



REVIEW ARTICLE

Community-based climate adaptation strategies in agriculture

Bikram Barman*, Bhaskar Ghosh, Meghana N, Sohana Sultana, Rajat Kumar Nath, Pushpendra Yadav, Sk Wasaful Quader & Sudip Kumar Gorai

Division of Agricultural Extension, ICAR-Indian Agricultural Research Institute, New Delhi 110 012, India

*Correspondence email - bikram.agriext@outlook.com

Received: 25 November 2025; Accepted: 17 April 2026; Available online: Version 1.0: 03 June 2026

Cite this article: Bikram B, Bhaskar G, Meghana N, Sohana S, Rajat KN, Pushpendra Y, Wasaful QSk, Sudip KG. Community-based climate adaptation strategies in agriculture. *Plant Science Today*. 2026; 13(sp2): 1-10. <https://doi.org/10.14719/pst.12923>

Abstract

Agriculture is one of the sectors most severely affected by climate change, facing multiple weather-related risks that threaten livelihoods and food security. In response, community-based adaptation (CBA) has gained significant attention as an approach that leverages indigenous knowledge, local resources and participatory decision-making to strengthen resilience. The CBA in agriculture assumes that the experiential knowledge of farmers and the capacity building of climate-impacted communities are indispensable for designing effective adaptation strategies. Grounded in traditional practices and culturally aligned innovations, CBA ensures that adaptation responses are ecologically relevant, context-specific and sustainable. Key community-driven measures include the adoption of climate-resilient seeds, diversification of livelihoods beyond agriculture, sustainable water management and agroecological practices that enhance soil fertility and reduce dependence on chemical inputs. However, CBA implementation remains highly context-dependent, influenced by land use policies, governance systems, market linkages and farmers' readiness to adopt new practices. Evidence highlights the critical roles of livelihood diversification, market participation and proactive planning in empowering communities to adapt to climate risks. Despite its potential, CBA faces persistent challenges, including limited financial resources, policy gaps, restricted institutional support and unequal access for marginalised groups such as women and smallholders. Strengthening CBA in agriculture requires supportive policies, investment in capacity development and strong partnerships among researchers, practitioners, governments and community organisations. As a bottom-up approach that enables local ownership and equity, CBA offers a transformative pathway toward sustainable climate resilience and long-term food security.

Keywords: agroecology; climate resilience; participatory governance; seed systems; smallholder farmers

Introduction

Climate change is dramatically reshaping agricultural systems worldwide, particularly affecting low- and middle-income countries where smallholder farmers depend directly on climatic conditions. As the Intergovernmental Panel on Climate Change (IPCC) notes in its Special Report on Climate Change and Land, there is emerging evidence of “declines and stagnation in yields, changes in sowing and harvest dates, increased infestation of pests and diseases and declining viability of some crop varieties” across every continent Africa, Asia, Europe, North America and South America (1). The IPCC further emphasises that agricultural productivity in mid- and low-latitude regions has declined over the past 50 years due to warming, a trend supported with high confidence (2). Crop outputs and nutritional quality are being hit from multiple angles. The IPCC reveals that global warming has already reduced yield trends for staple crops by approximately 4.9 % for wheat, 5.9 % for maize and 4.2 % for rice (3). These reductions are compounded by elevated atmospheric CO₂ levels, which, despite potential gains in biomass under moderate warming, led to declines in protein, zinc and iron content by 6–13 % and 4–8 %, respectively (3,4). The IPCC projections warn that such nutrient losses could severely impair food and nutrition security, particularly in low-income settings (3).

Furthermore, the frequency and severity of extreme events, such as droughts, floods and heatwaves, have amplified risks to cropping systems. For instance, floods ruin supply chains and transport infrastructure, disrupting food distribution at local to global scales (4). Nutrient stress, pests and subjective weather variability also restrict the CO₂ fertilisation effect, limiting or reversing expected gain in yield (5–7). The IPCC projects that such environmental change will increase crop prices worldwide by 1–29 % by mid-century, exposing an additional 1–183 million people in developing nations to food insecurity. For poor farmer households, these climatic shocks compound existing vulnerability, often undermining decades of development gains and eroding livelihood resilience.

For a few decades, adjustment to farm risk has favoured top-down, technology-led solutions: genetically modified crop varieties, large-scale irrigation schemes, macroeconomic incentives and national policy instruments. While offering efficiencies, these interventions tend to overlook the complex social systems, cultural traditions and ecological specificity observed at the local level. Consequently, these solutions have failed and created misaligned priorities, adaptation gaps and decoupling from local priorities.

In contrast, community-based adaptation (CBA) places local agency centre stage, emphasising participatory decision-making, local knowledge and locally appropriate solutions based on community realities (8, 9). The Cooperative for Assistance and Relief Everywhere (CARE) conceptualises CBA as a "grassroots-driven, small-scale, place-based" practice that combines local knowledge with broader development aims and has been disseminated globally, especially in rural systems directly facing climate variability (8, 10).

The CBA typically arises from a bottom-up perception of climate hazards through processes like participatory climate risk and vulnerability assessment (PCRVA). Farmers in Bangladesh's FAO-supported programs learned from the history of climate trends and adaptive capacities and disseminated locally suitable adaptation measures through processes like farmer field schools, demonstration fields and community mobilisation (11, 12). These processes facilitate social learning, which allows farmers to innovate, share and influence climate resilience measures collectively, a process important to bottom-up adaptation.

Following CARE's experience in south-western Bangladesh, practitioners have learned successful CBA strategies in agricultural diversification, access to water, livelihood security and gender equity (11). These locally valued strategies are anchored in indigenous ecological knowledge and social relations and they offer scalable lessons for national adaptation planning. CBA subverts dominant adaptation discourses by redefining vulnerability as a locally controlled outcome rather than a state-driven failure. It is founded on local control principles, social inclusion and context-specific legitimacy, insisting that communities are adaptation agents, not just their beneficiaries.

Conceptual framework of community-based adaptation

Definition and principles of community-based adaptation

The CBA is broadly defined as a bottom-up, participatory approach that aims to enhance the resilience and adaptation capacity of vulnerable communities to climate change (Fig. 1). The CBA process is driven by local priorities and integrates local knowledge and ownership with the most applicable adaptation methods to embed adaptation in the socio-cultural and ecological systems of communities (13).

Previous researchers points out that while CBA does not possess a consistent conceptual foundation, three widely accepted principles include: Local participation in identifying risks and options (13).

- Empowerment and ownership of adaptation strategies
- Integration of indigenous and local knowledge with scientific insights
- Linkages between adaptation and development goals
- Flexibility and learning-based governance
- Attention to equity, particularly for women and marginalised communities.

The UNFCCC's CBA framework similarly emphasizes participatory processes, building on existing capacities, fostering social learning and cultivating community-based adaptive strategies linked to broader development objectives (14).

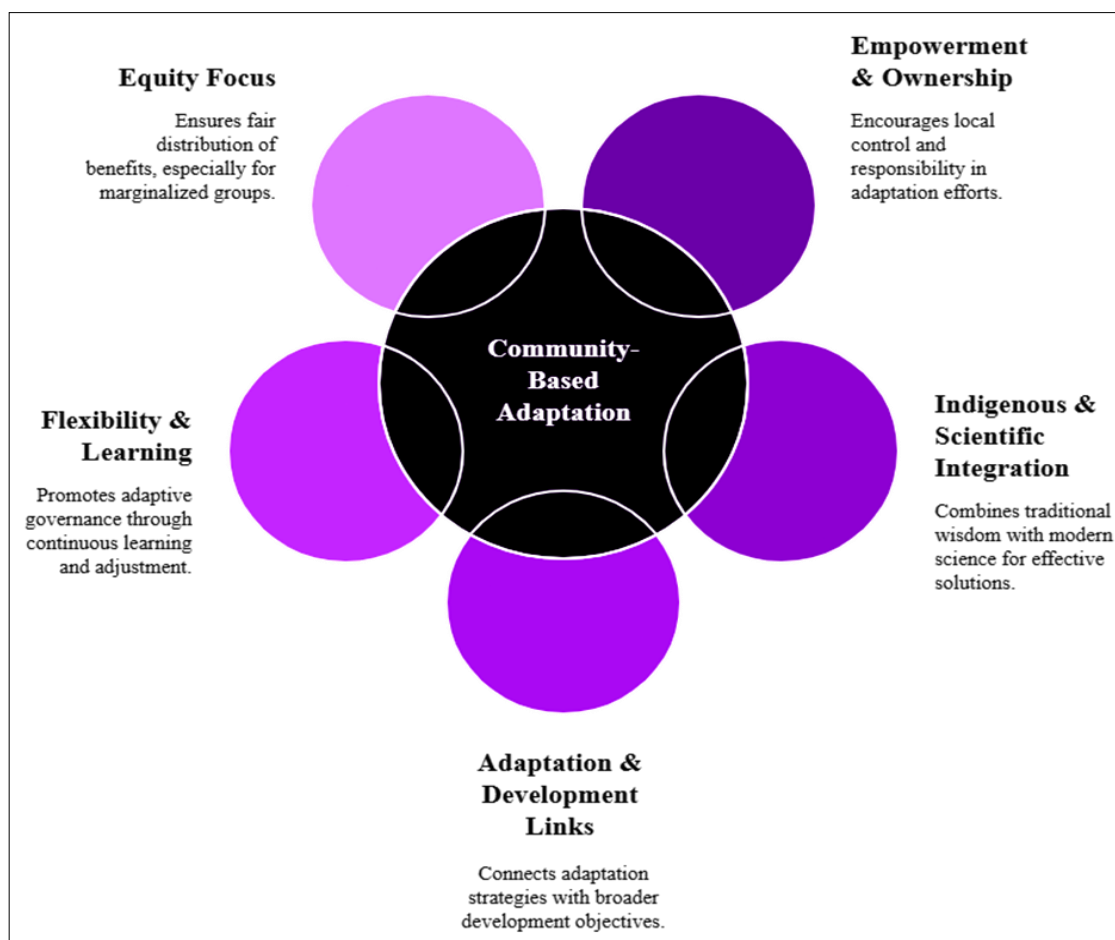


Fig. 1. Foundation of community-based adaptation.

Theoretical underpinnings: Resilience and adaptive governance

Resilience theory: The CBA is closely related to resilience theory. This places communities within complex adaptive systems influenced by disturbances such as environmental, social and economic changes. Communities have the capacity to absorb, adapt and transform with these changes (15, 16). Resilience consists of three capacities according to previous researchers (17, 18):

- **Robustness:** Ability to buffer perturbations through redundancy and stability (e.g., diverse seed systems).
- **Adaptability:** Capacity to learn and adjust practices amid change (e.g., shifting cropping calendars).
- **Transformability:** Readiness for profound changes when the system becomes untenable (e.g., diversifying livelihoods).

Adaptive governance The CBA draws on the principles of adaptive governance in decision-making processes at all levels, which can be decentralised, polycentric and based on learning cycles. Adaptive governance is supported when decisions can be made collaboratively between a range of scales of governance (from networks of communities up to local government), when learning and feedback are iterative, rather than linear.

What was highlighted from the study is that without actual synergy of governance between the farm level and supporting policy, there is no way that the three resilience capacities can be achieved (15). To achieve resilience, adaptive governance must be either promoted or, when conditions warrant, improved so that local communities can mobilise and realise resilience.

Conventional adaptation strategies such as large-scale irrigation, standardised seed systems, or agronomic packages often fail to align with the heterogeneity of local needs and ecological contexts (Table 1). In contrast, CBA is informed by contextual relevance, governance centred on learners and participation that is underpinned by equity (19, 20).

Critics caution that CBA risks romanticising "community," and reiterating the local power dynamics when internal inequalities go unexamined (13). These challenges do not reduce the potential for the type of vulnerability CBA creates, as a point of opportunity for localised systemic transformation when multi-scaled institutional reform is involved.

Methodology

A comprehensive literature search was conducted using major academic databases and scholarly platforms, including Elsevier (ScienceDirect), SpringerLink, Google Scholar and ResearchGate. These databases were selected to ensure broad coverage of peer-reviewed journal articles, book chapters, conference papers and relevant institutional publications.

Table 1. Community based Adaptation vs conventional adaptation

Feature	CBA	Conventional adaptation
Scale	Community-driven, small-scale	National or global policy-led
Governance	Participatory, decentralised, iterative	Centralised, top-down, often linear
Knowledge sources	Indigenous & local, experiential	Technocratic, expert-driven
Equity and Inclusion	Prioritizes marginalized voices	Often inequitable outcomes
Flexibility	Adaptive and context-responsive	Rigid and standardized schemes

The search was performed using combinations of keywords such as "community-based adaptation," "community-driven climate adaptation," "participatory climate adaptation," "local climate adaptation," "climate-resilient agriculture," "agroecology," and "smallholder farmer adaptation." These keywords were combined with agricultural terms such as "agriculture," "farming systems," and "smallholder farmers" using Boolean operators (AND, OR) to refine and broaden the search results. Reference lists of selected studies were also examined to identify additional relevant publications.

Inclusion and exclusion criteria

Studies were selected based on predefined criteria to ensure relevance and quality. Studies were included if they:

- Focused on community-based or participatory climate adaptation strategies in agriculture.
- Examined climate resilience practices among farming communities or rural livelihoods.
- Were published in peer-reviewed journals, books, or credible institutional reports.
- Were written in English.

Studies were excluded if they:

- Focused only on climate change impacts without discussing adaptation strategies.
- Addressed adaptation in sectors other than agriculture.
- Lacked sufficient conceptual or empirical relevance to community-based approaches.

Indigenous knowledge and local innovation

Role of traditional agricultural knowledge : Ancient indigenous and local knowledge systems, developed over centuries, are central reservoirs of climate resilience in agriculture. These knowledge systems comprise seed selection practices, agro-ecological calendars, phenological records and ecosystem-specific management procedures, thus allowing communities to sense and respond to climatic variability. Indigenous peoples had observed changes in seasonality, a decrease in snowfall frequency and an increase in rainfall yet continued to perceive traditional farming practices as both effective and adaptive (21–23). Other views of UNDP are that traditional drought-resistant crops and water-saving dwelling architecture are the main examples of the rich diversity of adaptive measures that have developed out of necessity and experiential observation, as opposed to formalised innovation.

In High Mountain Asia, traditional ecological knowledge (TEK) guides sowing and harvesting based on indicators such as snowmelt, frost patterns and ecological cues, details often overlooked by external meteorological services (24). Similarly, the Javanese pranata mangsa calendar aligns agricultural activities with solar and lunar cycles, enhancing farmers' flexibility in responding to hydrological extremes (25).

Traditional agricultural knowledge enhances resilience by ensuring robustness through diverse local seed varieties, adaptability through context-specific ecological observations and transformability via communal practices and livelihood diversification. Overall, it acts as a dynamic system that helps communities absorb shocks and adapt, supporting the goals of CBA.

Culturally adapted innovations: Locally rooted innovations constitute an essential pillar of CBA by combining indigenous knowledge with ecological suitability. Across regions, these innovations manifest as resource-sensitive, culturally anchored solutions:

- **Agroforestry in Mexico:** The Masehual “kuojtakiloyan” system integrates native fruit trees, crops and medicinal plants in forest patches, simultaneously supporting food, medicine, diversity and ecosystem conservation.
- **Rainwater harvesting in Nagaland (India):** The Angami Naga and Chakhesang communities have revitalised Rūza systems, mountain ponds that collect runoff, supplying gravity-fed irrigation to paddies and trees below. Since their revival, over 950 households share more than 200 ponds, growing rice (15+ varieties), vegetables and fish in integrated agro-ecological systems.
- **Controlled burning in Australia:** “Fire-stick farming” by Noongar, Karajarri and other Aboriginal communities mimics natural fire regimes to control weeds, regenerate biodiversity and prevent catastrophic wildfires.
- **Floating gardens in Myanmar & Mexico:** Adapted water-based cultivation methods that emerged from deep cultural-ecological understanding of flood-prone wetlands, recently highlighted in LOXTEK design work.

Each practice demonstrates how local innovations are shaped by cultural insight and ecological compatibility, offering resilience through integration rather than imposition.

Ecological appropriateness: Ecological appropriateness is central to CBA, ensuring adaptation strategies align with environmental characteristics and minimise ecological disruption. This principle sets CBA apart from industrial-intensification approaches that often externalise ecological consequences.

- **Agroecology in the Andes and Amazon:** Andean communities manage crop diversity and fallow cycles (e.g., aynuqa and ayllu systems in Bolivia), balancing cultivation, grazing and regeneration to maintain soil fertility and biodiversity.
- **Traditional ecological knowledge in Canada:** Traditional Indigenous tree and forest stewards, including controlled burning, are supported by ecological studies showing their contributions to healthy forests and wildfire resiliency.
- **Wetland restoration in the US:** The Coeur d’Alene tribe utilises indigenous knowledge to restore wetlands and traditional foods, such as the water potato-combining ecosystem restoration with cultural history (26).

These practices create social-ecological synergy by promoting contextual integrity. Instead of introducing non-local species and systems, appropriate ecological CBA preserves and enhances native biodiversity, builds local stewardship and mobilises community support for adaptation.

Building community capacity: Building community capacity lies at the heart of CBA, ensuring sustainable, locally led resilience. This multidimensional process encompasses experiential learning, inclusive social mobilisation and institutional strengthening.

Methods of capacity development: Farmer field schools (FFS) are currently the gold standard for peer-to-peer and experiential

education. First developed by the Food and Agriculture Organization (FAO) in Asia in 1989 through integrated pest management, FFS now educates farmers worldwide in climate change resilience practices and competencies (27, 28).

A longitudinal evaluation done across a time span from 1999 to 2008 in Kenya, Tanzania and Uganda showed that FFS participation brought a significant 61 % increase in agricultural revenue, together with significant increases in crop yields and livestock value, especially for female-headed and moderate land size households (29, 28). Crop yields expanded by up to 80 % in Kenya, while in Tanzania, agricultural revenue doubled (27).

In addition, FFS alumni diversified income sources, practiced collective marketing, organised savings-and-loan groups and accessed credit and services outside the project timeframe. The FAO analysis affirmed that FFS had an impact in four capitals: human (competencies), social (trust), natural (soil fertility) and financial (revenue, savings), with quantitative data from Uganda attesting to its impact (30). The FFS are becoming essential platforms not only for technical adaptation but also for social learning, allowing farmers to collectively witness, experiment and improvise solutions to climate drivers of stress.

Gender inclusion and social equity: Gender-sensitive and socially inclusive programming amplifies CBA’s efficacy. A multi-country CGIAR-led 2021 framework emphasises gender-responsive climate-smart agriculture, integrating women’s empowerment across technologies, information services, financing mechanisms and leadership roles (31).

Evidence from FAO shows female-headed households lose significantly more to climate events, 8% more in heatwaves and 3% in floods, totalling \$37 billion/year globally, yet are underrepresented in adaptation interventions (32). Investments in gender-inclusive programs, such as women-friendly credit schemes and cooperative quotas (e.g., in India), have elevated women’s decision-making power and productivity by up to 30% (33).

Moreover, FFS projects have produced meaningful gains in gender equity: women report increased confidence, agency and presence in leadership roles. One study noted that women felt empowered primarily through group dynamics and sustained involvement, although caste and gender discrimination persisted in some contexts (28).

Ensuring equity requires intentional incorporation of gender-responsive planning from the earliest design stages. The FAO guidance highlights critical actions: gender analysis, responsive budgeting and outreach strategies tailored to reduce time burdens on women and include youth and marginalised groups.

Strengthening community institutions: Beyond individual and household capacities, CBA depends on the presence of resilient, locally governed institutions. Examples include:

- **Savings and loan associations:** The FFS often catalyse the formation of Savings and loan associations (VSLAs), which double access to credit and enable investments in agriculture and income diversification.
- **Cooperatives and women’s groups:** Entities such as SEWA in India and women-only cooperatives have provided access to inputs, markets and voice in decision-making, though women remain underrepresented overall (7.5% membership in India).

- **Local governance forums:** Where communities engage with local governments and forest or water user committees, FFS alumni have gained confidence to lobby for resources and services.

These institutions foster social capital trust, norms and networks that support collective responses to climate shocks (community food sharing, joint irrigation, market negotiations). Their role has been linked to improved food security, resource stewardship and adaptation outcomes.

Promising community-based adaptation practices in agriculture : Communities across regions are adopting various locally driven strategies that strengthen agricultural resilience. Section 5 highlights four key streams: climate-resilient crop varieties and seed systems, livelihood diversification, participatory water management and agroecological approaches.

Climate-resilient crop varieties and seed systems : Community seed banks (CSBs) have become hubs for preserving biodiversity, supporting seed access and fostering knowledge transfer. India, for instance, now has many CSBs that collectively maintain traditional crop varieties, including millets, pulses, vegetables and oilseeds, particularly in biodiversity-rich states such as Uttarakhand, Karnataka and Maharashtra (34). The Pingdanda CSB in Nepal safeguards 117 varieties across 31 species of rice, maize, wheat, beans, millets and vegetables, producing 3–4 tonnes of certified seed annually and prioritising equitable access for women and resource-poor farmers (35).

A recent systematic review on CSBs in Ethiopia, Malawi and Nepal confirms that well-functioning seed banks enhance seed security and bolster community-level resilience to climate shocks (36). Similarly, India's ITPGR Benefit-Sharing Project recently identified nearly 30 climate-resilient varieties (primarily rice and finger millet) supported by community seed banking initiatives (37).

While national institutions (e.g., BAU in Bihar) are developing flood- and disease-resistant rice varieties such as Sabour Shri Sub-1 with 1.5× higher yields (38), rapid adoption depends on distribution access, agricultural extension and local seed multiplication systems akin to CBA mechanisms.

A McGill-World Bank scoping review across low- and middle-income countries underscores that adoption of climate-resilient crops is enhanced by effective extension, seed availability, farmer education and social inclusion, particularly of women and vulnerable groups (39).

Livelihood diversification: The CBA emphasises broadening livelihood portfolios to buffer against climate fluctuations. In Karnataka, India, nearly 3000 farmers transitioned to drought-resistant millets across 2000+ acres after persistent droughts. Their integrated millet-pulse systems reduce input costs by 12 % and the establishment of a farmers' producer organisation (Devadanya FPO) supplies seeds, training and market access, showcasing scalable community-driven diversification (40).

These strategies not only protect against risk but also reinforce food sovereignty, nutritional outcomes and autonomy.

Participatory water management : Farmer-led irrigation initiatives have become a transformative CBA approach in the Sahel and sub-Saharan Africa. Crop yields in irrigated plots often double or triple compared to rainfed systems. In certain contexts, household revenues have risen by tens of billions of USD when scaled across regions (41).

Studies found that irrigation protects against rainfall variability, supports dry-season crops and opens opportunities for high-value produce, boosting incomes and resilience (10). While Africa irrigates only 4–7 % of arable land (42), there is substantial potential to expand via decentralised, solar-powered, or groundwater-fed systems (43). However, inclusivity remains a challenge: farmer-led irrigation tends to favour male and wealthier households, excluding women and poorer farmers unless deliberate equity measures are adopted (44).

Agroecological approaches : Agroecological strategies offer resilience by building soil health, biodiversity and ecological synergy. In Karnataka, millets are grown in mixed cropping systems alongside pulses and leafy greens, enhancing soil fertility and reducing reliance on fertilisers (45). In Uttarakhand, Barahnaja represents a resilient polyculture model with ecological and cultural significance. Agroforestry systems like Mexico's kuojtakiloyan, integrating fruit trees with crops, medicinal plants and fodder species, support diversified production while enhancing ecosystem services.

These techniques, intercropping, crop-livestock integration, mulching and conservation tillage, reinforce resilience by boosting soil organic matter, moisture retention and pest resistance.

Challenges

Despite the potential of CBA, its effectiveness is constrained by interconnected structural, economic and cognitive factors. Insecure land tenure limits farmers' willingness to invest in long-term climate-resilient practices (46). Similarly, poor market access, weak value-chain linkages and limited infrastructure reduce incentives, income security and the scaling of adaptive practices, as evidenced in studies from The Gambia and broader global analyses (47). Cognitive constraints such as low-risk perception, risk aversion, climate skepticism and limited access to extension, credit and reliable information further hinder adoption decisions (47). These challenges are reinforced by systemic issues, including inadequate infrastructure and financial resources (48), policy and institutional gaps such as weak decentralisation, poor coordination and elite capture (49) and capacity limitations related to low technical literacy and weak ICT ecosystems (50, 51). Together, these interwoven constraints across tenure systems, market structures and perception dynamics restrict the adoption, scaling and sustainability of community-driven adaptation strategies under climate variability.

Addressing the challenges : To counter these constraints, successful CBA models must combine multiple enabling strategies:

1. **Resource investment in infrastructure:** Develop smallholder irrigation, rural transport and storage systems that support locally adapted cropping.

2. Institutional realignment

- Decentralise governance, grant formal recognition to community forests and seed banks and safeguard against elite capture through transparent representation.

- Institutionalise multi-stakeholder platforms aligning community, local government, NGOs and private sector roles.

3. Bridging knowledge systems

- Design co-leadership frameworks to integrate scientific and traditional knowledge equitably.
- Encourage learning cycles across sectors and invest in long-term ecological monitoring.

4. Capacity strengthening via information and Communication Technology

- Build digital literacy and expand information and communication technology (ICT) infrastructure so farmers can access weather forecasts, pest alerts and market data (51).
- Tailor technological interventions to local capacity and cultural contexts.

5. Robust monitoring, evaluation and learning

- Draw on evaluation frameworks tailored to CBA's multi-dimensional goals tracking ecological, social, financial and institutional outcomes.
- Support peer learning exchanges to spread best practices and build peer-to-peer institutional capacity.

Enabling conditions for scaling community-based adaptation

Scaling CBA requires deliberate alignment of policies, finance, partnerships and learning systems. Effective expansion demands integrating grassroots strengths into national frameworks and delivering financial, technical and institutional support (Fig. 2).

Policy support and mainstreaming community-based adaptation

Mainstreaming CBA into national and subnational plans ensures community initiatives are sustained and resourced (Table 2). A 2013 conference in Dhaka emphasised integrating community priorities into budget cycles and development strategies, embedding CBA within planning processes rather than as isolated projects (52–54). The GEF Small Grants Programme underscores the need for early engagement of local authorities and inclusion in policy frameworks to scale local adaptations (9).

Table 2. Effective scaling of community-based adaptation (CBA) revolves around four intertwined enablers

Enabler	Key components and actions
Policy and mainstreaming	Integrate CBA into development plans, budget cycles and resource-allocation frameworks.
Finance and local access	Expand funding via community-managed treasury, NGO channels, credit schemes and guarantee funds; address financial inclusion gaps
Partnerships	Foster multi-level collaboration among communities, NGOs, governments and private entities (e.g., Odisha CGIAR initiative)
Monitoring and learning	Establish inclusive MEL systems with community-defined indicators and learning cycles, aligned with national evaluation mechanisms

The Organisation for Economic Co-operation and Development's (OECD) 2023 review of agricultural adaptation emphasises that while nearly 600 adaptation programmes exist, many remain in the planning stage, highlighting a need for stronger implementation, monitoring and evaluation (55). To bring CBA to scale, governments must adopt enabling policies for seed system recognition, community water rights and local governance autonomy.

Financing local adaptation initiatives

Scaling CBA hinges on accessible, context-aware finance. Global adaptation finance remains low: Reuters reports only ~4% of climate finance reaches food systems, with just ~1% targeting smallholder agriculture, despite agriculture's centrality to poverty and climate risk (56). Effective financing models combine public funds (e.g., the GEF, Adaptation Fund), NGO channelling and private-sector instruments such as credit guarantees (57).

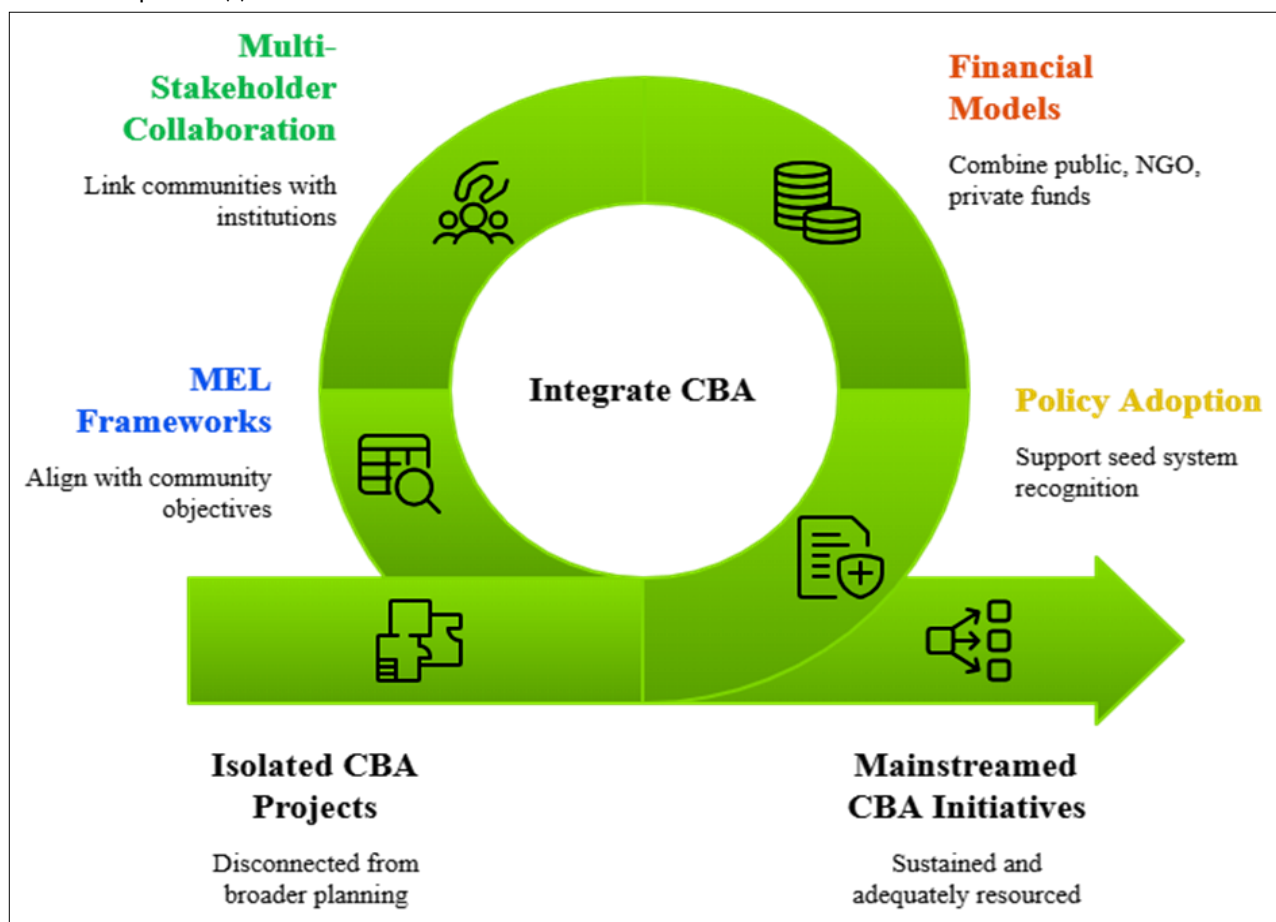


Fig. 2. Scaling community-based adaptation (CBA).

Partnerships (Researchers, NGOs and Governments)

Multi-stakeholder collaboration is essential. The CARE's framework stresses linking communities with municipal and national institutions, NGOs and research bodies to embed adaptation into governance systems (58). The CGIAR-led Climate Action Programme in Odisha demonstrates how alliances spanning state agencies, research institutes and civil society can align early warning systems, finance and technical support (45).

Monitoring, evaluation and learning frameworks

Monitoring, evaluation and learning (MEL) systems that align with community objectives and national goals help track CBA progress. Global Commission on Adaptation recommends MEL frameworks that capture local leadership, equity and adaptive finance flows. Regent FAO and UNDP tools encourage participatory MEL methods where communities define indicators, collect data and reflect on outcomes.

The CARE's 2014 toolkit provides step-by-step guidance on milestones, indicators and stakeholder-led tracking to ensure adaptive learning (58). The OECD also notes that evaluation, not just policy planning, is scarce in agriculture, stressing the need for consistent outcome monitoring to inform national and local CBA strategies.

Case studies

To ground our analysis in real-world complexities, this section presents three detailed case studies from South Asia, Sub-Saharan Africa and Latin America. Each case explores CBA strategies in agricultural systems, highlighting design, implementation, outcomes and lessons learned.

Community seed banks in South Asia (Nepal and India)

Background and design

Faced with climate stressors, erratic rains, heatwaves and pest pressures, communities in Nepal and India established Community Seed Banks (CSBs) to preserve locally adapted genetic diversity (59). In Pingdanda, Nepal, Local Initiatives for Biodiversity, Research and Development (LI-BIRD) initiated a CSB in Sindhupalchok district to counter dependency on hybrid seeds less suited to local climates. The goal: conserve native crop genetic resources, reduce input costs and strengthen climate resilience through locally governed seed systems (9).

In India's Kolli Hills (Tamil Nadu) and Uttarakhand, grassroots CSBs have preserved heirloom pulses, millets and vegetables, aligning seed sovereignty with resilient agroecological practices (60).

Implementation and community governance

The CSBs are managed by farmer committees (5–7 people in Pingdanda), often including women and youth, who oversee seed regeneration plots, storage and distribution. Nepal's CSBs distribute 3–4 t of diverse seed annually, prioritising socially marginalised farmers. India's CSBs hold seed festivals (e.g., Beejotsava) where farmers swap 100+ seed varieties and exchange agroecological ideas (60, 61).

Outcomes and lessons

- **Climate resilience:** Diverse seed portfolios buffered against drought and pest outbreaks (34).
- **Economic gains:** Farmers using CSB seeds saved roughly 30–50% in input costs and received price premiums for local varieties (62).

- **Social inclusion:** Women-led seed banks in India's Kolli Hills empowered female farmers and heirs (63).
- **Network and sustainability:** India's National Biological Farmers Movement (SRSB) and Nepal's CSBAN and LI-BIRD created multi-level support, though CSBs remain time- and resource-intensive, requiring institutional backing (34).
- **Add value services:** Seed cleaning, packaging, digital seed catalogues (e.g., Nepal's "Hamro Biu" app) improve sustainability (64).

Farmer-led irrigation in sub-Saharan Africa

Background and design

In the Sahel and Eastern Africa, smallholder communities-initiated farmer-led irrigation systems: low-cost, self-funded schemes, treadle pumps, dug wells, or solar pumps, supporting dry-season production. Senegal's delta region and Kenya/Zimbabwe show rising use of cost-effective, flexible irrigation (65, 66).

Implementation and institutional forms

Typically led by farmer groups or families, early adopters built and managed local irrigation, often supported by NGOs providing equipment and training. In Tanzania, one study found that capital, extension access, drought exposure, gender and water-group membership influenced uptake. Kenya and Zimbabwe exhibited long-term scalability of these appropriation types.

Outcomes and constraints

Positive outcomes:

- 2× to 3× increases in output and income.
- Health and nutrition benefits due to off-season horticulture.
- Modern pumps, e.g., MoneyMaker Plus (\$38), delivered economic empowerment in Kenya.

Equity and sustainability issues

- Benefits skewed toward male, wealthier farmers.
- Institutional gaps and weak water regulation led to natural resource competition.
- Lack of finance and collective management mechanisms hampers scale and equity.

Key lessons

- Ensure gender-equitable access, with subsidies for women and poor households.
- Strengthen local water governance, licensing mechanisms and equitable sharing.
- Bundle irrigation with borehole access, market linkage and technical aid (e.g., solar-diesel models).

Agroecological diversification in Latin America

Background and design

Indigenous agroecological systems in the Andean highlands (Bolivia, Peru) and the Amazon integrate biodiversity, cropping and pastoralism to enhance resilience. Barahnaja practices emergent agroforestry plots combining tubers, cereals and legumes, mirroring traditional polycropping systems.

Implementation

Communities employ TEK to guide planting windows, species assembly and crop cycles. The FAO-recognised practices, such as floating gardens, continue in Jali science. Some mixed plots incorporate tree species and managed fallows, making cultivation ecologically robust.

Outcomes and lessons

- System-level resilience due to biodiversity, biomass recycling and soil regeneration.
- Cultural cohesion is strengthened through seed-guardianship festivals and local knowledge networks.
- Data limitations persist; however, these systems align with both ecological logic and farmer priorities. Blending these systems into broader agricultural planning remains a challenge.

All cases (Table 3) confirm that sustainability emerges from combining local agency with external support through inclusive governance, supportive policy and investment in capacity and infrastructure.

Conclusion

Community-based adaptation (CBA) represents a promising and transformative approach to building agricultural resilience in the face of climate change. Unlike top-down models, CBA prioritises local agency, indigenous knowledge systems and participatory governance. The article has explored the conceptual foundations of CBA, its integration of traditional and scientific knowledge and its emphasis on social equity, particularly gender inclusion. Case studies from South Asia, Sub-Saharan Africa and Latin America provide empirical evidence of how community-led initiatives such as seed banks, farmer-led irrigation and agroecological diversification can strengthen adaptive capacity, improve food security and promote sustainable development. These examples highlight that effective CBA strategies are context-specific, co-created and supported by enabling institutions and policy environments. Moreover, the success of CBA hinges on strengthening community capacities, securing land and resource rights, fostering inclusive institutions and linking adaptation to local livelihoods. The interplay between ecological appropriateness, cultural values and decentralised governance systems emerges as a central theme throughout this article. At the same time, several systemic barriers including weak infrastructure, policy gaps and limited financing continue to impede the scalability of CBA practices.

Recommendations for policymakers

To mainstream and scale up effective community-based adaptation (CBA) interventions, the following recommendations are advanced:

Institutionalise CBA in climate policy

National Adaptation Plans (NAPs) and agricultural policies should formally integrate CBA approaches, including recognition of community seed systems, water user associations and traditional ecological knowledge.

Ensure equitable access to resources

Land tenure security, access to irrigation infrastructure, credit and markets must be guaranteed for marginalised groups, especially women and indigenous communities, to fully participate in adaptation processes.

Invest in local capacity and institutions

Long-term investments in farmer field schools, community training programs and grassroots institutions are essential to sustain adaptive learning and participatory decision-making.

Enhance financial support for CBA

Increase climate finance allocations for smallholder agriculture and locally led adaptation through public budgets, climate funds and blended finance models. Mechanisms must be in place to channel resources directly to communities.

Support monitoring, evaluation and learning systems

Design participatory MEL frameworks that track adaptation outcomes, enable feedback loops and facilitate cross-learning across regions and sectors.

Future directions and research gaps

Despite its potential, CBA remains under-researched in several critical areas. Future studies should explore:

- Longitudinal impacts of CBA on household resilience, ecological sustainability and gender dynamics.
- Scalability pathways that maintain community ownership while extending reach and institutional support.
- Integration frameworks that blend traditional knowledge with scientific innovation in agriculture.
- Quantitative metrics to assess social equity, adaptive capacity and transformational change in CBA initiatives.

Acknowledgements

The authors express their sincere gratitude to the Division of Agricultural Extension, ICAR–Indian Agricultural Research Institute, New Delhi, for providing academic support and a conducive environment for the preparation of this review.

Authors' contributions

BB conceptualised the review, designed its structure and prepared the initial draft. BG refined the review framework and provided critical revisions. MN conducted the literature search and assisted with screening and organization. SS contributed to the synthesis of the reviewed studies and strengthened the discussion. RKN handled reference management, formatting and proofreading. PY provided conceptual insights and interpretation. SWQ contributed methodological guidance and technical review. SKG offered expert supervision, overall guidance and critically reviewed the final version for intellectual quality. All authors read and approved the final manuscript.

Table 3. Scalable insights across cases

Theme	Seed banks	Irrigation	Agroecology
Local leadership	Farmer/committee	Farmer-headed groups	Community networks
Inclusive access	Marginalised inclusion	Equity mechanisms essential	Cultural embeddedness
Ecosystem alignment	Native seed varieties	Water-resource matched systems	Ecological compatibility
Enabling synergies	CSB + policy + digital tools	Irrigation + markets + governance	Agroecology + markets

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

References

- IPCC. Summary for policymakers. In: Lee H, Romero J, editors. Climate change 2023: Synthesis report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva (Switzerland): IPCC; 2023. p.1–34.
- IPCC. Sixth assessment report: Working Group II – impacts, adaptation and vulnerability. 2022.
- The Breakthrough Institute. The IPCC report on the impacts of climate change is depressing, but not for the reasons you might think. 2023.
- IPCC. FAQs chapter 5—Special report on climate change and land. 2025.
- EPA. Climate impacts on agriculture and food supply. Washington (DC): United States Environmental Protection Agency; 2017.
- Fei C, Jägermeyr J, McCarl B, Contreras EM, Muttter C, Phillips M, et al. Future climate change impacts on U.S. agricultural yields, production and market. *Anthropocene*. 2023;42:100386. <https://doi.org/10.1016/j.ancene.2023.100386>
- Lumsden CL, Jägermeyr J, Ziska L, Fanzo J. Critical overview of the implications of a global protein transition in the face of climate change: Key unknowns and research imperatives. *One Earth*. 2024;7:1187–201. <https://doi.org/10.1016/j.oneear.2024.06.013>
- Qomariah A, Purnaweni H, Utomo S. Community-based adaptation: Challenge and opportunity in Indonesia. *E3S Web Conf*. 2021;317:01075. <https://doi.org/10.1051/e3sconf/202131701075>
- WeADAPT. Increasing agricultural viability and climate resilience through community seed banks in Nepal. 2023.
- Wiggins S. How farmer-led irrigation can transform agriculture in Africa. ODI Global. 2019.
- Chowdhury RI, Hossain MdA, Ibn Farid Z. Gender-responsive climate resilience through community-based adaptation: A policy-practice interface study in southern Bangladesh. *Progress in Disaster Science*. 2026;30:100568. <https://doi.org/10.1016/j.pdisas.2026.100568>
- Ahmed AU, Mondal P, Islam M. Community-based adaptation: An analysis of best practices in the south-western region of Bangladesh. Dhaka: CARE Bangladesh; 2017. p.70.
- Barbon WJ, Myae C, Vidallo R, Thant PS, Monville-Oro E, Gonsalves J. Applying participatory action research methods in community-based adaptation with smallholders in Myanmar. *Front Clim*. 2021;3:734053. <https://doi.org/10.3389/fclim.2021.734053>
- Kirkby P, Williams C, Huq S. Community-based adaptation (CBA): adding conceptual clarity to the approach and establishing its principles and challenges. *Clim Dev*. 2018;10:577–89. <https://doi.org/10.1080/17565529.2017.1372265>
- UNFCCC. Community-based adaptation: Nairobi work programme on impacts, vulnerability and adaptation to climate change.
- Manevska-Tasevska G, Pettitt A, Larsson S, Bimbilovski I, Meuwissen MPM, Feindt PH, et al. Adaptive governance and resilience capacity of farms: The fit between farmers' decisions and agricultural policies. *Front Environ Sci*. 2021;9:668836. <https://doi.org/10.3389/fenvs.2021.668836>
- Hodbod J, Goralnik L, Vicari L, White S. From theory to transdisciplinary practice: Community-based resilience visioning in urban agriculture. *Soc Nat Resour*. 2024;37:143–67. <https://doi.org/10.1080/08941920.2023.2228264>
- Walker B, Holling CS, Carpenter SR, Kinzig A. Resilience, adaptability and transformability in social–ecological systems. *Ecol Soc*. 2004;9 (2). <https://doi.org/10.5751/ES-00650-090205>
- Meuwissen MP, Feindt PH, Spiegel A, Termeer CJ, Mathijs E, De Mey Y, et al. A framework to assess the resilience of farming systems. *Agric Syst*. 2019;176:102656. <https://doi.org/10.1016/j.agsy.2019.102656>
- Forsyth T. Community-based adaptation to climate change. Oxford: Oxford University Press; 2017. <https://doi.org/10.1093/acrefore/9780190228620.013.602>
- Shemshad M, Synowiec A, Kopyra M, Benedek Z. The community-driven ecosystem resilience and equity framework: A novel approach for social resilience in ecosystem services. *Sustainability*. 2025;17:3452. <https://doi.org/10.3390/su17083452>
- Sherpa TO. Indigenous people's perception of indigenous agricultural knowledge for climate change adaptation in Khumbu, Nepal. *Front Clim*. 2023;4:1067630. <https://doi.org/10.3389/fclim.2022.1067630>
- Selje T, Schmid LA, Heinz B. Community-based adaptation to climate change: Core issues and implications for practical implementations. *Climate*. 2024;12:155. <https://doi.org/10.3390/cli12100155>
- Chimi PM, Mala WA, Tchonang Djoumbi BL, Fobane JL, Fankam Kenmoe FU, Ngamsou Abdel K, et al. Indigenous agroecological knowledge and practices for climate change adaptation in the forest-savanna transition zone at Batchenga in the Centre Region of Cameroon. *Discov Environ*. 2025;3:16. <https://doi.org/10.1007/s44274-025-00192-z>
- Witharana L, Chen D, Curio J, Burman A. Traditional ecological knowledge in High Mountain Asia: A pathway to climate resilience in agriculture amidst changing climates. *Adv Clim Change Res*. 2025;16:167–82. <https://doi.org/10.1016/j.accre.2025.01.009>
- Karjanto N. Revisiting Javanese pranata mangsa: On ethnic groups and the four sample cities in Java. 2022.
- Lee J. The tiny potato at the heart of one tribe's fight against climate change. *Vox*. 2024.
- Davis K, Nkonya E, Kato E, Mekonnen DA, Odendo M, Miro R, et al. Impact of farmer field schools on agricultural productivity and poverty in East Africa. *World Dev*. 2012;40:402–13. <https://doi.org/10.1016/j.worlddev.2011.05.019>
- Van Den Berg H, Phillips S, Dicke M, Fredrix M. Impacts of farmer field schools in the human, social, natural and financial domain: a qualitative review. *Food Secur*. 2020;12:1443–59. <https://doi.org/10.1007/s12571-020-01046-7>
- Kavuma RM. Ugandan farmers on road to “remarkable” recovery after rebel war. *The Guardian*. 2010.
- FAO. Farmers taking the lead - thirty years of farmer field schools. Rome: FAO; 2019.
- Huyer S, Simelton E, Chanana N, Mulema AA, Marty E. Expanding opportunities: A framework for gender and socially-inclusive climate resilient agriculture. *Front Clim*. 2021;3:718240. <https://doi.org/10.3389/fclim.2021.718240>
- Nelson S, Hill C. Gender in adaptation planning for the agriculture sectors: Guide for trainers. Rome; 2019.
- Sandosham S. To feed a warming world, we must also serve up gender equality. *Reuters*. 2025.
- Varshney V, Chauhan S. Celebrating community seed banks of India: Conversations on climate-resilient seeds. New Delhi: Centre for Science and Environment; 2025.
- ICIMOD. Increasing agricultural viability and climate resilience through community seed banks. 2022.
- Andersen R, Vásquez VM, Mulesa TH, Westengen OT, Gauchan D, Wynberg R, et al. The contribution of community seed banks to climate-resilient seed systems: Evidence from Ethiopia, Malawi and Nepal. 2024. <https://doi.org/10.2139/ssrn.4962379>

38. IISD. ITPGR benefit-sharing project in India identifies climate-resilient crop varieties. 2015.
39. The Times of India. BAU scientists develop 4 new climate-resilient rice varieties. 2025.
40. Acevedo M, Pixley K, Zinyengere N, Meng S, Tufan H, Cichy K, et al. A scoping review of adoption of climate-resilient crops by small-scale producers in low- and middle-income countries. *Nat Plants*. 2020;6:1231–41. <https://doi.org/10.1038/s41477-020-00783-z>
41. The Times of India. Millet magic: How 3,000 farmers sowed life on parched lands in Karnataka. 2025.
42. IWMI. Farmer-led irrigation schemes could alter food security in sub-Saharan Africa, South Asia. 2012.
43. CGIAR. African smallholders can double their yields with half the water. 2017.
44. World Bank. Accelerating irrigation expansion in Sub-Saharan Africa: Policy lessons from the global revolution in farmer-led smallholder irrigation. 2020.
45. Lefore N, Giordano M, Ringler C, Barron J. Sustainable and equitable growth in farmer-led irrigation in sub-Saharan Africa: What will it take? *Water Altern*. 2019;12(1):156–68.
46. The Times of India. Climate action initiative launched in Odisha. 2025.
47. Karki S, Yokota S. Community-based farming water resource management and important factors for adaptation practices in Terai, Nepal. *Water*. 2024;17:47. <https://doi.org/10.3390/w17010047>
48. Lambarraa-Lehnhardt F, Ceesay S, Ndiaye MBO, Thiaw D, Sawaneh M. Climate risk perception and adaptation strategies of smallholder farmers in The Gambia. *Discov Sustain*. 2024;5:506. <https://doi.org/10.1007/s43621-024-00616-5>
49. Alie MEK, Yateh M, Bavumiragira JP, Liao Z. Identifying challenging barriers to farmers' adaptation to climate change in Bo district, Sierra Leone: A review. *J Water Clim Change*. 2024;15:2992–3014. <https://doi.org/10.2166/wcc.2024.634>
50. Forsyth T. Community-based adaptation: a review of past and future challenges. *Wiley Interdiscip Rev Clim Change*. 2013;4:439–46. <https://doi.org/10.1002/wcc.231>
51. Chetri P, Sharma U, Ilavarasan PV. Role of information and ICTs as determinants of farmer's adaptive capacity to climate risk: An empirical study from Haryana, India. 2021.
52. Ayim C, Kassahun A, Tekinerdogan B, Addison C. Adoption of ICT innovations in the agriculture sector in Africa: A systematic literature review. 2020.
53. Reid H, Coirolo C, Christensen K, Fenton A, Roberts E, Stott C, et al. Community-based adaptation: Mainstreaming CBA into national and local planning. 2013.
54. United Nations Environment Programme. Adaptation gap report 2020. 2020.
55. Villalba R, Joshi G, Daum T, Venus TE. Financing climate-smart agriculture: a case study from the Indo-Gangetic Plains. *Mitig Adapt Strateg Glob Change*. 2024;29:33. <https://doi.org/10.1007/s11027-024-10127-3>
56. OECD. Agricultural policy monitoring and evaluation 2023: Adapting agriculture to climate change. OECD Publishing; 2023.
57. Nieuwkoop M van. Comment: How empowering smallholder farmers with AI tools can bolster global food security. Reuters. 2025.
58. Fankhauser S, Britz K, Dickie I, England K, Howarth C, Ranger N. Case studies in adaptation finance. Oxford: Oxford Smith School of Enterprise and the Environment; 2023.
59. CARE. Community-based adaptation in practice: A global overview of CARE International's practice of community-based adaptation to climate change. 2014.
60. ICARDA. Building nature-positive seed systems for community seed banks in Kenya and India. 2024.
61. Krishnan T. Community seed banks revive diversity in India's Kolli Hills. Rapid Transition Alliance; 2024.
62. Vernoooy R, Adokorach J, Gupta A, Otieno G, Rana J, Shrestha P, et al. Promising strategies to enhance the sustainability of community seed banks. *Sustainability*. 2024;16:8665. <https://doi.org/10.3390/su16198665>
63. Tiboris M. Farmer-led irrigation for agricultural intensification. 2019.
64. CGIAR. Planting seeds of hope: Community seed banks empower farmers and address climate risk in India. 2023.
65. Maharjan S, Maharjan K. Roles and contributions of community seed banks in climate adaptation in Nepal. *Dev Pract*. 2018;28:292–302. <https://doi.org/10.1080/09614524.2018.1418838>
66. Harmon G, Jepson W, Lefore N. Farmer-led irrigation development in sub-Saharan Africa. *Wiley Interdiscip Rev Water*. 2023;10:e1631. <https://doi.org/10.1002/wat2.1631>

Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

Reprints & permissions information is available at https://horizonpublishing.com/journals/index.php/PST/open_access_policy

Publisher's Note: Horizon e-Publishing Group remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Indexing: Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS, UGC Care, etc
See https://horizonpublishing.com/journals/index.php/PST/indexing_abstracting

Copyright: © The Author(s). This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution and reproduction in any medium, provided the original author and source are credited (<https://creativecommons.org/licenses/by/4.0/>)

Publisher information: Plant Science Today is published by HORIZON e-Publishing Group with support from Empirion Publishers Private Limited, Thiruvananthapuram, India.