similar agro-ecological conditions (Adhikari et al., 2025).
2. **Mekong Delta, Vietnam:** A riverine delta facing saltwater intrusion and flooding, offering lessons on participatory mapping and planned relocation (Rodríguez Arrieta, 2025).
3. **Peruvian Andes:** A highland region facing glacial retreat and water scarcity, demonstrating community deliberation and popular communication strategies (Rodríguez Arrieta, 2025).

Additional insights were drawn from European co-design pilots (Englund et al., 2026) and global systematic reviews (Mukerji et al., 2024; Oyshi et al., 2025).

Limitations

This study has several limitations that should be acknowledged. **First**, the absence of primary field research in Bahraich means that community perspectives are accessed indirectly through secondary sources rather than directly through interviews, focus groups, or participatory observation. Future research should prioritise fieldwork to capture lived experiences and local knowledge. **Second**, climate data, while drawn from reputable sources, rely on reanalysis and modelling rather than ground-based observations for some parameters. Local meteorological data, where available, would enhance precision. **Third**, the comparative cases, while carefully selected, cannot capture Bahraich's unique institutional, cultural, and political configurations. Transferability of insights requires careful attention to contextual differences. **Fourth**, the review's English-language restriction may exclude relevant studies published in Hindi or other regional languages. Despite these limitations, the study provides a robust foundation for understanding

climate-induced social transformation in Bahraich and offers actionable recommendations for policy and practice.

4. Findings

Climate Change Trends in Bahraich District: Analysis of climate data reveals significant and accelerating changes in Bahraich's climate over the past four decades. These changes encompass temperature increases, precipitation declines, heightened variability, and increased extreme event frequency.

Temperature Trends: Since 2010, Bahraich has experienced a temperature increase of 0.9°C, representing a 3.4% change compared to the previous 15-year baseline (AQI.in, 2025). Long-term analysis confirms this warming trend, with mean annual temperatures showing consistent upward movement since the 1980s (meteoblue, 2025). Warming stripes visualisations—where blue represents cooler years and red warmer years—demonstrate a marked shift toward warmer conditions in recent decades, consistent with global climate change patterns. The warming is not uniform across seasons. Summer temperatures have increased more rapidly than winter temperatures, extending the period of heat stress for crops and communities. Heatwave days have increased by 10.4 days annually compared to historical baselines, exposing populations to prolonged periods of extreme heat with implications for health, labour productivity, and water demand (AQI.in, 2025).

Precipitation Changes: The most dramatic changes are evident in precipitation patterns. Annual rainfall has declined by 54.2% when comparing 2010–2025 data with historical baselines (AQI.in, 2025). This reduction is not simply a uniform decline but reflects fundamental shifts in the distribution of rainfall across seasons and the frequency of rain days. Analysis of weather conditions reveals that rainy days have decreased by 52.3%, while cloudy days have increased by 45.1% (AQI.in, 2025). This suggests that when rain occurs, it may be more intense (given stable or increasing total precipitation in some models), but the frequency of rain events has substantially declined. The implications for rain-fed agriculture are profound: farmers face longer dry spells punctuated by potentially damaging heavy rainfall events. Long-term precipitation data confirm these trends. Since 1979, annual precipitation has shown considerable inter-annual variability superimposed on a declining trend (meteoblue, 2025). Precipitation anomaly analysis reveals that dry years have become more frequent and more severe in recent decades, while wet years, though still occurring, are less common than in the historical record.

Water Scarcity Hazard: The combination of reduced rainfall, increased temperatures (and thus higher evapotranspiration), and changing rainfall patterns has produced a "High" water scarcity hazard classification for Bahraich (ThinkHazard, 2025). This means that droughts are expected to occur on average every five years—a frequency that exceeds the adaptive capacity of current agricultural systems and water management arrangements. Model projections for climate change impact are inconsistent in their estimates of future drought hazard, reflecting the inherent uncertainty in precipitation modelling (ThinkHazard, 2025). However, the present hazard level may increase due to the effects of climate change, requiring that projects and communities design for increased drought risk in the long-term.

Composite Severity: The Climate Change Severity Score, which integrates multiple indicators into a single measure, places Bahraich at 71 out of 100, categorised as "Very High" severity (AQI.in, 2025). This represents a 43.3% worsening in the climate score compared to the last 15 years, suggesting deteriorating conditions with increasing negative impacts on weather patterns and environmental conditions. Additional indicators include an 8.9% reduction in average humidity, a 28.7% decline in PM2.5 levels (potentially

reflecting changed atmospheric circulation or reduced local emissions), an 8-day reduction in coldwave days, and a 2.7 km/h increase in wind speeds.

Summary: Bahraich is experiencing significant climate change characterised by warming temperatures, declining and more variable rainfall, increased drought frequency, and more frequent extreme heat events. These biophysical changes form the backdrop against which social transformation is unfolding.

Social Transformation Pathways: The climate changes documented above are not abstract environmental phenomena; they are actively reshaping social and economic life in Bahraich. Drawing on the systematic review and comparative case analysis, this section identifies key pathways through which climate change is driving social transformation.

Agricultural System Transformation: Agriculture, the foundation of Bahraich's economy and social structure, is undergoing fundamental change in response to climate pressures. Three interconnected processes are evident. Crop diversification and substitution: Farmers facing uncertain rainfall and increased drought risk are experimenting with new crop varieties and cropping patterns. This mirrors strategies documented in Nepal's Madi region, where farmers diversified crop types and adjusted planting seasons in response to unpredictable rainfall and increased temperatures (Adhikari et al., 2025). In Bahraich, this may involve shifts from water-intensive paddy to less water-demanding millets, pulses, or oilseeds, or adoption of short-duration varieties that mature before moisture stress becomes acute.

However, diversification is constrained by multiple factors: market preferences that favour established crops, limited access to seeds for alternative varieties, knowledge gaps about unfamiliar crops, and institutional biases that channel extension services toward mainstream commodities. Transformation therefore proceeds unevenly, with better-resourced farmers better positioned to experiment and adapt.

Irrigation expansion and groundwater depletion: As rainfall becomes less reliable, farmers invest in irrigation to buffer production risk. Tube wells have proliferated across the district, enabling continued paddy cultivation even in years of below-average rainfall. Yet this adaptation strategy creates new problems. Groundwater tables are declining as extraction exceeds recharge, raising questions about long-term sustainability. The energy-irrigation nexus—subsidised electricity enabling pumping—creates fiscal and environmental pressures. And farmers without capital for well construction face increasing disadvantage as rain-fed agriculture becomes more precarious.

Livelihood diversification within agriculture: Climate pressures are prompting diversification into non-crop agricultural activities. Fisheries, livestock rearing, and poultry offer alternative livelihood sources that may be less climate-sensitive than cropping or that exploit niches created by changing conditions. In riverine areas, changing hydrological regimes create opportunities for some fishery activities while undermining others. Forest-fringe communities may increase reliance on non-timber forest products as crops fail. These shifts reshape household labour allocation, gender roles (with women often assuming responsibility for new activities), and relationships between agricultural and non-agricultural sectors.

Livelihood Transformation Beyond Agriculture: Climate change is accelerating broader livelihood transformations that extend beyond the agricultural sector.

Migration: Migration has emerged as a central adaptation strategy for climate-affected households. While migration from Bahraich to urban centres has historical precedents, climate pressures are reshaping migration patterns. Drought years see increased out-migration as agricultural labour demand collapses and household consumption needs become pressing. Remittances from migrants provide critical income for remaining family members, enabling investment in agriculture, education, and health. Yet migration also imposes costs: separation of families, children's education disrupted, and the loss of young and productive

adults from rural communities. Comparative insights from the Peruvian Andes are instructive. There, more than 72,000 families left rural areas between 2018 and 2024, driven by prolonged droughts, soil erosion, and lack of institutional support (Rodríguez Arrieta, 2025). Yet many communities also chose to reorganise internally and develop local strategies before deciding whether to move. This suggests that migration is not simply an automatic response to climate stress but a considered decision shaped by collective deliberation, available alternatives, and perceived possibilities for in situ adaptation.

Non-farm employment: The decline in agricultural viability is pushing households toward non-farm employment, both locally and through migration. Local non-farm opportunities—construction, transport, petty trade, services—absorb some displaced agricultural workers but often offer low wages, precarious conditions, and limited prospects for advancement. The growth of the non-farm sector is itself shaped by climate dynamics: drought years may reduce local economic activity, limiting opportunities precisely when they are most needed.

Asset strategies: Households adapt to climate risk by adjusting their asset portfolios. Liquid assets (jewellery, livestock, bank deposits) enable consumption smoothing during crises. Productive assets (land, equipment, irrigation infrastructure) determine long-term livelihood potential. Climate shocks may force distress sales of productive assets, undermining future adaptive capacity. Households with diversified asset portfolios—including assets located in different risk environments—are better positioned to absorb shocks.

Social and Institutional Transformation: Climate change is also reshaping social structures, institutions, and relationships.

Changing gender relations: Climate impacts and adaptation responses are deeply gendered. Women bear primary responsibility for water collection, fuelwood gathering, and household food security—activities made more difficult by climate change. Drought increases women's labour burden as water sources recede and collection times lengthen. Crop failure intensifies pressures on women to manage household consumption with reduced resources. Migration of male household members increases women's agricultural responsibilities while potentially expanding their decision-making roles. Yet adaptation interventions often fail to address gender dynamics. Early warning systems may not reach women. Agricultural extension services target male farmers. Participatory processes, without deliberate design, reproduce male dominance in decision-making. As Rodríguez Arrieta (2025) notes, in both Vietnamese and Peruvian cases, female participation was only significant when specific strategies were designed—facilitating groups, differentiated spaces, inclusive language. Without this, women tended to be listeners, not decision-makers, even though they often bear the brunt of climate impacts.

Intergenerational dynamics: Climate change is reshaping relationships between generations. Older farmers possess knowledge of past climate patterns and traditional coping strategies, but this knowledge may be less relevant under unprecedented conditions. Younger people may be more open to new technologies, crops, and livelihood strategies, but may also be more inclined to leave agriculture altogether. Intergenerational transmission of agricultural knowledge—traditionally central to rural social reproduction—is disrupted as climate change renders some knowledge obsolete and as younger generations question agricultural futures. Research on intergenerational environmental engagement offers insights. Sieverding et al. (2025) show that older adults who engage with younger generations and develop legacy motivation are significantly more likely to support climate protection. Syropoulos, Law, and Young (2025) find that nations with a strong sense of longevity and historical continuity exhibit greater

environmental commitment. These findings suggest that framing climate action as intergenerational responsibility could mobilise support across age groups.

Community institutions under pressure: Traditional community institutions—panchayats, caste councils, kinship networks, mutual aid arrangements—are being tested by climate pressures. These institutions mediate access to resources (water, grazing land, common property resources), coordinate collective action (maintenance of irrigation systems, disaster response), and provide social safety nets (support during crises). Climate change may strengthen some institutions as communities recognise interdependence, while undermining others as resource scarcity intensifies competition. The Water Users' Associations in the Peruvian Andes exemplify institutional adaptation (Rodríguez Arrieta, 2025). These community regulatory bodies for water use prioritise equitable water allocation for essential crops through open assemblies involving women farmers, young herders, and older adults. They adjust traditional practices to new climatic patterns while maintaining inclusive deliberation. This suggests that existing institutions can evolve to address climate challenges when they retain legitimacy and adaptability.

Inequality and differentiation: Climate change does not affect all households equally. Pre-existing inequalities—in landholding, caste status, access to credit, political connections—shape vulnerability and adaptive capacity. Better-off households, with larger landholdings, irrigation access, and diversified income sources, are better positioned to weather climate shocks and invest in adaptation. Poorer households, particularly landless labourers and marginal farmers, face greater exposure and more limited options. Moreover, climate change may amplify inequality. Distress sales of land and assets by vulnerable households concentrate resources among the better-off. Differential access to adaptation resources (subsidies, credit, information) advantages those with existing capabilities. Migration, while potentially beneficial for sending households, removes young and productive adults from communities, potentially undermining collective adaptive capacity.

Emerging Adaptation Practices: Despite these challenges, communities in Bahraich and comparable contexts are developing innovative adaptation practices.

Water management innovations: Farmers are experimenting with water harvesting, efficient irrigation techniques (drip systems, sprinklers), and altered cropping patterns that align with water availability. Collective management of water resources—through user groups, rotational irrigation, and maintenance of traditional water bodies—is being revived in some areas. These practices build on indigenous knowledge while incorporating new technologies.

Crop and livelihood experimentation: As documented in Nepal, farmers are diversifying crop types, adjusting planting seasons, and integrating crops with livestock and fisheries (Adhikari et al., 2025). These experiments draw on local knowledge, peer learning, and, where available, extension advice. Successful innovations spread through social networks, adapted to local conditions.

Collective action and mutual support: Climate shocks often trigger collective responses—shared access to remaining resources, labour exchanges, mutual assistance during crises. These practices build on existing social capital while creating new forms of solidarity. Community-managed disaster funds, grain banks, and seed banks provide buffers against shocks.

Knowledge integration: Farmers combine traditional knowledge (weather indicators, drought-resistant varieties, soil management practices) with new information from extension services, media, and mobile technologies. This knowledge integration enables context-appropriate responses that neither reject external inputs nor abandon local wisdom.

Barriers to Just Transformation: The transformation pathways described above are not automatic or inevitable. They are shaped by multiple barriers that constrain options and shape outcomes.

Institutional barriers: Formal institutions often hinder rather than help community adaptation. Bureaucratic procedures favour standardised, top-down interventions rather than flexible, community-led initiatives. Sectoral divisions (agriculture, water, disaster management operating separately) impede integrated responses. Short-term planning cycles conflict with the long-term nature of climate change. Regulatory frameworks may criminalise adaptation strategies (e.g., restrictions on groundwater extraction that push farmers into illegality) rather than supporting them.

Resource constraints: Adaptation requires resources—financial, technical, human—that are unequally distributed. Poor households lack savings to invest in irrigation, drought-resistant seeds, or livelihood diversification. Community institutions lack funds for collective infrastructure. Local governments lack budgets for climate-responsive planning. While adaptation finance has increased globally, it often fails to reach local levels or is channeled through mechanisms inaccessible to communities.

Information and knowledge gaps: Communities lack access to climate information relevant to their decisions—seasonal forecasts, drought predictions, long-term projections. Where information exists, it may not be in accessible formats or languages. Local knowledge, while valuable, may be insufficient for unprecedented conditions. The combination of scientific and local knowledge that enables robust adaptation requires sustained engagement that is rarely supported.

Exclusion and marginalisation: As documented throughout this paper, adaptation processes systematically exclude marginalised groups—women, lower castes, ethnic minorities, the poor. Formal decision-making venues favour elite voices. Even community-led processes, without deliberate design, reproduce existing inequalities. Climate interventions that fail to address exclusion not only perpetuate injustice but also undermine effectiveness, as they miss the knowledge and needs of those most affected.

5. Discussion:

Towards an Integrated Framework for Equitable Climate Transformation: The findings from Bahraich, viewed through the lens of comparative cases and theoretical literature, suggest the contours of an integrated framework for equitable climate transformation. This framework, presented schematically in Figure 1, identifies four interconnected pillars and the pathways through which they can be operationalised.

Pillar 1: Climate Justice and Equity: Climate justice must be foundational, not incidental, to transformation pathways. This requires:-

Centring marginalised voices: Deliberate strategies to include those typically excluded—women, lower castes, landless labourers, ethnic minorities—in all stages of climate decision-making. Not tokenistic consultation, but genuine participation in problem definition, option identification, and solution selection. This may require separate spaces for marginalised groups to develop confidence and articulate priorities before engaging in mixed forums.

Addressing structural inequalities: Climate interventions must confront, not accommodate, existing inequalities. This means targeting resources to those most vulnerable, not those best positioned to access them. It means challenging land, water, and credit distributions that concentrate adaptive capacity among elites. It means ensuring that adaptation does not become a vehicle for accumulation by the already-advantaged.

Intersectional analysis: Vulnerability is not singular but intersectionally constituted—by gender, caste, class, age, location, and other axes of difference. Interventions must analyse how these dimensions interact to shape differentiated experiences of climate change and capacities for response. As Amorim-Maia et al. (2025) argue, adaptation policies must address overlapping vulnerabilities while integrating ethics of care and community resilience.

Pillar 2: Community Resilience: Building community resilience requires strengthening the social, institutional, and material foundations of adaptive capacity.

Investing in social capital: Social networks, trust, and norms of reciprocity enable collective action and mutual support during crises. Interventions should strengthen, not undermine, these relationships. This means working through existing community institutions where they are inclusive and legitimate, while supporting their evolution toward greater equity and effectiveness.

Diversifying livelihoods: Livelihood diversity spreads risk and provides options when particular activities become unviable. Support for diversification—through skills training, credit access, market linkages, and infrastructure—enables households to navigate climate uncertainty. But diversification must be genuinely chosen, not forced by distress, and must provide decent livelihoods, not precarious survival.

Building flexible institutions: Institutions that can learn, adapt, and reorganise in response to changing conditions outperform rigid bureaucracies. This requires decision-making autonomy at local levels, mechanisms for incorporating new information, and iterative planning processes that adjust as circumstances evolve. Participatory governance arrangements that engage communities in ongoing adaptation planning exemplify such flexibility.

Knowledge integration: Robust adaptation integrates scientific and local knowledge systems. This requires sustained engagement, not one-off extraction of local knowledge. It means treating communities as partners in knowledge production, not sources of data for external experts. It involves translating climate information into locally relevant formats and languages, while supporting communities to contribute their own observations and insights.

Pillar 3: Participatory Governance: Effective climate governance must be genuinely participatory, with communities exercising real authority over decisions affecting their lives.

Binding consultation: Participation without authority is hollow. Communities must have not only the right to be consulted but the right to co-create alternatives and have their decisions recognised. As Rodríguez Arrieta (2025) argues, this requires binding consultation protocols, defined with communities, that guarantee the right to co-create alternatives, not merely receive information.

Legal recognition of community decisions: Community decisions—whether made through assemblies, customary processes, or formal votes—must be legally recognised, even when they do not take conventional forms. This means adapting planning and budgeting systems to accommodate community-generated proposals, not requiring communities to conform to bureaucratic templates.

Co-managed resources: Financial resources for adaptation should be co-managed between governments and communities, enabling flexible, responsive allocation aligned with local priorities. This requires moving beyond vertical, top-down project models to flexible funds that communities can draw on as needs evolve. It means trusting communities to manage resources responsibly, with appropriate accountability mechanisms.

Continuity and long-term engagement: Participation cannot be episodic, confined to project cycles. Effective engagement requires continuity—sustained relationships, iterative processes, and institutional memory. This means embedding participatory processes in ongoing governance arrangements, not treating

them as one-off exercises. It requires funding that supports long-term engagement, not short-term deliverables.

Pillar 4: Ethically Deployed Technology: Technology can support community-led adaptation when deployed within justice-centred frameworks.

Participatory design: Technologies for climate adaptation—early warning systems, information platforms, decision-support tools—should be co-designed with intended users. This ensures relevance, usability, and cultural appropriateness. It builds local capacity to use and maintain technologies. It prevents imposition of tools that do not fit local contexts or needs.

Community data ownership: Data generated through participatory processes—mapping, monitoring, citizen science—should be owned and controlled by communities. This means clear protocols for data access, use, and benefit-sharing. It requires resisting appropriation of community-generated data by external actors without community consent and benefit.

Digital equity: Technology deployment must address, not reinforce, digital divides. This means ensuring access for those without connectivity, literacy, or technical skills. It involves multiple channels—not only digital but also radio, community networks, face-to-face communication—to reach all community members. It requires attention to language, format, and accessibility.

Complementarity, not substitution: Technology should strengthen grassroots action, not replace it. As Arai et al. (2021) emphasise, digital tools should support human relationships and local institutions, not substitute for them. The goal is technology that enhances community capacity, not technology that makes communities dependent on external expertise.

Integrating the Pillars: A Transformation Pathway for Bahraich

For Bahraich specifically, these principles suggest concrete pathways. Climate-resilient agriculture would be developed through participatory research with farmers, integrating indigenous practices with scientific knowledge, and ensuring equitable access to seeds, credit, and extension. Water management would combine revived traditional water bodies with modern efficiency technologies, governed through inclusive user associations. Livelihood support would enable diversification on communities' own terms, with particular attention to women and landless households. Migration, where chosen, would be supported through portable entitlements, migrant rights, and investments in receiving areas. And all interventions would be developed through sustained participatory processes with binding community authority over decisions.

6. Conclusion and Recommendations

Summary of Contributions: This paper has examined climate change and social transformation in Bahraich District through integrated analysis of climate trends, community adaptation literature, and comparative case studies. The findings reveal that Bahraich is experiencing significant climate change—warming temperatures, declining and more variable rainfall, increased drought frequency—that is driving profound social transformation across agricultural systems, livelihoods, social institutions, and community structures. These transformations are neither automatic nor uniform; they are shaped by pre-existing inequalities, institutional arrangements, and community agency. The study makes several contributions. First, it provides the first integrated analysis of climate trends and social transformation for Bahraich District, establishing a baseline for future research and policy. Second, it demonstrates how climate data and social analysis can be productively combined to understand transformation pathways. Third, it offers an integrated framework for equitable climate transformation that centres justice, community resilience,

participatory governance, and ethically deployed technology. Fourth, it generates actionable recommendations for policy and practice in Bahraich and similar contexts across the Indo-Gangetic Plain.

Policy Recommendations: For policymakers at district, state, and national levels-

1. **Institutionalise participatory climate governance:** Establish binding consultation protocols that guarantee communities the right to co-create climate adaptation alternatives. Embed participatory processes in ongoing governance arrangements, with adequate resources, time, and institutional support. Ensure legal recognition of community decisions, even when they do not conform to bureaucratic templates.
2. **Target resources to the most vulnerable:** Design climate finance mechanisms that deliberately reach marginalised groups—women, lower castes, landless labourers, small and marginal farmers. Move beyond eligibility criteria that favour those with existing capacity to access resources. Monitor distributional outcomes and adjust programmes to address inequalities.
3. **Support knowledge integration:** Invest in platforms and processes that bring scientific and local knowledge systems into sustained dialogue. Translate climate information into locally accessible formats and languages. Support community-based monitoring and citizen science that enable communities to contribute their own observations. Train extension personnel in participatory, knowledge-integrative approaches.
4. **Enable livelihood diversification within communities:** Provide skills training, credit access, market linkages, and infrastructure that enable households to diversify livelihoods on their own terms. Ensure that diversification support reaches women and landless households, not only landed farmers. Link diversification to broader economic development strategies that create decent local employment.
5. **Address structural inequalities:** Confront land, water, and credit distributions that concentrate adaptive capacity among elites. Challenge caste- and gender-based exclusion from decision-making. Ensure that climate interventions do not become vehicles for elite accumulation. Integrate climate action with social justice agendas.
6. **Invest in long-term engagement**: Move beyond short-term project cycles to sustained engagement with communities. Fund participatory processes adequately and consistently. Build institutional memory and relationships. Treat adaptation as ongoing learning, not one-time intervention.

Recommendations for Practice: For development practitioners, civil society organisations, and community-based organisations-

1. **Start with listening:** Before designing interventions, invest time in understanding community priorities, knowledge, and capacities. Use participatory methods that enable communities to articulate their own perspectives. Recognise that communities are not passive recipients but active agents with valuable knowledge and experience.
2. **Build on existing institutions:** Work with and through existing community institutions—panchayats, user groups, mutual aid networks—where they are inclusive and legitimate. Support these institutions to become more equitable and effective. Avoid creating parallel structures that undermine community cohesion.
3. **Design for inclusion:** Deliberately design processes that include marginalised groups. Use separate spaces, facilitated groups, and inclusive language to enable participation by women, lower castes, and others typically excluded. Address practical barriers to participation—timing, location, childcare, translation.

4. **Link local and scientific knowledge:** Create opportunities for dialogue between local knowledge holders and scientific experts. Support communities to integrate external information with their own observations. Resist both romanticisation of local knowledge and dismissal of scientific inputs.
5. **Support community agency:** Frame interventions as supporting community-led adaptation, not delivering external solutions. Ensure communities have genuine authority over decisions, not merely consultation. Build local capacity to access resources, engage with governance systems, and advocate for community priorities.
6. **Document and share learning:** Systematically document adaptation experiences—successes, failures, and lessons. Share learning across communities and contexts. Contribute to collective knowledge about what works, for whom, and under what conditions.

6.4 Directions for Future Research: This study identifies several priorities for future research-

1. **Primary research in Bahraich:** Field research is urgently needed to capture community perspectives, document local adaptation practices, and understand how climate transformation is being experienced and negotiated in specific villages and social groups. Participatory action research approaches that engage communities as co-researchers would be particularly valuable.
2. **Longitudinal studies:** Understanding social transformation requires tracking change over time. Longitudinal studies that follow households and communities through climate shocks, adaptation experiments, and transformation processes would illuminate dynamics that cross-sectional studies miss.
3. **Comparative research across the Indo-Gangetic Plain:** Systematic comparison across districts and states in the Indo-Gangetic Plain would identify patterns and variations in climate-induced social transformation, enabling learning across contexts while attending to local specificities.
4. **Intersectional analysis:** Research is needed on how gender, caste, class, age, and other axes of difference intersect to shape climate vulnerability, adaptive capacity, and transformation outcomes. Such analysis should inform both theory and practice.
5. **Evaluation of participatory governance:** Rigorous evaluation of participatory governance arrangements—what works, for whom, under what conditions—would generate evidence to guide institutional design. Comparative studies across different participation models would be particularly valuable.
6. **Technology assessment:** Research on digital tools for climate adaptation should assess not only technical performance but also equity implications, community control, and effects on social relationships. Participatory design and evaluation approaches that involve communities as partners would align with the principles articulated in this paper.

Concluding Reflection

Climate change is not a future threat for Bahraich; it is a present reality reshaping landscapes, livelihoods, and lives. The transformations underway are profound—agricultural systems reorganising, livelihoods diversifying, migration accelerating, social institutions adapting. Yet these transformations are not predetermined. They are shaped by choices—individual and collective—about how to respond, who to include, what to prioritise. The framework proposed in this paper insists that these choices can and should be guided by principles of justice, participation, and equity. The challenges are immense. Structural inequalities, institutional barriers, and resource constraints limit options and shape outcomes. Yet the evidence from communities across South Asia and beyond demonstrates that transformation need not be passively endured. Communities are experimenting, innovating, and organising. They are drawing on

indigenous knowledge while integrating new information. They are building institutions that enable collective response. They are asserting their right to shape their own climate futures.

For researchers, policymakers, and practitioners, the task is not to design solutions for communities but to support communities' own transformative agency. This means listening before acting, following community priorities rather than imposing external agendas, and ensuring that communities have genuine authority over decisions affecting their lives. It means confronting inequalities that marginalise some voices while privileging others. It means building institutions that are flexible, inclusive, and accountable. And it means recognising that climate transformation, while driven by environmental necessity, is ultimately a social and political process—one that must be navigated with justice at its centre. The people of Bahraich, like climate-affected communities everywhere, are not waiting for salvation. They are already transforming their worlds. The question is whether external actors will support these transformations in ways that enhance equity, build resilience, and honour the dignity of those most affected. This paper has sought to contribute to that project—not by offering final answers, but by clarifying questions, synthesising evidence, and proposing directions for just and inclusive climate transformation.

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