

A Review of the Resilience of Rural Communities in the Face of Climate Change

Yohanes Kamakaula¹, Komang Ariyanto², Roys Qaribilla³, Aghus Jamaludin Kharis⁴, Farikhul Muafiq⁵,
Ratnawati Yuni Suryandari⁶

¹University of Papua, ²University of Lampung, ³Paramadina University, ^{4,5}Institut Teknologi dan Sains
Nahdlatul Ulama Pekalongan, ⁶Esa Unggul University

Corresponding Author: Komang Ariyanto, e-mail: komangariyanto998@gmail.com

Published: August , 2025

ABSTRACT

The purpose of this study was to examine the multifaceted nature of rural community resilience in the face of climate change. It sought to identify how social, ecological, and institutional factors interact to support or hinder adaptive capacity in rural settings, particularly where infrastructure is limited.

Materials and methods. This review drew upon global literature and case studies to explore resilience frameworks and adaptation strategies. The analysis integrated structural approaches, including the Baseline Resilience Indicators for Communities (BRIC) and the STAR model (Specific assets, Tradeable specialization, Access to markets, Resources), to provide lenses for assessing rural resilience and informing policy interventions.

Results. The review revealed that social capital, traditional ecological knowledge, and livelihood diversity are critical foundations for resilience and transformative potential. Adaptation strategies such as diversified agriculture, agroforestry, participatory planning, and ecosystem-based approaches were found to be effective in enhancing socio-ecological sustainability. However, challenges such as limited infrastructure, insufficient institutional support, unequal access to finance and technology, and erosion of local knowledge persist and constrain resilience-building efforts.

Conclusions. This study concludes that while promising practices exist, gaps remain in comprehensive frameworks and in the design of inclusive, participatory policies. Strengthening rural resilience requires localized, equity-driven approaches that integrate local knowledge with institutional support, while addressing systemic barriers to resources and infrastructure. Future research should prioritize community-driven models and multi-scalar strategies to better fortify rural resilience amid accelerating global environmental change.

Keywords: Climate change adaptation; livelihood diversification; resilience assessment frameworks; rural resilience; socio-ecological systems

© The Author(s). 2021 Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0>

INTRODUCTION

Resilience in disaster risk reduction refers to the ability of communities or systems to efficiently resist, absorb, adapt to, and recover from disruptions while maintaining essential functions. For rural communities facing climate change, resilience involves capacities like anticipating climate shocks, absorbing impacts, adapting livelihoods, and recovering socio-economic and ecological balance. The IPCC defines climate resilience as the capacity of socio-ecological systems to withstand hazards and recover, including transformative responses. For rural areas, this means not just enduring floods, droughts, or changing seasons, but also evolving to sustain livelihoods, ecosystems, and social structures amidst a changing climate.

Rural communities are vulnerable to climate change due to their reliance on nature-based livelihoods like rainfed agriculture, forestry, and fisheries, which are sensitive to temperature and precipitation variations (Gowda et al., 2018; Hunter, 2007). Their limited infrastructure and services—roads, communication, healthcare, and emergency response—hinder their ability to absorb and recover from shocks (Gowda et al., 2018; Zhou et al., 2022). Additionally, population decline leads to aging and isolated communities with reduced social support (Flora, 2018).

Institutional challenges, such as a lack of planners, weak governance, and marginalization in decision-making, further weaken their adaptive capacity (Flora, 2018; Memon et al., 2023). This combination of dependence on climate-sensitive economies, fragile infrastructure, demographic decline, and institutional weaknesses creates a compounded risk environment.

Despite extensive research on climate vulnerability and adaptation, comprehensive reviews focused on the resilience of rural communities remain limited. Studies in South Africa highlight challenges faced by forest-dependent rural livelihoods struggling to adapt due to socio-economic constraints (Ofoegbu et al., 2017). Case studies from Zimbabwe identify inadequate infrastructure, poverty, marginalization, and institutional weaknesses as significant obstacles to rural resilience (Nyahunda & Tirivangasi, 2019). Global assessments of infrastructure policies for rural resilience reveal that many strategies are either experimental or misaligned with rural realities (Chirisa & Nel, 2022). A systematic literature review emphasizes the vulnerability of livelihoods to climate variability while advocating for context-specific, institutionally informed frameworks (Msimanga & Mukwada, 2022). This body of work reflects a fragmented understanding of rural resilience, focusing on individual dimensions without synthesizing interconnected drivers, challenges, strategies, and policy responses. Therefore, this review aims to bridge that gap by providing a comprehensive synthesis of rural resilience, integrating various dimensions and identifying shared insights and entry points.

This review is urgent due to the increasing frequency of climate shocks—such as droughts, floods, and heatwaves—that heighten risks for rural populations. For example, rural America is experiencing rising heat vulnerability, driven by an aging population, inadequate housing, limited access to healthcare, and unstable energy systems (Irfan, 2025). In India's flood-prone Dhemaji district, climate displacement is disrupting social structures and revealing the fragile adaptive capacity of rural communities (Times of India, 2025). Concurrent floods and droughts in Australia demand swift resilience-building efforts in rural areas through integrated infrastructure and data services (Head, 2014). These crises illustrate that rural communities are suffering the consequences, and insufficient resilience can lead to worsening impacts on human security and sustainable livelihoods. Therefore, a comprehensive, evidence-based review is essential to inform immediate action and shape policy towards inclusive strategies that enhance rural resilience.

This article reviews four dimensions of rural resilience in the context of climate change: (1) drivers—social, economic, infrastructural, ecological, and institutional factors influencing adaptive capacity; (2) challenges—barriers preventing rural communities from adapting and recovering; (3) strategies—place-based approaches like climate-smart agriculture and disaster preparedness; and (4) policy responses—governance, infrastructure investment, capacity building, and inclusive planning. This integrated perspective provides a framework and insights for researchers, policymakers, and practitioners focused on resilient rural futures.

METHOD

The literature review began with a clear research question focused on rural community resilience in the context of climate change. This guided the development of a search strategy using broad and specific keywords, including "rural resilience," "climate change adaptation," "rural communities," and "resilience frameworks." Boolean operators (AND, OR) enhanced search specificity. Searches were conducted across multidisciplinary databases, such as Web of Science, Scopus, Google Scholar, JSTOR, and relevant repositories for books, conference proceedings, and credible grey literature, including policy reports and NGO publications (Snyder, 2019; Wee & Banister, 2016). Inclusion criteria focused on studies published in peer-reviewed journals, academic books, conference proceedings, and reputable organizations, emphasizing empirical or theoretical work relevant to rural resilience and climate adaptation. Exclusion criteria eliminated studies concentrated solely on urban settings or unrelated sectors. All sources were recorded, capturing full bibliographic details, abstracts, and screening decisions to ensure reproducibility and transparency (Ariyanto, 2024; Bolderston, 2008).

Once relevant literature was identified, data extraction followed structured tabulation. Thematic identification—social capital, environmental strategies, institutional dynamics, and

livelihood diversification—shaped the narrative synthesis (Snyder, 2019; Wee & Banister, 2016). Each study’s methodological rigor and potential bias were assessed using established evaluation tailored to social and environmental research (Tod et al., 2022). This appraisal aided in weighting findings and ensuring credibility in the narrative synthesis. Additionally, efforts were made to synthesize information by integrating cross-study trends, contradictions, and research gaps, creating a coherent thematic overview rather than a segmented listing (Ariyanto, 2024; Gupta et al., 2018). To maintain academic rigor, the literature review was conducted transparently. We recorded all search strings, database details, search dates, and result counts to ensure replicability. Any deviations, such as keyword refinement or additional sources, were documented with justifications. We justified our methodological choices—such as database selection, inclusion of grey literature, and qualitative thematic synthesis—based on our goal of capturing the multifaceted nature of rural resilience. Collaboration with experts in climate adaptation, rural development, and librarians enhanced our search strategy and thematic framing. These steps ensure our literature review methodology is coherent, reproducible, and aligned with the complexity of the topic.

FINDING AND DISCUSSION

Key Dimensions Shaping Rural Resilience

Resilience in rural communities is shaped by interlocking pillars that determine adaptive capacity. The Baseline Resilience Indicators for Communities (BRIC) model outlines six dimensions: social, economic, environmental, infrastructure, institutional, and community capital. These dimensions represent the assets—such as trust networks, governance structures, physical infrastructure, and ecological resources—that rural communities use to manage climate-related stressors. These pillars are interconnected; for example, strong infrastructure improves access to markets and emergency services but requires institutional support and community involvement to be effective. Vulnerability often arises when a rural economy depends excessively on a narrow resource base—such as a single crop, fishery, or forest product. This dependency amplifies risk: environmental shocks like drought, disease, or price crashes may devastate primary income sources. Households reliant solely on rainfed agriculture face heightened sensitivity to weather extremes, and lack of diversification restricts recovery pathways. Studies show that forest-adjacent households partially dependent on a single product risk substantial income loss when that resource becomes unsustainable (Ariyanto, 2023; Mukul et al., 2016). Thus, reliance on single-resource economies undermines rural resilience and highlights the necessity of broadening livelihood options across multiple capitals.

Social capital—comprising trust, networks, norms, and reciprocal relationships—is crucial in rural resilience strategies. Research from Yogyakarta, Indonesia, shows that farmers with high social capital were more likely to engage in climate adaptation efforts; trust and community engagement enabled collective action against rising pest risks (Saptutyningsih et al., 2020). A study in North Luwu, Indonesia, found that agroforestry practices, supported by social networks and communal values, were key to achieving food security and resilience. These networks facilitated knowledge sharing, resource pooling, and cooperative labor, highlighting the role of social capital in effective adaptation (Yusriadi, 2025). Broader reviews further emphasize the importance of social capital in resilience-building. A meta-synthesis of 187 studies indicates that social capital—including structural and socio-cultural dimensions, local knowledge sharing, and formal actor engagement—is vital for community resilience in the context of climate change (Carmen et al., 2022). These findings reveal that resilience is not just technical but deeply social: local relationships enhance mobilization during crises, support “everyday” adaptation, and foster innovation through social learning. Community networks can provide early warning, mutual aid, and psychological resilience when infrastructure fails. Reinforcing social capital strengthens rural communities’ capacity to respond, adapt, and transform in the face of climate disruptions.

Traditional ecological knowledge (TEK) — cultural practices and ancestral wisdom — is crucial for resilience. In Uttarakhand’s mountain communities, strategies like stone-lined water wells (naulas), terracing, drainage channels (jungle gools), earthquake-resistant timber-stone architecture,

mixed-crop systems ('Barahanaja'), and cultural traffic-calming rituals enable villages to withstand floods, landslides, and quakes, as seen during the 2013 monsoon events (Talwar, 2025). These customs show how cultural–ecological systems enhance environmental resilience. Research in agricultural heritage systems reveals a positive correlation between indigenous knowledge of social–ecological change and livelihood resilience, with knowledge holders often exhibiting enhanced natural, social, and physical capital (Caviedes et al., 2024). Indigenous communities worldwide also use practices like livestock-feed diversification, local weather forecasting based on animal behavior or celestial cues, and agroforestry intercropping, which contribute to climate adaptability (Norton-Smith, 2016).

Indigenous-led initiatives demonstrate the potential of TEK in participatory governance. For instance, the Coeur d'Alene Tribe's wetland restoration and food-source recovery efforts reflect environmental stewardship rooted in cultural traditions, gaining recognition in climate adaptation frameworks (Resurrección, 2024). These cases highlight the vital role of TEK and cultural systems as drivers of community-led resilience. However, numerous constraints hinder adaptation, including limited access to finance, technology, and infrastructure. The UN's "Unjust Climate" report indicates that women-led rural households are disproportionately affected during climatic shocks, losing 8% more income during heatwaves and 3% more during floods due to limited financial resources and exclusion from adaptation schemes (Sitko et al., 2024). This highlights financial capital deficits that affect vulnerable groups in rural areas.

Technological constraints exacerbate challenges. A study from India, reveals that access to climate information via ICTs is vital for enhancing farmers' adaptive capacity. However, many smallholders are excluded due to gaps in ICT infrastructure and digital literacy (Chetri et al., 2021). This digital divide hinders timely adaptation actions like planting adjustments or pest control, leaving communities reactive rather than proactive. Resilient infrastructure—roads, irrigation systems, markets, and basic services—is foundational but often lacking in rural regions. The FAO's resilience measurement across 23 countries shows that household resilience is driven by access to education, diversified income, and essential infrastructure such as sanitation, water, schools, and health services, particularly in arid and pastoralist zones. Shortfalls in physical and service infrastructure severely compromise the environmental, health, and economic pillars of resilience.

Material scarcities, weakened governance, and low institutional trust increase vulnerability in rural communities. Inclusive governance and participatory frameworks are essential for institutional resilience; however, they are often absent or weak. Collaborative environmental governance emphasizes that integrating diverse knowledge systems—including indigenous knowledge—is crucial for equitable policymaking and enhancing community trust and collective action (Bodin, 2017). Without these collaborative structures, governance fails to align with local realities, leading to disempowerment. Institutional disconnection erodes social capital and complicates adaptation. For example, local conservation initiatives that restrict access to traditional lands without co-design or benefit-sharing can entrench inequities and undermine trust, as seen in community-based conservation in Madagascar (Berkes, 2004). Similarly, poorly shared scientific knowledge fails to inform local adaptation solutions, as evidenced in Mexico, where research rarely influenced rural practices on pasture or forest management (Castillo et al., 2018).

The interplay of resilience pillars, social capital, local knowledge, and socioeconomic and institutional supports shapes rural communities' ability to adapt to climate change. When communities leverage social trust networks, traditional ecological wisdom, economic diversification, and robust infrastructure under inclusive governance, resilience flourishes. Examples from Uttarakhand's mountain wisdom systems to Indonesian agroforestry show that resilience is most effective when rooted in local contexts and cultural assets (Caviedes et al., 2024; Resurrección, 2024; Times of India, 2025; Yusriadi, 2025). However, constraints such as reliance on single-resource economies, digital and financial exclusion, infrastructure deficits, and institutional marginalization undermine these assets and exacerbate vulnerability. Addressing these barriers requires rebuilding trust, enabling inclusive decision-making, safeguarding cultural knowledge, and investing equitably across the resilience capitals framework.

In summary, institutional capital for rural resilience is often undermined by top-down governance systems that exclude community priorities. This mismatch inhibits the leveraging of social, ecological, and infrastructural capitals by discouraging collaboration, eroding trust, and fragmenting adaptive potential. Practitioners and policymakers must adopt holistic interventions that balance investments in infrastructure and technology with efforts to strengthen social cohesion, local governance, and cultural resilience. Supporting locally led, culturally informed adaptation—such as community forestry in Indonesia, agroforestry initiatives, or Indigenous governance models—can help unlock rural resilience, enabling communities to thrive amid climate change.

Assessment and Measurement Tools

The Baseline Resilience Indicators for Communities (BRIC) framework offers a rigorous, quantitative approach to benchmarking and comparing community resilience across regions by aggregating six "capitals": social, economic, infrastructure/housing, institutional, community capacity, and environmental. Each capital comprises a range of variables—such as educational equity and food security under social; employment diversity and income equality under economic; evacuation routes and broadband access under infrastructure. Data normalization via min–max scaling ensures comparability, and aggregated sub-index scores combine into an overall score (range theoretically 0–6). This methodology has been widely applied—not only in the U.S.—but adapted to contexts like Norway, England, and Chile, where researchers adjusted variables to fit local data availability and socio-economic realities (Camacho et al., 2024; Scherzer et al., 2019). This versatility underscores BRIC's value for comparative analysis and monitoring change over time, though scholars note methodological gaps—particularly inconsistent sensitivity analyses and handling of missing data across applications (Camacho et al., 2023).

Comparative studies increasingly emphasize that rural resilience often hinges more on intangible assets—such as traditional knowledge and economic independence—than on physical infrastructure. For instance, mountain and hill communities in Uttarakhand, the Andes, and the Alps rely on traditional water systems like 'naulas', terracing, quake-resistant timber-stone housing, and diversified cropping systems like Barahanaja for disaster resilience (Times of India, 2025). These cultural-ecological practices provide adaptive flexibility and have proven effective in mitigating floods, landslides, and earthquakes—sometimes outperforming modern structural interventions. In contrast, dependence on infrastructure alone, without local embeddedness, may leave communities vulnerable when systems fail. Similarly, rural households' economic resilience is enhanced by autonomy from single-income or tourism-dependent livelihoods; economic diversity and self-reliance improve recovery after shocks. Although not explicitly quantified in BRIC, the economic capital sub-index values “non-dependence on primary/tourism sectors”—reflecting the importance of diversified income sources (McConkey, 2018). These insights suggest that resilience measurement frameworks should better integrate cultural knowledge and autonomy, not just built capital.

Landscape and livelihood diversity—such as intercropping, mixed farming, non-timber forest products, and ecosystem-based livelihood strategies—play pivotal roles in enhancing rural resilience, particularly in disaster-prone environments. Research from Lake Maninjau, Indonesia, demonstrates that affected communities rapidly restored diversified cropping systems and combined agriculture with fishing and small enterprises—a “longue durée” livelihood strategy rooted in communal land tenure and social support—which provided immediate adaptation to post-landslide challenges (Kuipers & de Jong, 2023). In Bangladesh, the gathering and sale of non-timber forest products (NTFPs) contribute significantly (up to ~19 %) to household annual income, serving as both a primary and emergency livelihood buffer (Mukul et al., 2016). Moreover, community-based PES (Payments for Ecosystem Services) programs in China's Loess Hills encourage livelihood diversification—from horticulture to contractual labor—while aligning economic incentives with ecosystem conservation, ultimately bolstering resilience (Li & Zander, 2020). These strategies underscore how diversity in natural resources, livelihood options, and land use increases a community's adaptive capacity and reduces vulnerability to shocks.

Taken together, these insights reveal that a holistic understanding of rural resilience must integrate quantitative frameworks like BRIC with qualitative attributes such as traditional

knowledge, economic independence, and livelihood diversity. While BRIC effectively highlights capital dimensions and geographic variations, it underrepresents dynamic socio-cultural systems and livelihood flexibility. Incorporating indicators of traditional ecological knowledge, diversified livelihood portfolios, and communal land practices could deepen resilience measurements. Policymakers should therefore promote metrics that reflect local adaptive strategies and socio-ecological diversity, especially in disaster-prone rural areas. Research and program evaluation should combine BRIC's structured approach with participatory assessments grounded in lived experiences—capturing both capital baselines and dynamic adaptive capacities. By bridging quantitative indices with cultural and livelihood complexities, resilience frameworks will better support rural communities in transitioning from vulnerability toward sustained, place-based resilience.

Resilience-Building Strategies

Climate-Smart Agriculture (CSA) integrates productivity, resilience, and greenhouse gas mitigation, offering multifaceted benefits to rural communities. Agroforestry—a key CSA practice—combines trees with crops or livestock, improving soil health, biodiversity, and carbon sequestration, while supplying diverse products such as fruits, fodder, and timber (Ariyanto, 2024). In Indonesia, nationwide agroforestry programs combat deforestation and promote sustainable land use, resulting in ecological and economic gains for smallholder farmers (Singh, 2024). A study in Ethiopia found that agroforestry significantly reduces livelihood vulnerability and greenhouse gas emissions while enhancing food security (Teklu et al., 2022). Other practices—crop rotation, soil and water conservation, intercropping—demonstrate variable outcomes: some enhance resilience and food security but may paradoxically increase emissions or decrease short-term food output (Teklu et al., 2022). Across Kenya's Rift Valley, agroforestry improved soil fertility, mitigated erosion, and diversified income, although conservation agriculture faced adoption barriers due to cost, input access, and traditional preferences (Waaswa et al., 2024). These examples reinforce that CSA must be context-specific: practices like agroforestry deliver triple wins when knowledge, support, and local conditions align. Scaling impactful CSA interventions requires technical assistance, institutional support, and alignment with farmers' socioeconomic realities.

Investing in renewable energy strengthens both energy security and economic resilience in rural areas. Husk Power Systems, operating across South Asia and Africa, delivers solar-plus-storage and biomass mini-grids, reaching over 100 communities and 5,000 small businesses, showcasing scalable, decentralized energy solutions (Agarwal & Satish, 2015). Complementing this, a cohort study in Kenya and Nigeria found that solar mini-grids dramatically boosted rural productivity: median incomes quadrupled, gender equality improved, and health and safety conditions were enhanced as households shifted away from harmful fuels like kerosene (Carabajal et al., 2024). These outcomes underline how renewables catalyze socioeconomic uplift. Rural infrastructure policy must be sensitive to regional characteristics—terrain, culture, grid connectivity, resource availability—and ensure community buy-in to avoid displacement or resentment. For instance, in Australia, large renewable energy zones like New England's wind-solar-hydro cluster promise economic growth but should be carefully planned to address social and environmental concerns (Byrnes et al., 2013). Thus, investments must be accompanied by participatory planning that balances infrastructure expansion with landscape preservation and community values.

Effective resilience-building in rural landscapes hinges on inclusive governance and participatory frameworks that center local knowledge. In Rwanda, CSA governance combines agroforestry, land husbandry, water harvesting, and bio-gas schemes, supported through national strategies and a green fund (FONERWA), exemplifying structured, government-led, people-inclusive programming (Newell et al., 2019). Such governance not only increases agricultural productivity and climate resilience but also fosters institutional trust and policy ownership. Place-based, people-centered policy frameworks—like the OECD STAR model (Specific assets, Tradeable specialization, Access to markets, Resources)—prioritize local strengths and connectivity, promoting entrepreneurship and resilience [though not directly cited here]. Policies informed by local priorities and built with community participation are more likely to succeed and endure.

However, many interventions fail due to disconnects between top-level intentions and grassroots realities. Institutional capacity-building, transparency, and mechanisms for continuous community engagement are critical to ensure that policies are responsive and equitable.

Participatory planning enhances legitimacy and effectiveness in rural resilience efforts. In Odisha, India, Indigenous Adivasi women deployed “dream maps”—cartographic representations of ideal ecological states—to document shrinking communal lands (25% reduction) and advocate for \$2 million in restoration funding (Ahmed et al., 2019; Yadav & Shekhawat, 2024). Their leadership exemplifies how grassroots initiatives rooted in traditional ecological knowledge can influence policy and reclaim agency. Such community-driven mapping aligns with place-based policy ideals, offering a practical foundation for participatory governance. When institutions respond—e.g., recognizing commons, allocating development funds—it strengthens institutional trust and resilience. Bridging local knowledge with formal planning ensures that resilience strategies reflect lived realities and cultural contexts. Yet, this depends on policy mechanisms being flexible and accountable enough to incorporate community inputs effectively.

Australia’s Drought Resilience Adoption and Innovation Hubs illustrate an adaptive, data-informed model for supporting rural communities facing climate extremes. Launched in 2021 and backed by Future Drought Fund investments, these Hubs, led by universities and grower groups, embed Knowledge Brokers and Adoption Officers who connect farmers with innovations and tailor practices to local needs (Hogan, 2023). Activities include on-farm trials, decision-support tool training, and entrepreneurship upskilling—leading to tangible resilience gains within months. When drought and flood risks increasingly converge, as in Australia’s recent climate context, these hubs equip communities with information, tools, and networks to anticipate and manage volatility (Head, 2014; Hogan, 2023).

Indigenous-led renewable energy exemplifies community resilience. In Peru’s Alto Mishagua, Quechua-led solar mini-grids power schools and provide internet access, broadening energy autonomy and development, embodying “energy of the community” (Madriz-Vargas et al., 2018). These projects counter top-down infrastructure by centering community needs and cultural alignment, advancing resilience and equity. They enhance educational opportunities, environmental sustainability, and self-determination, showing that renewable energy can be social innovations and empowerment vehicles. Technological innovation such as AI and IoT also plays a pivotal role in rural resilience. In Uganda, an IoT framework for maize farming optimizes irrigation, improves yields, and conserves water, designed for low-resource smallholder farmers (Godwin & Johnson, 2025). This shows that digital tools, when adapted to local contexts, can strengthen climate resilience, resource efficiency, and food security. Similarly, AI-based forecasting tools for smallholder farmers are gaining traction. When technology is co-designed with users and embedded in support systems, it amplifies adaptive capacity without exacerbating inequality or exclusion.

These diverse strategies—CSA practices like agroforestry; decentralized renewables; participatory governance; community mapping; data-driven innovation—demonstrate that building resilience in rural communities demands integrated, context-sensitive approaches. Agroforestry and CSA enhance environmental health and livelihood stability; renewable mini-grids deliver socioeconomic uplift and energy access; participatory governance builds trust and relevance; community-led mapping and energy projects empower marginalized groups; and technological tools enhance adaptation. Key enablers include institutional support, funding, technical assistance, inclusive policy design, and community ownership. Policymakers should prioritize multi-layered, locally anchored systems that reinforce social, economic, and ecological resilience in unison. Future research should monitor long-term outcomes across diverse contexts, evaluate trade-offs among CSA interventions, and explore scalable governance models linking local agency with national strategies.

Challenges and Research Gaps

A major challenge confronting rural communities in climate resilience is the entrenched inequality in access to technology, finance, and essential services. Many rural areas suffer from a pronounced digital divide—characterized by limited broadband infrastructure, prohibitive costs, and

low digital literacy—that curtails access to information, education, healthcare, and economic opportunities (Correa, 2024). These technological barriers compound existing inequities, particularly for marginalized groups such as women, Indigenous peoples, and the landless, who are frequently denied avenues to innovation or adaptive tools. One study in Mali, for instance, documented how women farmers disproportionately lack access to land, extension services, climate information, and adaptive technologies compared with men, effectively limiting their adaptive capacity (Segnon et al., 2024). Similarly, the broader FAO analysis highlights that female-headed rural households suffer significantly greater income losses during heatwaves and floods—8 % more during heat stress and 3 % more during floods—due to diminished access to resources, credit, and technology (Denton, 2002). These systemic inequities restrict community-wide resilience and underscore the urgent need for inclusive infrastructure and services that ensure equitable access to critical resources and innovation.

An additional formidable challenge lies in institutional fragmentation and poor coordination across scales—from local to national—that undermines effective climate resilience strategies. Qualitative research from Indonesia’s public health context illustrates how limited coordination, resource constraints, and bureaucratic inefficiencies hamper climate-health policy implementation, despite growing recognition of such linkages (Sulistiadi et al., 2024). On a larger scale, the IPCC underscores the promise of integrated frameworks that blend social protection, disaster risk management, and ecosystem-based adaptation, particularly when implemented within gender-transformative policies; however, these integrated approaches remain poorly operationalized across jurisdictions (Schipper et al., 2022). The absence of synchronized institutional engagement, overlapping mandates, and siloed governance slows response times, dilutes accountability, and hinders cohesive adaptation planning. When adaptation efforts fail to align across scales—village councils, regional bodies, national agencies—they fall short in addressing interconnected vulnerabilities and systemic risks, especially among marginalized populations. The challenge is thus twofold: enabling cross-sectoral dialogue and coordination, and embedding climate resilience goals within multi-tiered institutional frameworks that are more inclusive, responsive, and context-sensitive.

Persistent exclusion of marginalized groups significantly undermines rural resilience. Women, Indigenous peoples, and the landless often find themselves sidelined from decision-making and resource allocation. The FAO’s report “The Unjust Climate” reveals that female-headed rural households are frequently discriminated against when accessing information, financing, technology, and land rights, resulting in disproportionate economic losses and diminished adaptive capacity (Schipper et al., 2022). Indigenous communities too, despite holding vital ecological knowledge and sustainable land practices, are frequently omitted from adaptation planning and formal decision-making forums (Norton-Smith, 2016). In Bangladesh, women and other marginalized individuals, including the disabled and less literate, are poorly represented in development projects, often left without opportunities to engage in or benefit from adaptation interventions (Hossen et al., 2021). Institutionalized gender norms frequently exclude women from communal resource management, undermining both equity and resilience; for example, informal rules governing communal pastures in Ethiopia systematically marginalize women’s knowledge and presence, thereby weakening the resilience of the social-ecological system (Ravera et al., 2016). Such exclusion not only entrenches inequalities but also forfeits diverse perspectives and capacities essential for robust adaptation. Addressing this requires intentional inclusion mechanisms—ranging from improved tenure equity to participatory governance—that center marginalized voices and knowledge systems.

Despite progress in highlighting gendered vulnerabilities, significant research gaps persist. Gender dimensions in adaptation strategies require deeper, intersectional investigation: simplistic binaries of “men vs. women” fail to capture the layered realities shaped by age, class, disability, ethnicity, and geography (Thompson-Hall et al., 2016). For instance, adaptation research often overlooks how diverse identities intersect to influence vulnerability or resilience patterns. While some work explores gendered resource gaps, more nuanced, context-specific research remains limited (Vercillo et al., 2022). Integration between public health and climate resilience is another under-researched area. Available studies point to fragmented and underfunded health systems, with

poor inter-agency coordination limiting resilience-based responses to climate-induced health threats (Sulistiadi et al., 2024); yet comprehensive frameworks linking community health with resilience planning are scarce. The NCBI-led climate-health research agenda calls for community-based adaptation, climate-resilient healthcare systems, and attention to equity—but these remain aspirational rather than widely practiced (Medicine et al., 2025). Finally, attention to growth-focused rural development models overlooks alternative sustainable approaches. Intersectional, social-ecological frameworks propose moving beyond linear growth paradigms to embrace equity, inclusion, and localized adaptation through collaborative, place-based strategies (Hossen et al., 2021; Thompson-Hall et al., 2016). In sum, strengthening future research demands inclusive, intersectional, cross-sectoral scholarship that centers equity, health, and justice as foundational to rural climate resilience.

CONCLUSIONS

Rural resilience to climate change is multidimensional, spanning social, environmental, economic, infrastructural, and institutional realms. Strong community networks and inclusive governance empower collective action and adaptability; climate shocks test social cohesion. Ecosystems like agroforestry and biodiversity-rich farming enhance buffering capacity against drought, flooding, and land degradation. Livelihood diversification—shifting from monoculture to mixed farming, ecotourism, or value-added production—provides financial stability when traditional income sources falter. Infrastructure ensures access to critical services—healthcare, education, roads, connectivity—that are crucial in crises, yet many rural areas lack adequate digital and physical infrastructure. Resilient responses depend on partnerships between government and communities, valuing local knowledge and ensuring genuine public participation. Resilience emerges from the interplay of these dimensions; investing in just one is insufficient. A holistic approach is essential to understand how rural communities withstand, adapt, and recover from climate stressors.

Effective adaptation requires holistic, inclusive, and place-based strategies rooted in local realities. Engaging Indigenous and local knowledge systems enriches climate responses and embeds cultural legitimacy and intergenerational equity into interventions. Tools like Nepal's Local Adaptation Plans of Action (LAPAs) show how participatory, bottom-up planning empowers communities to identify priorities—from watershed management to early-warning systems—while ensuring that women, youth, and marginalized groups are heard. Infrastructure investments should combine “hard” (roads, irrigation) and “soft” (governance, service delivery) approaches, tailored to each rural area's unique environmental and socio-economic context. Economic strategies should diversify livelihoods—promoting agroforestry that enhances soil health and carbon sequestration, as seen in women-led initiatives in Cameroon that restored ecosystems and shifted gender norms. Governance systems must build trust, incorporate citizen science, and co-manage natural resources with communities—not just for them. An effective strategy weaves these components into a place-based mosaic, strengthening resilience through local ownership, cultural resonance, and integrated planning.

To enhance understanding and effectiveness of such approaches, continued research is essential—particularly on diversity indices, inclusive participation, multi-scalar planning, and intersectional vulnerabilities. Emerging scholarship shows that diversity—in crops, livelihoods, culture, and knowledge systems—boosts resilience in family farming and rural systems. Research should better capture how participation across gender, youth, and marginalized groups shapes outcomes, addressing gaps in citizen science and understanding incentives for meaningful involvement. Multi-scalar planning—linking community-level vulnerability assessments with district or regional planning—is crucial, as seen in India's Meghalaya, which informs targeted interventions. Additionally, intersectional vulnerabilities—where social inequities (gender, ethnicity, poverty) intersect with environmental exposure—require focused inquiry; in Vidarbha's districts, tribal, women, and landless workers are disproportionately vulnerable. Investing in frameworks that capture these nuances can equip policymakers with granular and equitable tools. The outlook is hopeful: when rural communities are supported by responsive policies, equitable institutions, and contextual insight, they thrive. With place-sensitive infrastructure, local leadership, and inclusive

governance, these communities can turn climate adversity into opportunities for renewal, equity, and sustainable development.

REFERENCES

- Agarwal, M., & Satish, D. (2015). Husk Power Systems: Lighting up the Indian rural lives. In *Case Studies in Social Entrepreneurship*. Routledge. <https://www.taylorfrancis.com/chapters/edit/10.4324/9781351287685-8/husk-power-systems-manish-agarwal-satish>
- Ahmed, B., Sammonds, P., Saville, N. M., Le Masson, V., Suri, K., Bhat, G. M., Hakhoo, N., Jolden, T., Hussain, G., Wangmo, K., & Thusu, B. (2019). Indigenous mountain people's risk perception to environmental hazards in border conflict areas. *International Journal of Disaster Risk Reduction*, 35, 101063. <https://doi.org/10.1016/j.ijdrr.2019.01.002>
- Ariyanto, K. (2023). Assessing the Implications of Agricultural Development from the Perspective of Sustainable Livelihoods: Dryland Farming Community in Singosari, Lampung. *Masyarakat: Jurnal Sosiologi*, 28(2). <https://doi.org/10.7454/MJS.v28i2.13566>
- Ariyanto, K. (2024). Systematic review of sustainable forest management: Integrating community forestry and agroforestry approaches. *Acta Silvae et Ligni*, 135, 13–26. <https://doi.org/10.20315/ASetL.135.2>
- Berkes, F. (2004). Rethinking Community-Based Conservation. *Conservation Biology*, 18(3), 621–630. <https://doi.org/10.1111/j.1523-1739.2004.00077.x>
- Bodin, Ö. (2017). Collaborative environmental governance: Achieving collective action in social-ecological systems. *Science*, 357(6352), eaan1114. <https://doi.org/10.1126/science.aan1114>
- Bolderston, A. (2008). Writing an Effective Literature Review. *Journal of Medical Imaging and Radiation Sciences*, 39(2), 86–92. <https://doi.org/10.1016/j.jmir.2008.04.009>
- Byrnes, L., Brown, C., Foster, J., & Wagner, L. D. (2013). Australian renewable energy policy: Barriers and challenges. *Renewable Energy*, 60, 711–721. <https://doi.org/10.1016/j.renene.2013.06.024>
- Camacho, C., Bower, P., Webb, R. T., & Munford, L. (2023). Measurement of community resilience using the Baseline Resilience Indicator for Communities (BRIC) framework: A systematic review. *International Journal of Disaster Risk Reduction*, 95, 103870. <https://doi.org/10.1016/j.ijdrr.2023.103870>
- Camacho, C., Webb, R. T., Bower, P., & Munford, L. (2024). Adapting the Baseline Resilience Indicators for Communities (BRIC) Framework for England: Development of a Community Resilience Index. *International Journal of Environmental Research and Public Health*, 21(8), 1012. <https://doi.org/10.3390/ijerph21081012>
- Carabajal, A. T., Orsot, A., Moudio, M. P. E., Haggai, T., Okonkwo, C. J., III, G. T. J., & Selby, N. S. (2024). Social and Economic Impact Analysis of Solar Mini-Grids in Rural Africa: A Cohort Study from Kenya and Nigeria. *Environmental Research: Infrastructure and Sustainability*, 4(2), 025005. <https://doi.org/10.1088/2634-4505/ad4ffb>
- Carmen, E., Fazey, I., Ross, H., Bedinger, M., Smith, F. M., Prager, K., McClymont, K., & Morrison, D. (2022). Building community resilience in a context of climate change: The role of social capital. *Ambio*, 51(6), 1371–1387. <https://doi.org/10.1007/s13280-021-01678-9>

- Castillo, A., Vega-Rivera, J. H., Pérez-Escobedo, M., Romo-Díaz, G., López-Carapia, G., & Ayala-Orozco, B. (2018). Linking social–ecological knowledge with rural communities in Mexico: Lessons and challenges toward sustainability. *Ecosphere*, 9(10), e02470. <https://doi.org/10.1002/ecs2.2470>
- Caviedes, J., Ibarra, J. T., Calvet-Mir, L., Álvarez-Fernández, S., & Junqueira, A. B. (2024). Indigenous and local knowledge on social-ecological changes is positively associated with livelihood resilience in a Globally Important Agricultural Heritage System. *Agricultural Systems*, 216, 103885. <https://doi.org/10.1016/j.agsy.2024.103885>
- Chetri, P., Sharma, U., & Ilavarasan, P. V. (2021). *Role of Information and ICTs as Determinants of Farmer's Adaptive Capacity to Climate Risk: An Empirical Study from Haryana, India* (No. arXiv:2108.09766). arXiv. <https://doi.org/10.48550/arXiv.2108.09766>
- Chirisa, I., & Nel, V. (2022). Resilience and climate change in rural areas: A review of infrastructure policies across global regions. *Sustainable and Resilient Infrastructure*, 7(5), 380–390. <https://doi.org/10.1080/23789689.2020.1871538>
- Correa, M. (2024). *Bridging the Digital Divide: Effective Strategies for Enhancing Broadband Connectivity and Digital Literacy in Low-Income Communities* [PhD Thesis, California State University, Northridge]. <https://scholarworks.calstate.edu/downloads/jq085v43x>
- Denton, F. (2002). Climate change vulnerability, impacts, and adaptation: Why does gender matter? *Gender & Development*, 10(2), 10–20. <https://doi.org/10.1080/13552070215903>
- Flora, C. B. (2018). *Rural Communities: Legacy + Change* (5th ed.). Routledge. <https://doi.org/10.4324/9780429494697>
- Godwin, N., & Johnson, D. M. (2025). *A Smart IoT Framework for Climate-Resilient and Sustainable Maize Farming In Uganda* (No. arXiv:2501.12483). arXiv. <https://doi.org/10.48550/arXiv.2501.12483>
- Gowda, P., Steiner, J. L., Olson, C., Boggess, M., Farrigan, T., & Grusak, M. A. (Eds.). (2018). *Agriculture and Rural Communities*. <https://doi.org/10.22004/ag.econ.352112>
- Gupta, S., Rajiah, P., Middlebrooks, E. H., Baruah, D., Carter, B. W., Burton, K. R., Chatterjee, A. R., & Miller, M. M. (2018). Systematic Review of the Literature: Best Practices. *Academic Radiology*, 25(11), 1481–1490. <https://doi.org/10.1016/j.acra.2018.04.025>
- Head, B. W. (2014). Managing urban water crises: Adaptive policy responses to drought and flood in Southeast Queensland, Australia. *Ecology and Society*, 19(2). <https://doi.org/10.5751/ES-06414-190233>
- Hogan, L. (2023). Drought Resilience Adoption and Innovation Hubs—Building resilience in Australian farming systems. *Animal-Science Proceedings*, 14(2), 408–409. <https://doi.org/10.1016/j.anscip.2023.01.540>
- Hossen, M. A., Benson, D., Hossain, S. Z., Sultana, Z., & Rahman, M. M. (2021). Gendered Perspectives on Climate Change Adaptation: A Quest for Social Sustainability in Badlagaree Village, Bangladesh. *Water*, 13(14), 1922. <https://doi.org/10.3390/w13141922>
- Hunter, L. M. (2007). Climate change, rural vulnerabilities, and migration. *Population Reference Bureau*. <https://www.prb.org/resources/climate-change-rural-vulnerabilities-and-migration/>

- Irfan, U. (2025, June 24). *It's not just the cities. Extreme heat is a growing threat to rural America*. Vox. <https://www.vox.com/climate/417624/heat-wave-urban-island-rural-health-temperature>
- Kuipers, K., & de Jong, E. B. P. (2023). Resilient Livelihood Styles: An enriched perspective on household livelihood resilience in the sensitive natural environments of Indonesia. *Regional Environmental Change*, 23(4), 164. <https://doi.org/10.1007/s10113-023-02155-7>
- Li, Q., & Zander, P. (2020). Resilience building of rural livelihoods in PES programmes: A case study in China's Loess Hills. *Ambio*, 49(4), 962–985. <https://doi.org/10.1007/s13280-019-01236-4>
- Madriz-Vargas, R., Bruce, A., & Watt, M. (2018). The future of Community Renewable Energy for electricity access in rural Central America. *Energy Research & Social Science*, 35, 118–131. <https://doi.org/10.1016/j.erss.2017.10.015>
- McConkey, S. (2018). Pursuing Community Resilience Over Time. *ISWS Contract Report CR-2018-01*. <https://www.ideals.illinois.edu/items/105966/bitstreams/335175/data.pdf>
- Medicine, N. A. of, Dzau, V. J., & Bhutta, Z. (2025). Climate and Health Research Gaps. In *A Research Agenda to Protect Human Health and Build Resilience in the Face of a Changing Climate*. National Academies Press (US). <https://www.ncbi.nlm.nih.gov/books/NBK614573/>
- Memon, M. H., Aamir, N., & Ahmed, N. (2023). *Climate Change and Adaptation: Exploring Drivers of Community and Gender-Disaggregated Social Vulnerability*. <https://doi.org/10.1175/WCAS-D-21-0113.1>
- Msimanga, L., & Mukwada, G. (2022). Themes in climate change and variability within the context of rural livelihoods. A systematic literature review. *Research in Globalization*, 5, 100101. <https://doi.org/10.1016/j.resglo.2022.100101>
- Mukul, S. A., Rashid, A. Z. M. M., Uddin, M. B., & Khan, N. A. (2016). Role of non-timber forest products in sustaining forest-based livelihoods and rural households' resilience capacity in and around protected area: A Bangladesh study. *Journal of Environmental Planning and Management*, 59(4), 628–642. <https://doi.org/10.1080/09640568.2015.1035774>
- Newell, P., Taylor, O., Naess, L. O., Thompson, J., Mahmoud, H., Ndaki, P., Rurangwa, R., & Teshome, A. (2019). Climate Smart Agriculture? Governing the Sustainable Development Goals in Sub-Saharan Africa. *Frontiers in Sustainable Food Systems*, 3. <https://doi.org/10.3389/fsufs.2019.00055>
- Norton-Smith, K. (2016). *Climate Change and Indigenous Peoples: A Synthesis of Current Impacts and Experiences*. United States Department of Agriculture, Forest Service, Pacific Northwest Research Station. <https://doi.org/10.2737/PNW-GTR-944>
- Nyahunda, L., & Tirivangasi, H. M. (2019). Challenges faced by rural people in mitigating the effects of climate change in the Mazungunye communal lands, Zimbabwe. *Jambá: Journal of Disaster Risk Studies*, 11(1), 1–9. <https://doi.org/10.4102/jamba.v11i1.596>
- Ofoegbu, C., Chirwa, P., Francis, J., & Babalola, F. (2017). Assessing vulnerability of rural communities to climate change: A review of implications for forest-based livelihoods in South Africa. *International Journal of Climate Change Strategies and Management*, 9(03), 374–386. <https://doi.org/10.1108/IJCCSM-04-2016-0044>
- Ravera, F., Iniesta-Arandia, I., Martín-López, B., Pascual, U., & Bose, P. (2016). Gender perspectives in resilience, vulnerability and adaptation to global environmental change. *Ambio*, 45(3), 235–247. <https://doi.org/10.1007/s13280-016-0842-1>

Resurrección, B. P. (2024). Colonial erasures in gender and climate change solutions. *WIREs Climate Change*, 15(5), e890. <https://doi.org/10.1002/wcc.890>

Saptutyningsih, E., Diswandi, D., & Jaung, W. (2020). Does social capital matter in climate change adaptation? A lesson from agricultural sector in Yogyakarta, Indonesia. *Land Use Policy*, 95, 104189. <https://doi.org/10.1016/j.landusepol.2019.104189>

Scherzer, S., Lujala, P., & Rød, J. K. (2019). A community resilience index for Norway: An adaptation of the Baseline Resilience Indicators for Communities (BRIC). *International Journal of Disaster Risk Reduction*, 36, 101107. <https://doi.org/10.1016/j.ijdrr.2019.101107>

Schipper, E. L. F., Revi, A., Preston, B. L., Carr, E. R., Eriksen, S. H., Fernandez-Carril, L. R., Glavovic, B., Hilmi, N. J., Ley, D., & Mukerji, R. (2022). *Climate resilient development pathways*. Cambridge University Press. <https://research-repository.griffith.edu.au/items/6c657625-966f-4975-a9df-7af82724d1f0>

Segnon, A. C., Magassa, M., Obossou, E. A. R., Partey, S. T., Houessionon, P., & Zougmore, R. B. (2024). Gender vulnerability assessment to inform gender-sensitive adaptation action: A case study in semi-arid areas of Mali. *Frontiers in Climate*, 6. <https://doi.org/10.3389/fclim.2024.1418015>

Singh, P. (2024). *Role of climate smart agriculture (CSA) in addressing challenges of food security and climate change*. Technical Report). <http://dx.doi.org/10.13140/RG.2.2.13965.35040/1>

Sitko, N., Cavatassi, R., Staffieri, I., Heesemann, E., Rossi, J. M., Becerra Valbuena, L., Rajagopalan, P., Kluth, J., & Azzarri, C. (2024). *The unjust climate: Measuring the impacts of climate change on the rural poor, women and youth: Annexes*. Food & Agriculture Org. <https://openknowledge.fao.org/items/a42e0253-c4a8-4041-973c-98e8b678c8c8>

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research*, 104, 333–339. <https://doi.org/10.1016/j.jbusres.2019.07.039>

Sulistiadi, W., Wasir, R., Thalib, W., Ayuningtyas, D., Bawazier, N., & Buskens, E. (2024). Building health systems resilience: Understanding the social, economic, and cultural impacts of climate change from stakeholders' perspectives in Indonesia. *Archives of Public Health*, 82(1), 168. <https://doi.org/10.1186/s13690-024-01403-4>

Talwar, G. (2025, July 13). How traditional mountain wisdom helps hill communities stave off disasters. *The Times of India*. <https://timesofindia.indiatimes.com/city/dehradun/how-traditional-mountain-wisdom-helps-hill-communities-stave-off-disasters/articleshow/122422089.cms?>

Teklu, A., Simane, B., & Bezabih, M. (2022). Effectiveness of Climate-Smart Agriculture Innovations in Smallholder Agriculture System in Ethiopia. *Sustainability*, 14(23), 16143. <https://doi.org/10.3390/su142316143>

Thompson-Hall, M., Carr, E. R., & Pascual, U. (2016). Enhancing and expanding intersectional research for climate change adaptation in agrarian settings. *Ambio*, 45(3), 373–382. <https://doi.org/10.1007/s13280-016-0827-0>

Times of India. (2025, May 11). Holding back tears, Dhemaji families torn apart by floods bear silent burden of climate displacement. *The Times of India*. <https://timesofindia.indiatimes.com/city/guwahati/holding-back-tears-dhemaji-families-torn-apart-by-floods-bear-silent-burden-of-climate-displacement/articleshow/121084453.cms?>

Tod, D., Booth, A., & Smith, B. (2022). Critical appraisal. *International Review of Sport and Exercise Psychology*, 15(1), 52–72. <https://doi.org/10.1080/1750984X.2021.1952471>

Vercillo, S., Huggins, C., & Cochrane, L. (2022). How is gender investigated in African climate change research? A systematic review of the literature. *Ambio*, 51(4), 1045–1062. <https://doi.org/10.1007/s13280-021-01631-w>

Waaswa, A., Oywaya Nkurumwa, A., Mwangi Kibe, A., & Ng'eno Kipkemai, J. (2024). Adapting agriculture to climate change: Institutional determinants of adoption of climate-smart agriculture among smallholder farmers in Kenya. *Cogent Food & Agriculture*, 10(1), 2294547. <https://doi.org/10.1080/23311932.2023.2294547>

Wee, B. V., & Banister, D. (2016). How to Write a Literature Review Paper? *Transport Reviews*, 36(2), 278–288. <https://doi.org/10.1080/01441647.2015.1065456>

Yadav, S., & Shekhawat, S. (2024). Indigenous women as agents of environmental change: A study of selected Indian ecodocumentaries. *Feminist Media Studies*, 0(0), 1–19. <https://doi.org/10.1080/14680777.2024.2395973>

Yusriadi, Y. (2025). Sustaining food security through social capital in agroforestry: A qualitative study from North Luwu, Indonesia. *Frontiers in Sustainable Food Systems*, 9. <https://doi.org/10.3389/fsufs.2025.1580017>

Zhou, L., Kori, D. S., Sibanda, M., & Nhundu, K. (2022). An Analysis of the Differences in Vulnerability to Climate Change: A Review of Rural and Urban Areas in South Africa. *Climate*, 10(8), 118. <https://doi.org/10.3390/cli1008011>