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Building Africa's climate resilience: understanding the impacts and future strategies in the face of climate change

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Climate change is reshaping Africa's environmental, economic, and social landscapes, intensifying vulnerabilities across agriculture, water resources, public health, and socioeconomic stability. This paper examines the multifaceted impacts of a changing climate on key sectors in Africa and highlights the urgent need for integrated adaptation strategies. Through the synthesis of traditional wisdom and modern innovations, the study showcases how indigenous knowledge, community-led initiatives, and climate-smart agricultural practices contribute to enhanced resilience. Case studies from diverse regions demonstrate the effectiveness of combining traditional practices with advanced technologies, while policy and governance frameworks emphasize the importance of inclusive, data-driven decision-making. The research further addresses critical investment gaps and advocates for robust financial and technical support to empower local communities in managing climate risks. By leveraging established frameworks such as the African Climate Resilience Acceleration roadmap and fostering cross-sectoral collaboration, the paper outlines forward-looking strategies that could mitigate immediate climate threats and lay the groundwork for sustainable development. Ultimately, through coordinated efforts and strategic investments, African nations can transform the challenges of climate change into opportunities for resilience and growth.

KEYWORDS

climate change adaptation, Africa's resilience, indigenous knowledge, climate-smart agriculture, sustainable development, community-based adaptation

1 Introduction

Africa faces a critical challenge: climate change, which profoundly disrupts its social, economic, and environmental systems. With over 60% of its population relying on climate-sensitive sectors like agriculture, increasing variability along with frequent extreme weather events now jeopardizes food security and livelihoods (Teklu et al., 2023). As human-induced factors and natural variability continue to alter climate patterns, community vulnerability, especially among marginalized groups, grows (Badolo, 2024). In light of these changes, the Intergovernmental Panel on Climate Change (IPCC) projects that Africa will experience rising temperatures, altered precipitation regimes, and more frequent extremes, such as droughts and floods (Wright et al., 2024).

The impacts of climate change extend well beyond agriculture. Intensified climate variability, including hotter extremes, erratic rainfall, and a surge in severe weather events, threatens fisheries, water resources, public health, and overall socio-economic stability (Vijai

et al., 2023; Selvaraju et al., 2011). In agriculture, these uncertainties have been linked to reduced crop yields, disrupted supply chains, and heightened food insecurity that imperils millions of rural households (Pimpa, 2024). Likewise, shifts in temperature and rainfall patterns are undermining fisheries and water management systems, leading to diminished fish stocks and compromised freshwater availability (Ibrahim, 2025; Khakimov et al., 2020). Collectively, these multidisciplinary challenges underscore the urgency of designing robust adaptation strategies and integrated risk management approaches to secure both agricultural and broader food systems against the adverse effects of a changing climate (Giannini et al., 2021; Amare and Simane, 2017).

Building climate resilience is essential for the continent's sustainable development. Climate resilience is defined as the capacity of individuals, communities, and systems to anticipate, prepare for, and rebound from climate-related disruptions (Weldegebriel and Amphune, 2017). Many African communities have historically relied on traditional ecological knowledge, developing adaptive strategies over generations (Asmamaw et al., 2019). However, the rapidly evolving nature of climate change calls for multifaceted approaches that integrate these traditional methods with modern agricultural techniques and climate-smart practices, thereby enhancing the adaptive capacity of vulnerable populations (Graham, 2020).

A range of practical measures is essential to build resilience among smallholder farmers and rural communities in Africa. Early warning systems and decision-support tools, for instance, enable timely adjustments to changing climatic conditions (Mthembu and Zwane, 2017), while the innovative Water-Energy-Food Nexus framework transforms rural livelihoods by addressing critical interdependencies to reduce vulnerability (Mabhaudhi et al., 2019). Empowering local communities to adopt new technologies enhances an inclusive approach to resilience building (Gould and Rudolph, 2015), and integrating public health considerations is critical as rural health service managers anticipate mounting climate-related challenges (Purcell and McGirr, 2017). Ultimately, a collaborative strategy that merges scientific research, indigenous knowledge, and health perspectives, and accounts for gender dynamics, local governance, and economic policies, is indispensable for creating resilient systems across Africa (Popoola et al., 2020; Rankoana, 2023; Adzawla et al., 2019; Khoza et al., 2021).

In practice, integrating early warning systems with decision-support mechanisms plays a vital role in alerting farmers to imminent hazards and facilitating timely adaptation. Advanced notifications of droughts, floods, and other extreme events allow for efficient resource mobilization, reallocation of inputs, and adjustments to cropping calendars (Antwi-Agyei and Nyantakyi-Frimpong, 2021; Sarr and Sultan, 2022), while coupling these tools with information and communication technologies enhances forecast precision and risk assessment (Chen et al., 2023; Meechang et al., 2020). Moreover, effective implementation of such systems fosters community engagement and builds trust in climate services, spurring proactive responses and long-term strategic planning, like altering planting schedules and diversifying crop varieties, to reduce exposure to climate hazards and support sustainable agricultural practices (Agbehadji et al., 2023).

This study provides an innovative analysis of climate change impacts across Africa by addressing critical gaps in our

understanding of adaptation processes. Moving beyond earlier research that has examined isolated aspects of climate change, our work synthesizes indigenous knowledge with modern scientific insights to develop comprehensive adaptation strategies, responding to calls for merging traditional wisdom with contemporary methods (Nyadzi et al., 2021; Ajani et al., 2013). Central to our approach is the creation of innovative governance and policy frameworks tailored to local contexts, reflecting evidence that context-specific measures and locally driven initiatives are vital for enhancing resilience in under-resourced communities (Sesugh Aule, 2025; Adebola, 2024). By addressing a continent-wide challenge, our study transcends narrow sectoral responses and presents integrative methods to bolster climate resilience. Recent work illustrates that indigenous strategies can significantly contribute to disaster risk reduction (Motsumi and NemaKonde, 2024) and that community-led adaptations effectively buffer climatic variability (Ajani et al., 2013). Furthermore, studies by Mercer et al. (2010) and Datta and Kairy (2024) underscore the importance of centering traditional knowledge in policy-making, while Shammin et al. (2021) reported that community-based models demonstrate the benefits of blending indigenous practices with modern governance structures. Together, these insights support our novel, holistic framework for addressing the multifaceted challenges posed by climate change across Africa.

The primary aim of this study is to explore the multifaceted impacts of climate change across Africa and to identify effective strategies for strengthening the continent's resilience. To achieve this aim, the study pursues three specific objectives: (1) evaluate the vulnerability of critical sectors such as agriculture, health, and water resources, by examining how climate change exacerbates existing challenges; (2) identify, categorize, and critically evaluate effective adaptation strategies currently employed in various African communities; and (3) examine the prevailing governance and policy frameworks that guide climate resilience initiatives. By fostering a multidimensional approach that combines traditional knowledge with modern adaptations, this paper advances the dialogue on sustainable development in Africa and paves the way for more effective strategies to create a resilient future.

2 Climate change vulnerability in Africa

Africa remains one of the most climate-vulnerable regions globally, facing unique susceptibilities compared to more economically diversified areas. Its diverse landscapes and economies are frequently exposed to extreme weather events, and, unlike many other regions, Africa's heavy reliance on climate-sensitive sectors, particularly agriculture, renders it especially susceptible to adverse impacts. This vulnerability is further compounded by pervasive socio-economic challenges, limited infrastructural development, and constrained financial resources, all hindering effective adaptation. A comprehensive understanding of these distinctive climate risks is essential for developing targeted strategies that boost resilience and promote sustainable development amid escalating climate challenges.

2.1 Regional exposure and adaptive capacity

Across Africa, climate vulnerability is intensified by widespread dependence on rain-fed agriculture, which underpins the livelihoods of millions (Ayodotun et al., 2019). In West Africa, projections indicate that rising temperatures, erratic rainfall, and recurrent droughts will increasingly subject communities to compound events, such as simultaneous heatwaves and heavy precipitation, that imperil food security and public health (Quenum et al., 2021; Weber et al., 2020). Similarly, countries across sub-Saharan Africa including Sudan, Niger, and Ethiopia are already experiencing dramatic shifts in precipitation and rising temperature anomalies that undermine agricultural productivity and strain water resources (Adzawla et al., 2019; Smith et al., 2023). These physical challenges are further exacerbated by socio-economic constraints such as persistent poverty, limited access to education, healthcare, technology, and an overreliance on subsistence farming (Aryana et al., 2024; Blennow and Persson, 2021). Institutional shortcomings, inadequate infrastructure, and insufficient investment in adaptive technologies, coupled with social issues like gender inequality and the marginalization of vulnerable groups, further hinder effective climate resilience, making urgent and systematic interventions essential (Giarola et al., 2022; Binuyo et al., 2022).

Annual fluctuations in precipitation and evolving temperature trends offer additional insight into Africa's escalating climate risks. Despite a broadly consistent precipitation cycle across the continent, significant interannual variability emerges, particularly in southern Africa, where declining mean annual rainfall and increased variability have led to drier conditions and elevated risk of extreme events (Samuel et al., 2024; Gaughan et al., 2015). Concurrently, a steady rise in annual mean temperatures over recent decades further stresses agriculture and water resources already challenged by erratic rainfall (Neate-Clegg et al., 2021). Model simulations based on the CMIP6 framework project indicate that increasing temperature anomalies will worsen moisture deficits and heighten the frequency of extreme hydrometeorological events (Almazroui et al., 2020). However, persistent uncertainties in observational reanalysis datasets, particularly regarding precipitation, underscore the need for ongoing refinement in both data collection and modeling techniques (Gleixner et al., 2020). Collectively, these shifting climatic patterns necessitate adaptive strategies and integrated policy responses tailored to the unique vulnerabilities of Africa (Samuel et al., 2024).

2.2 Multi-hazard mapping of climate extremes

We built a 10 km resolution vulnerability atlas of Africa for 2000–2024 using Google Earth Engine. Daily MOPIDIS surface-temperature layers were transformed into heatwave-frequency rasters, and CHIRPS rainfall records were converted into drought- and flood-frequency images following thresholds defined by Eze and Siegmund (2024). Gaps in these time series were filled with ERA5 reanalysis to ensure temporal continuity, as outlined by Heydari et al. (2024). Each hazard layer was then normalized via min-max scaling to align disparate

units and suppress extreme outliers before computing an equal-weighted composite index. The resulting country scores and high-resolution maps appear in Figure 1a and Supplementary Table S1, while subnational patterns are detailed in Figure 1b.

Country-level vulnerability indices range from 0.0 in Morocco, Algeria, Tunisia, Libya, and Egypt to a maximum of 1.92 in Sierra Leone, Liberia, Côte d'Ivoire, Ghana, and Nigeria (Figure 1a). Central African Republic and select provinces of the Democratic Republic of the Congo also exceed 1.0, and Southern African nations like Angola, Zambia, Malawi, Zimbabwe, and Botswana populate the upper half of the vulnerability spectrum. Supplementary Table S1 provides the full list of national scores, highlighting how West African and parts of Central and Southern Africa bear the heaviest cumulative risk, whereas North Africa remains comparatively sheltered.

Despite these national averages, Figure 1b exposes striking subnational disparities. In Sudan and Chad, several northern provinces record vulnerability values upward of 1.5, far outstripping their national means. Kenya's northern and coastal counties likewise surpass the country's aggregate index, and eastern districts in South Africa reveal vulnerability pockets hidden beneath its moderate national score. Liverman (2024) attributes much of this spatial heterogeneity to geographic diversity, ranging from Sahelian heat extremes to equatorial flood regimes, while Cutter et al. (2003) demonstrate how local topography and land cover can amplify or mitigate hazard exposure.

Underlying these physical drivers, socioeconomic and methodological factors further explain regional variation. Communities with limited infrastructure and governance capacity absorb shocks less effectively, as Brooks et al. (2005) have shown, and Ayodotun et al. (2019) document how poverty intensifies flood and drought impacts in West Africa. Assigning equal weights to all five hazards can obscure synergistic effects such as drought-driven wildfire amplification, a caveat raised by Jurgilevich et al. (2017). Moreover, uncertainties in climate-model projections and evolving socioeconomic trajectories necessitate flexible response frameworks (Sherbinin et al., 2019). Incorporating local coping practices illustrated by river-basin resilience studies in Tanzania can refine vulnerability estimates and support tailored adaptation strategies (Macharia et al., 2020).

2.3 Hotspots and critical impact zones

Identifying the most affected climate change hotspots is key to designing focused interventions. The Sahel, which stretches as a semi-arid belt from Senegal to Chad, endures severe disruptions from prolonged dry spells and erratic rainfall, jeopardizing agriculture, water resources, and food security. This region is increasingly troubled by these climatic stresses (Diffenbaugh and Giorgi, 2012), with tropical West Africa encompassing nations like Ghana, Nigeria, and Côte d'Ivoire experiencing pronounced risks to both agriculture and biodiversity (Müller et al., 2014). The convergence of these physical hazards with socio-economic challenges such as widespread poverty and limited adaptive capacity underscores an urgent need for region-specific responses (Turco et al., 2015; Fan et al., 2021). Climate models further predict that rising temperatures and altered precipitation

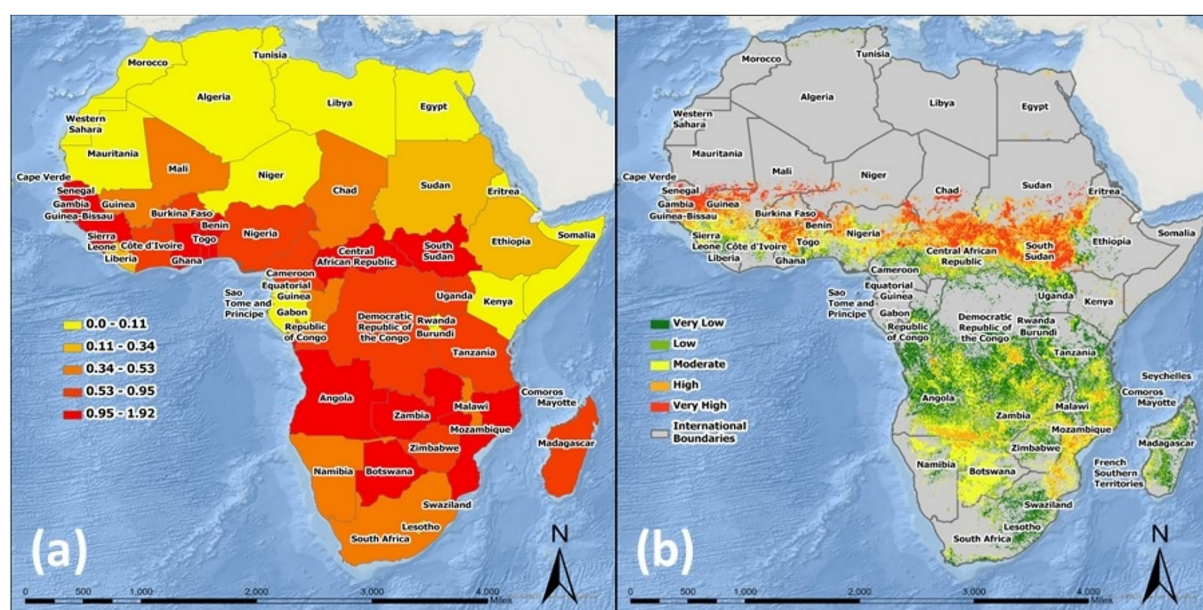


FIGURE 1

Vulnerability map across Africa based on climate extremes, (a) country-level, (b) sub-national level.

patterns may reduce yields of staple crops such as maize and sorghum by up to 20% by mid-century (Jantz et al., 2015). Increased variability is also expected to drive more frequent extreme events, such as droughts and floods, which disrupt agricultural cycles and further compromise food security for communities already grappling with production uncertainties (Omer et al., 2024; Schroth et al., 2016). Such trends have broader implications, undermining rural economies, public health, and community resilience, thereby necessitating robust, integrated climate adaptation measures in these vulnerable zones (Bezeng et al., 2017; Salamanca et al., 2023).

3 Impacts of climate change on key sectors

Climate change is fundamentally altering Africa's critical sectors, with sweeping impacts on agriculture, water resources, public health, and overall socioeconomic stability. Rising temperatures, erratic precipitation, and an increase in extreme weather events are eroding food security, disrupting water management systems, and worsening health and economic vulnerabilities. By bringing together evidence from these diverse yet interconnected areas, this section highlights the urgent need for comprehensive adaptation strategies that address the complex challenges facing African communities. Such integrated approaches are essential for charting a path toward resilient and sustainable development.

3.1 Agriculture and food security

Climate variability is negatively affecting agricultural production across Africa, especially in sub-Saharan regions, West, East, Central, and Southern Africa, where subsistence farming predominates. Rising

temperatures and shifting precipitation patterns have already reduced yields of staple crops such as millet and sorghum, with projections suggesting potential crop losses of around 8% under future scenarios (Sultan et al., 2019). In West Africa, prolonged droughts and an increased frequency of extreme weather events disrupt planting and harvesting cycles, while excessive rainfall and long dry spells further trigger widespread crop failures and shrink the area suitable for farming (Aboua, 2020; Sultan et al., 2023).

In response to these escalating challenges, smallholder farmers are increasingly embracing a variety of adaptive strategies. Many are diversifying their crop portfolios by introducing drought-resistant and climate-resilient varieties capable of withstanding temperature extremes and unpredictable rainfall (Waha et al., 2018; Baya et al., 2019). Practices such as conservation agriculture and agroforestry are gaining momentum as effective approaches to sustain soil health and bolster resilience against climate variability (Tarchiani et al., 2018). Enhanced access to agrometeorological services also enables farmers to better synchronize their planting and harvesting schedules with reliable weather forecasts, while educational initiatives continue to empower them to implement these adaptive practices more effectively (Mechiche-Alami and Abdi, 2020; Umetsu and Miura, 2023).

The repercussions of these climate-induced disruptions extend beyond reduced crop yields to directly threaten food security across sub-Saharan Africa. As yields become increasingly volatile, agriculture-dependent households face higher risks of food shortages, and declining outputs drive food prices upward, exacerbating the hardships of impoverished families (Deryng et al., 2011; Parkes et al., 2015). Moreover, the interplay between climate change and demographic pressures may further intensify migration as communities seek improved living conditions (Defrance et al., 2020). Thus, addressing the impacts of climate change on agriculture is vital not only for sustaining production

TABLE 1 Climate extremes' impact on African regions.

Region	Climate extreme	Impact	Reference citations
Sahel	Droughts	Severe water scarcity, reduced agricultural productivity, food insecurity, and increased resource conflicts.	Wright et al. (2024), Badolo (2024)
West Africa	Floods	Displacement of communities, destruction of infrastructure, and increased incidence of waterborne diseases.	Wright et al. (2024), Nigatu et al. (2014)
East Africa	Droughts and Floods	Crop failures, livestock mortality, food and water shortages, displacement of communities.	Mthembu and Zwane (2017), Hummel et al. (2018)
Southern Africa	Heatwaves	Heat-related illnesses, reduced crop yields, increased energy demand for cooling, and wildfires.	Clarke and Berry (2012), Hummel et al. (2018)
Central Africa	Heavy Rainfall	Landslides, soil erosion, disruption of transportation networks, and flooding of urban areas.	Perez et al. (2022)
North Africa	Droughts	Water scarcity, desertification, reduced agricultural productivity, and migration.	Antwi-Agyei et al. (2017), Ebi and Barrio (2017)

levels but also for ensuring stable and accessible food systems. Facilitating the adoption of effective adaptation measures among smallholder farmers is key to safeguarding food security and enhancing overall resilience in a changing climate (Olabanji et al., 2020).

3.2 Water resources

Many African communities have long drawn on indigenous knowledge to manage water scarcity and optimize water use. Traditional practices, such as rainwater harvesting for seasonal capture, constructing small reservoirs, designing pervious surfaces to promote groundwater recharge, and building contour bunds to reduce runoff, demonstrate a profound understanding of local hydrology deeply connected to ecological rhythms and cultural calendars (Mganga et al., 2021; McNally et al., 2019). These time-honored methods have enabled communities to effectively adapt to shifting climate conditions and maintain sustainable water supplies in the absence of formal management systems.

However, despite the clear benefits of these indigenous approaches, modern policy frameworks often prioritize technical solutions over local expertise (Wallace and Gregory, 2002). Integrating indigenous wisdom with contemporary scientific methods can enhance adaptive capacity and lead to more efficient water use, as evidenced by studies showing higher resilience to climate variability when traditional practices are employed (Das et al., 2015; Ferrand and Cecunjanin, 2014). Numerous examples illustrate the effectiveness of these strategies: the Akwamu community in Ghana employs religious norms and ancestral conservation techniques to preserve water bodies (Osei, 2023), while in South Africa, practices like rainwater harvesting, terracing, and wetland management mitigate water scarcity amid erratic rainfall patterns (Sahani et al., 2025). Similarly, Zimbabwe's Ndau community blends cultural rituals with environmental wisdom (Tenson and Richard, 2014), and local governance in Northern Namibia draws on

historical practices to facilitate resource distribution and build resilience (Hossain and Helao, 2008).

In response to escalating climate challenges, governments and non-governmental organizations across Africa are adopting a range of adaptation strategies within the water sector. Efforts include modernizing infrastructure, implementing water-saving technologies such as drip irrigation (Adonadaga et al., 2022), and establishing transboundary management frameworks to encourage regional collaboration (Rankoana, 2020). Concurrently, rising populations and rapid urbanization, projected to increase urbanization from about 40% to over 60% by 2050 and urban water demand by 50–80% over the next three decades, are further stressing freshwater supplies (Santos et al., 2017; He et al., 2021; Bojer, 2025). Additionally, climate variability decreases per capita water availability as resources are increasingly diverted to meet domestic, agricultural, and industrial needs, while intensified anthropogenic activities degrade water quality and burden treatment and supply systems (Gebrehiwot and Gebrewahid, 2016; Hasan et al., 2019). In this context, innovative adaptation strategies that blend traditional knowledge with modern technologies are essential for achieving sustainable water management and bolstering climate resilience (Nhamo et al., 2018). Table 1 offers an overview of how climate extremes affect various regions of Africa, providing detailed regional insight that enables stakeholders to develop targeted adaptation strategies to address each area's unique vulnerabilities and build greater resilience.

3.3 Health and socioeconomic impacts

Climate change is significantly compromising both public health and socioeconomic stability in Africa. Increased temperatures, altered precipitation patterns, and more frequent extreme weather events are intensifying health risks and disrupting livelihoods. This section examines the interdependent nature of these challenges, revealing how deteriorating health outcomes and economic instability mutually

TABLE 2 Health impacts due to climate change in Africa.

Health impact	Contributing climate factors	Examples and observations	Reference citations
Heat-related illnesses	Rising temperatures, heatwaves	Increased incidence of heat stress, heat exhaustion, and heat stroke among vulnerable populations.	Berry et al. (2018)
Respiratory conditions	Altered precipitation patterns, increased air pollution	Worsening of asthma and other respiratory diseases due to higher pollution levels and pollen distribution changes.	Clarke and Berry (2012)
Vector-borne diseases	Shifting climatic zones, increased humidity	Expanded range and transmission of diseases like malaria and dengue fever to previously unaffected areas.	Obradovich et al. (2017)
Mental health issues	Extreme weather events, displacement	Higher rates of anxiety, depression, and trauma among individuals exposed to climate-related disasters.	Stilita and Charlson (2024)
Waterborne diseases	Flooding, contaminated water sources	Increased incidence of cholera, typhoid, and other waterborne diseases following flooding and water contamination.	Nigatu et al. (2014), Perez et al. (2022)
Nutritional deficiencies	Declining agricultural productivity, food insecurity	Malnutrition and stunting are due to reduced crop yields and food shortages.	Ebi and Barrio (2017), Hummel et al. (2018)
Non-communicable diseases	Rising temperatures, altered lifestyle factors	Higher prevalence of conditions such as cardiovascular diseases is linked to heat stress and changes in physical activity.	Cardwell and Elliott (2013)

reinforce each other. It underscores the urgent need for integrated adaptation strategies to foster resilient communities across the continent.

3.3.1 Assessment of health vulnerabilities

Environmental shifts driven by climate change elevate public health risks by intensifying exposures in climate-stressed regions. Increasing temperatures, irregular precipitation, and recurrent extreme events contribute to a range of ailments, from heat-related illnesses and respiratory conditions to the accelerated spread of infectious diseases (Berry et al., 2018). Moreover, shifts in climatic zones are expanding the prevalence of vector-borne illnesses such as malaria and dengue fever, exposing populations that were previously at lower risk (Obradovich et al., 2017). Extreme weather events also precipitate mental health challenges, with affected individuals experiencing greater levels of anxiety and depression. Incorporating these diverse risk factors into public health assessments is crucial for directing effective adaptation strategies (Buse, 2018).

In Africa, the impact of climatic stressors on health is particularly pronounced. Vulnerable communities, especially internally displaced persons and refugees, face heightened mental health challenges, as evidenced by studies in regions like Somalia and Tanzania that report increased trauma and anxiety linked to forced migration (Stilita and Charlson, 2024; Sanni et al., 2022). Additionally, extreme events such as flooding not only lead to immediate physical injuries but also accelerate the spread of waterborne diseases, intensifying overall health risks. The World Health Organization has identified climate change as a major threat, with children, the elderly, and those with pre-existing conditions being especially susceptible (Nigatu et al., 2014).

Beyond direct health impacts, climate-induced stress on healthcare systems compromises access to quality care and contributes to higher morbidity and mortality rates related to climate-sensitive conditions (Cardwell and Elliott, 2013). It is essential to integrate localized health vulnerability insights into public health planning and response initiatives to build resilient systems (Cheng and Berry, 2013). Enhancing awareness and implementing targeted training for health professionals can help synchronize healthcare responses with adaptive strategies, bridging critical knowledge gaps (Berry et al., 2018; Andersen et al., 2021). Table 2 summarizes both the direct and indirect impacts of these climatic changes on African populations, providing a basis for developing informed and robust public health strategies.

3.3.2 Broader socioeconomic consequences

Climate change triggers wide-ranging socioeconomic impacts that affect nearly every facet of life. Unstable climatic conditions diminish agricultural productivity, thereby compromising food security and contributing to malnutrition and health disparities among vulnerable populations (Ebi and Barrio, 2017). In addition, the economic fallout, including increased healthcare costs, reduced productivity, and disrupted livelihoods, intensifies existing inequalities and deepens poverty. These conditions often spur climate-induced migration, as people abandon increasingly uninhabitable areas and place additional pressure on host communities (Eckelman and Sherman, 2016; Krasna et al., 2020).

In Africa, these repercussions are particularly severe. Low-income communities that depend on climate-sensitive sectors suffer notable declines in crop production, as rising temperatures and altered precipitation patterns reduce yields; for example, drought stress is expected to diminish common bean yields in southern Africa,

TABLE 3 Broader socioeconomic consequences of climate change on African regions.

Region	Socioeconomic consequence	Description	Reference citations
Sahel	Declining agricultural productivity	Reduced crop yields and livestock productivity due to prolonged droughts, leading to food insecurity.	Hummel et al. (2018), Ebi and Barrio (2017)
West Africa	Migration and displacement	Increased migration and displacement of populations due to flooding and loss of arable land.	Krasna et al. (2020), Wright et al. (2024)
East Africa	Economic losses	Economic losses from damaged infrastructure and reduced tourism due to extreme weather events.	Badolo (2024), Perez et al. (2022)
Southern Africa	Health impacts	Higher incidence of waterborne diseases and malnutrition due to disrupted water resources and food supply.	Nigatu et al. (2014), Perez et al. (2022)
Central Africa	Social strain and conflicts	Increased social strain and conflicts over diminishing natural resources such as water and arable land.	Ebi and Barrio (2017), Chersich and Wright (2019)
North Africa	Water scarcity	Severe water scarcity is affecting agriculture, domestic use, and industrial activities.	Antwi-Agyei et al. (2017), Zvobgo et al. (2022)
Sub-Saharan Africa	Poverty and inequality	Exacerbation of poverty and inequality due to economic disruptions and loss of livelihoods.	Eckelman and Sherman (2016), Hummel et al. (2018)

impacting both the available growing area and the nutritional quality of produce (Hummel et al., 2018). Reduced agricultural output drives food prices higher, which increases the risk of malnutrition among populations already burdened by economic hardship (Kirchhoff and Watson, 2019). Meanwhile, disruptions in water resources hinder agricultural irrigation and domestic supply, elevating the spread of waterborne diseases and further straining public health systems (Chersich and Wright, 2019; Perez et al., 2022).

Socioeconomic disparities further compound these challenges. Marginalized groups, particularly women and individuals with lower incomes, often lack the means to adapt effectively, while governance structures tasked with implementing adaptation measures are hampered by inadequate infrastructure, limited funding, and low political commitment (England et al., 2018; Quintana et al., 2024). Rapid urban expansion also challenges access to safe drinking water, intensifying the adverse effects of climate change in many regions (Zvobgo et al., 2022). Addressing these complex issues requires a cross-sectoral approach that weaves climate adaptation strategies into disaster risk reduction, food security, and public health policies, along with robust community engagement to ensure context-specific responses (Ford et al., 2014; Ekstrom et al., 2017). Table 3 summarizes the broader socioeconomic consequences of climate change across various African regions, providing essential insights for developing targeted strategies to mitigate adverse impacts on vulnerable communities.

4 Strategies for enhancing climate resilience

Addressing the multifaceted challenges of climate change demands holistic strategies that reinforce resilience across diverse sectors. This section examines an array of innovative adaptation approaches that blend indigenous wisdom, modern agricultural methods, and forward-thinking policy frameworks. By combining time-honored traditional practices with state-of-the-art technology and fostering active community participation, these strategies aim to

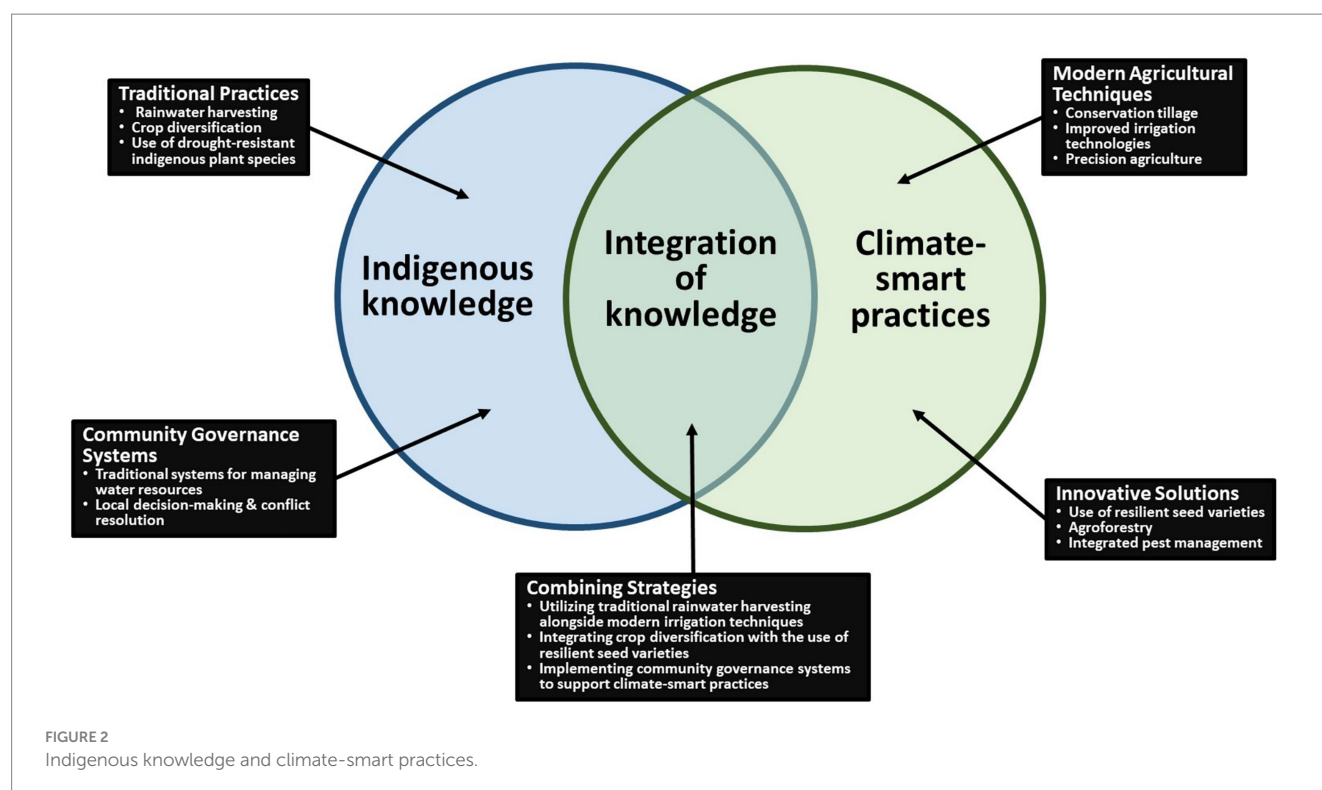
build robust systems capable of withstanding climate-related adversities while promoting sustainable development throughout Africa.

4.1 Leveraging indigenous knowledge and community approaches

Figure 2 exemplifies the power of merging indigenous insights with climate-smart agricultural strategies to enhance community resilience while preserving cultural heritage. By integrating time-tested local methods with modern innovations, communities are empowered to more effectively mitigate and adapt to the impacts of climate change. This visual representation highlights key examples of both traditional and advanced practices, demonstrating how their complementary roles contribute to the development of sustainable, adaptive agricultural systems.

4.1.1 Role of indigenous knowledge in climate adaptation

Indigenous knowledge is a vital component of climate adaptation strategies, particularly in Africa, where local communities have developed profound interactions with their natural environments. For example, Egah et al. (2023) emphasize that indigenous knowledge systems enable communities to predict climate events effectively, thereby enhancing food security in agro-pastoral households. Traditional methods, such as rainwater harvesting, crop diversification, and the cultivation of drought-resistant indigenous species, have long been employed to manage water scarcity and support food security (Chanza and Musakwa, 2022). Furthermore, practices like agroecological techniques and the selective breeding of locally adapted crops highlight how context-specific adaptive strategies are developed to endure shifting climatic conditions (Egah et al., 2023). Such insights are crucial for anticipating and mitigating the adverse impacts of climate extremes, which increasingly threaten agricultural productivity in many regions.



Blending these time-tested practices with innovative scientific approaches not only reinforces the resilience of agricultural systems but also promotes local ownership of adaptation initiatives (Nesterova, 2020). Valuing indigenous knowledge, shaped by centuries of interaction with the local environment, ensures that adaptation measures are culturally relevant and effectively counter contemporary climate stresses (Acharibasam, 2022). Indigenous communities continually refine their agricultural techniques by closely monitoring environmental changes, thus actively managing climate risks (Datta, 2024). When combined with scientific research, these local insights lead to holistic strategies that empower communities to respond proactively to climate change, preserve cultural heritage, and strengthen social cohesion. Such integrative approaches ultimately enhance environmental stewardship, foster healthier ecosystems, and build more resilient food systems, contributing to broader climate resilience (Rahman and Alam, 2016; Smith, 2018; Fillmore and Singletary, 2021).

4.1.2 Case studies of community-based adaptation initiatives

Across Africa, numerous initiatives illustrate how blending indigenous knowledge with community-based adaptation measures can significantly boost resilience. In Kenya, for example, farmers have reintroduced traditional crop varieties that are naturally attuned to local climatic conditions, thereby enhancing food security and fostering sustainable agricultural practices (Korovulavula et al., 2019). Similarly, communities in southern Ethiopia have revived time-honored water management systems to effectively cope with drought, ensuring a reliable water supply for both agricultural and domestic needs (Agholor et al., 2023). These locally driven adaptations not only reinforce resilience but also strengthen community cohesion through empowered, decentralized decision-making.

Educational programs and participatory workshops further amplify these efforts by enabling communities to share experiences and collectively refine adaptive strategies. In rural Ghana, interactive workshops have provided a platform for farmers to exchange insights and develop adaptation measures that align traditional practices with evolving climate realities (Rankoana, 2020). Such initiatives underscore the importance of incorporating cultural values and indigenous knowledge into official adaptation plans, resulting in solutions that are both contextually relevant and sustainable (Rivero-Romero et al., 2016). An inclusive approach that values traditional practices has proven instrumental in fortifying community resilience against climate change (Scotti et al., 2023; Kamakaula, 2024).

Additional research further highlights the pivotal role of indigenous knowledge in climate adaptation. In North Benin, studies have shown that traditional forecasting methods are crucial for predicting climate events and safeguarding food security for agro-pastoral households (Egah et al., 2023). Likewise, Afar pastoralists in northeastern Ethiopia rely on ancestral weather forecasting techniques to inform critical decisions on livestock management and resource allocation amid climate variability (Balehegn et al., 2019). Table 4 presents a comprehensive overview of these case studies from diverse African regions, offering valuable insights into how indigenous knowledge and modern scientific methods can be integrated to craft scalable, resilient adaptation strategies.

4.2 Adoption of climate-smart agriculture

In the face of escalating climate challenges, the agricultural sector is increasingly turning to climate-smart agriculture (CSA) as a crucial strategy for promoting both sustainable productivity and resilience. CSA represents an integrated framework that fuses advanced

TABLE 4 Community-based adaptation initiatives in Africa.

Region	Adaptation initiative	Key strategies	Observed outcomes	Reference citations
Kenya	Use of indigenous crop varieties	Reverting to traditional seeds resilient to local climate conditions.	Improved food security and sustainability.	Korovulavula et al. (2019)
Southern Ethiopia	Traditional water resource management	Establishing systems for managing water resources during droughts.	Ensured water availability for agricultural and domestic use.	Agholor et al. (2023)
Rural Ghana	Participatory workshops for climate adaptation	Empowering farmers through knowledge sharing and collective adaptive strategies.	Improved agricultural practices align with the changing climate.	Rankoana (2020)
North Benin	Indigenous knowledge for climate prediction	Using traditional knowledge to predict climate events and safeguard food security.	Enhanced decision-making and resource management.	Egah et al. (2023)
Northeastern Ethiopia	Indigenous weather forecasting by Afar Pastoralists	Utilizing traditional weather forecasting for informed decisions on livestock management.	Better preparedness and resilience to climate variability.	Balehegn et al. (2019)

technological innovations with longstanding indigenous practices and community-led initiatives, enhancing resource management, boosting crop yields, and mitigating greenhouse gas emissions. By combining cutting-edge techniques with local wisdom, CSA offers a comprehensive solution that equips smallholder farmers to effectively adapt to climate variability while securing long-term food security. In this section, we examine the core practices, technological developments, and integrative methodologies that are driving the successful adoption of climate-smart agriculture across Africa.

4.2.1 Overview of climate-smart practices and technologies

Climate-smart agriculture (CSA) is a holistic framework intended to boost productivity, enhance climate resilience, and reduce greenhouse gas emissions ([Scherer and Verburg, 2017](#)). It merges a range of practices and technologies specifically tailored to local environmental, agricultural, and socio-economic conditions. For example, CSA often incorporates drought-resistant crop varieties, agroforestry, crop rotation, conservation tillage, and advanced irrigation systems such as drip and sprinkler technologies ([Anuga et al., 2022](#); [Nandini et al., 2023](#)). These methods optimize resource use, improve soil quality, and facilitate carbon sequestration, thereby supporting sustainable land management.

In Africa, CSA has become essential for smallholder farmers, who form the backbone of the agricultural sector, as it helps manage climate impacts while increasing productivity and ensuring food security ([Khoza et al., 2021](#); [Gugissa et al., 2022](#)). By emphasizing improved soil management, diversified crop production, and resilient seed varieties, farmers are better equipped to endure climate stress. Nonetheless, the widespread adoption of CSA faces challenges, with limited access to resources, technological expertise, and financial support remaining significant obstacles that require coordinated responses from governments, NGOs, and local communities ([Clay and Zimmerer, 2020](#)).

Moreover, noteworthy CSA innovations include organic farming practices that reduce the reliance on synthetic fertilizers and pesticides, thus mitigating the environmental footprint of agriculture ([Sanogo](#)

[et al., 2017](#)). Techniques such as rainwater harvesting and precision agriculture utilize data to minimize waste and maximize yields under variable climatic conditions. The integration of these advanced strategies with traditional practices supports sustained agricultural output, lowers farming systems' vulnerability to climate variability, and ultimately enhances food security and the livelihoods of smallholder farmers ([Fiawoo et al., 2024](#)).

4.2.2 Integrative approaches to improve productivity and sustainability

Enhancing agricultural productivity and sustainability requires a cohesive strategy that combines technological innovations, traditional knowledge, and active community engagement ([Teklewold et al., 2018](#)). By fostering participatory research methods and implementing educational initiatives, farmers are enabled to tailor CSA practices to their specific local conditions, thereby boosting acceptance and effective implementation ([Mirzabaev, 2017](#)). Critical to this process is the role of local leadership and the willingness of farmers to adopt practices that align with their cultural values and longstanding agricultural traditions ([Sanogo et al., 2017](#)).

Creating synergies among agricultural policies, climate resilience strategies, and economic incentives is equally vital. Programs that offer improved access to credit, sophisticated training, and practical resources for climate-smart technologies can drive broader adoption of these systems ([Amare and Gacheno, 2021](#)). Additionally, collaboration among government entities, NGOs, and local communities fosters a holistic approach to resilient agricultural development by integrating diverse perspectives and expertise to address climate change challenges ([Nkonya et al., 2017](#)). For example, agroecological practices, integrating modern techniques with traditional methods, have been shown to enhance biodiversity, improve water retention, and boost soil fertility, all of which are essential to sustaining robust food systems ([Kifle et al., 2020](#)). As the impacts of climate change become more severe, embedding these integrative approaches within CSA is key to building agricultural systems that are resilient and capable of withstanding future climatic challenges.

4.3 Policy and governance frameworks

Building climate resilience in Africa calls for strong adaptation policies supported by effective local governance and participatory mechanisms. By basing policies on local conditions and engaging stakeholders throughout the adaptation process, governments can foster environments that support sustainable development and robust risk management.

4.3.1 Need for robust climate change adaptation policies

Addressing Africa's escalating climate challenges requires strong adaptation policies that provide a clear framework for governments at every level, national, regional, and local, to design and implement strategies that respond to their communities' unique needs (Chersich and Wright, 2019). Grounded in scientific research and adapted to local realities, these policies ensure that measures are both practical and context-specific. For instance, South Africa's National Climate Change Response Policy, which effectively integrates climate health considerations into local government plans, serves as an inspiring model for other nations (Quintana et al., 2024). Furthermore, aligning adaptation policies with existing sectoral strategies in areas such as agriculture, water, and health, as well as ensuring that local governments possess the necessary capacity to execute these plans, is critical to their overall success (Antwi-Agyei et al., 2017).

To be truly effective, adaptation policies must also prioritize inclusiveness by actively engaging marginalized and vulnerable communities in the decision-making process (Ranabhat et al., 2018). Climate governance frameworks that emphasize transparency, accountability, and collaboration among diverse stakeholders are essential for fostering sustainable practices and building robust community resilience (Chersich and Wright, 2019). Ultimately, well-crafted and comprehensive climate adaptation policies empower governments to proactively mitigate climate impacts, enabling communities to not only survive but thrive in the face of environmental challenges.

4.3.2 Mechanisms for effective local governance and stakeholder participation

Effective climate adaptation relies on strong local governance paired with active stakeholder participation. Local governments, which possess an intimate understanding of community vulnerabilities, are crucial for transforming climate policies into actionable measures (Pasquini et al., 2014). Establishing multi-stakeholder platforms that bring together government representatives, community leaders, NGOs, and citizens fosters ongoing dialogue and ensures that adaptation initiatives are finely tuned to local conditions and diverse perspectives (Twinomuhangi et al., 2019).

Enhancing the capacity of local authorities through proper resource allocation and targeted capacity building is equally important for the success of adaptation measures. Equipping decision-makers with data-driven insights, supported by accurate climate information and forecasting, greatly improves their ability to respond proactively (Huh et al., 2017). Additionally, integrating indigenous knowledge into formal governance structures enhances local responsiveness and adaptability (Crane et al., 2011). Maintaining robust communication channels between governments and communities is vital for shared understanding of climate risks and the appropriate adaptation

measures. Public awareness campaigns that underline climate impacts and adaptive strategies help foster community engagement and cultivate a sense of ownership over adaptation efforts (Harris and Howe, 2023). When stakeholders are well-informed, trained, and actively involved in both planning and implementation, communities build the agency necessary to enhance their resilience against climate change challenges (Quintana et al., 2024).

5 Future directions in building Africa's climate resilience

As Africa grapples with mounting climate impacts, it is imperative to devise forward-thinking strategies that not only address today's challenges but also establish the foundation for long-term resilience and sustainability. This section outlines future directions designed to strengthen climate adaptive capacity throughout the continent. By enhancing existing adaptation frameworks, filling crucial knowledge gaps, and prioritizing strategic investments, African nations can better anticipate and manage the complex spectrum of climate challenges ahead. Moving forward, collaborative efforts, innovative approaches, and robust policy development will be key to building a resilient and sustainable future for all communities across Africa.

5.1 Building on existing frameworks for climate resilience

As climate change impacts in Africa intensify, it is imperative to strengthen and refine existing resilience frameworks to support effective adaptation strategies. A key initiative in this effort is the African Climate Resilience Acceleration (ACRA) roadmap, which serves as an essential decision-support tool for policymakers and local governments (Badolo, 2024). This roadmap employs a comprehensive framework that incorporates methodologies to assess climate vulnerabilities, identify context-specific solutions, and prioritize actions that build adaptive capacity. By leveraging the ACRA roadmap, governments can develop strategies that are coherent with local priorities and foster sustainable development amid increasing climate variability.

Beyond its tailored solutions, the ACRA roadmap actively promotes collaboration among diverse stakeholders, including local communities, NGOs, and the private sector, thereby creating a united front against climate impacts (Gemenne and Blocher, 2017). Drawing on the perspectives of these varied actors enables the development of innovative interventions across critical sectors such as agriculture, health, and water management (Keane et al., 2018). The framework also emphasizes the need for robust monitoring and evaluation systems to track progress and guide ongoing adaptations, fostering a culture of continuous learning and improvement (Sultan et al., 2019).

Enhancing climate resilience further requires integrated, multi-sectoral approaches where climate-smart agriculture, sustainable water management, and effective public health policies converge to create synergistic pathways for adaptation (Wang et al., 2024; Roy et al., 2022). Joint initiatives that facilitate resource sharing and expertise exchange align local adaptation efforts with broader development objectives like the Sustainable Development Goals (Mayer et al., 2023). Empowering local governance enables authorities

to tailor measures to specific community landscapes, while participatory governance models engage citizens and reinforce socio-ecological resilience (Badolo, 2024). Figure 3 illustrates these integrative approaches, highlighting how uniting sectors such as agriculture, water management, and public health is essential for building long-term climate resilience across Africa.

5.2 Addressing knowledge gaps

Addressing knowledge gaps is critical for fostering climate resilience across Africa, as socio-economic conditions, cultural practices, and environmental factors jointly shape how communities perceive and respond to climate risks. Historically, analyses have prioritized ecological processes over socio-economic dimensions, leaving a divide between natural-science insights and human-centered adaptation needs (Hulme, 2018). Bridging these divides requires integrated frameworks that unite ecological, social, and cultural expertise to inform holistic strategies, especially in contexts where resources for interdisciplinary research are limited (Orr et al., 2022; Chausson et al., 2020).

One of the most pressing gaps exists among smallholder farmers, many of whom acknowledge climate change but lack detailed understanding of its causes, specific local threats, and viable adaptation options (Ubisi et al., 2017). A lack of accurate weather forecasts and reliable meteorological infrastructure further undermines their decision-making on crop management, risk mitigation, and resource allocation (Ayanlade et al., 2017; Gebre et al., 2023). To address these shortfalls, educational initiatives must blend scientific research with indigenous knowledge systems, using locally adapted technologies such as traditional water-harvesting techniques paired with modern

sensors to empower farmers and deepen community-wide comprehension of climate-smart practices (Kom et al., 2020; Sibiya et al., 2022).

Socio-political dynamics also influence the uptake of adaptation measures, as communities that perceive climate change as human-driven tend to engage more readily with resilience initiatives (González and Sánchez, 2022). In contrast, skepticism or indifference can stall local projects unless communication strategies are tailored to resonate with lived experiences and values (Ziervogel et al., 2014). At the policy level, insufficient climate literacy among government officials limits the development of comprehensive adaptation frameworks, and narrowly economic policies risk exacerbating vulnerabilities by sidelining environmental sustainability (Onyeneke et al., 2021; Wako et al., 2017). Establishing knowledge-sharing platforms that convene researchers, policymakers, and community representatives is essential to ensure that diverse perspectives guide robust, context-sensitive policy design (Joseph et al., 2021).

The availability and quality of climate data remain foundational to informed adaptation planning. Investments in regional meteorological networks and data-management systems can enhance forecast accuracy and enable proactive responses to extreme events (Faiyetole and Adesina, 2017). Integrating technological innovations such as drought-tolerant seed varieties, precision irrigation systems, and sustainable land-management practices with capacity-building programs ensures that new tools are effectively adopted and maintained (Cairns et al., 2013; Ampadu et al., 2018). By advancing data infrastructure, educational outreach, and interdisciplinary collaboration, Africa can close critical knowledge gaps and build a resilient foundation for sustainable livelihoods in the face of climate change. Table 5 details a concise summary of Section 5.2, outlining the

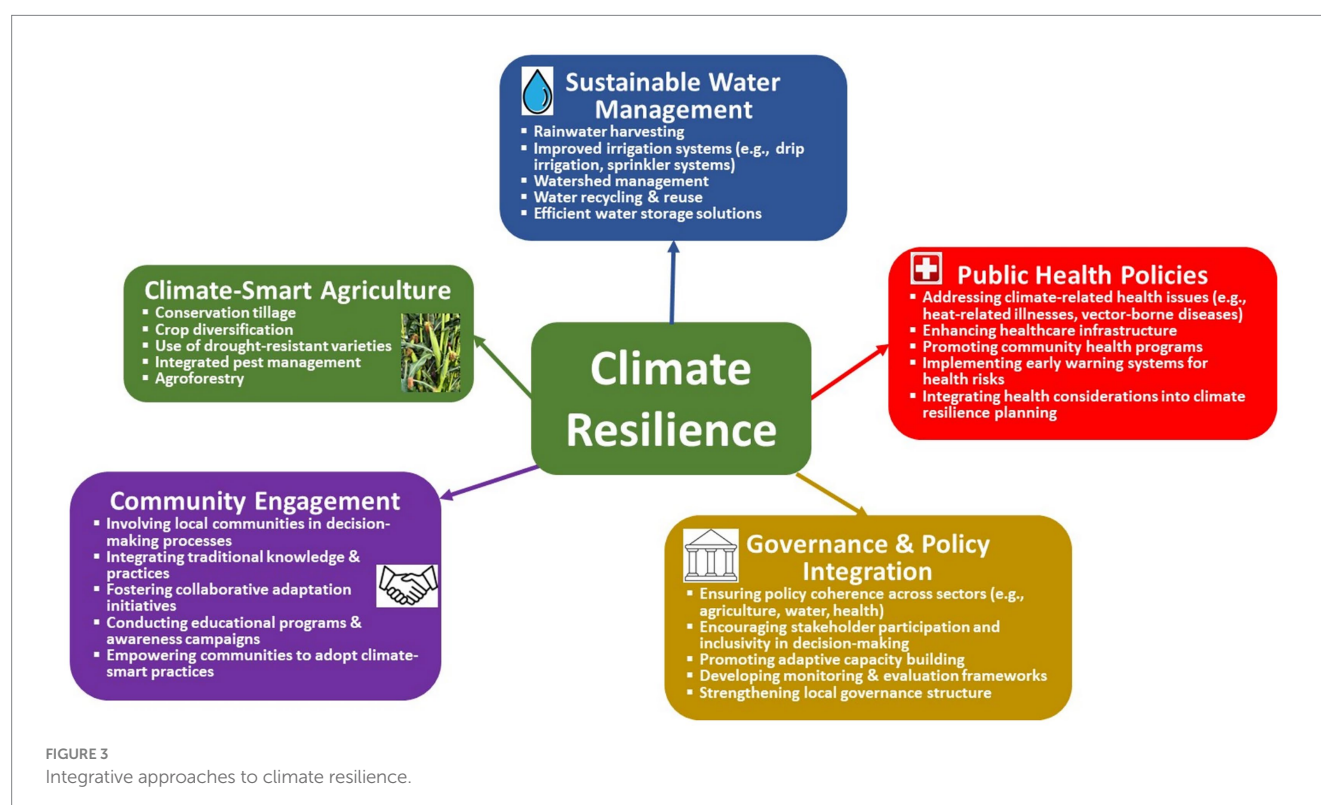


TABLE 5 Knowledge gaps, implications, and proposed actions for building Africa's climate resilience.

Theme	Challenges/Details	Proposed actions	References
Integrating natural and social sciences	Historical emphasis on ecological processes over socio-economic impacts, limiting holistic adaptation frameworks	Establish interdisciplinary teams and co-created research agendas bridging environmental and human dimensions	Chausson et al. (2020) , Hulme (2018) , Orr et al. (2022) , Turner et al. (2022)
Farmer understanding of climate	Limited awareness of specific local climate threats, causes, and adaptation options; inadequate meteorological data	Blend scientific research with indigenous knowledge; deploy locally adapted technologies; strengthen data systems	Ayanlade et al. (2017) , Gebre et al. (2023) , Kom et al. (2020) , Sibiya et al. (2022) , Ubisi et al. (2017)
Socio-political dynamics and policy literacy	Skepticism or indifference hinders uptake of adaptive practices; policymakers often lack climate literacy	Tailor communication strategies to community beliefs; create knowledge-sharing platforms for policymakers and stakeholders	González and Sánchez (2022) , Joseph et al. (2021) , Onyeneke et al. (2021) , Wako et al. (2017) , Ziervogel et al. (2014)
Data availability and technological integration	Inadequate meteorological infrastructure yields unreliable forecasts; risk of low adoption of innovations	Invest in regional climate networks and data management; integrate drought-tolerant seeds, precision irrigation, and land-management training	Ampadu et al. (2018) , Cairns et al. (2013) , Faiyetole and Adesina (2017)

main knowledge gaps, their implications, proposed actions, and key citations.

5.3 Innovative financing for climate projects

Securing adequate financial support for climate change adaptation is vital for African nations to address the multifaceted impacts of a shifting climate. Research by [Betzold and Weiler \(2017\)](#) reveals a significant gap between current financial resources and the investments required for effective adaptation, with particularly severe shortfalls in the continent's most vulnerable regions. As climate risks escalate, governments must prioritize funding that not only mitigates hazards but also enhances community resilience and promotes climate-smart practices. Climate-smart agriculture represents a critical approach to addressing agricultural development amid climate adversity, facilitating adaptations such as sustainable land and water management, which directly contribute to food security while minimizing greenhouse gas emissions ([Abegunde et al., 2019](#); [Kurgat et al., 2020](#)). This backing can be sourced from bilateral and multilateral aid, domestic budgets, and innovative mechanisms such as the Green Climate Fund ([Berrang-Ford et al., 2014](#)), ensuring that under-resourced communities whose capacities to cope with climate impacts are already stretched receive the support they need ([Moser et al., 2019](#)).

Innovative financial instruments such as green bonds, climate risk insurance, and blended finance offer pathways to mobilize public and private capital for adaptation and mitigation. [Cutter et al. \(2003\)](#) emphasize that these tools enable risk-sharing arrangements that lower investment barriers, while [Ayodotun et al. \(2019\)](#) document how green bonds have successfully financed renewable energy projects across Africa, bolstering local economies and advancing climate goals. Public-private partnerships further deepen private-sector engagement. [Brooks et al. \(2005\)](#) demonstrate the effectiveness of PPPs in delivering resilient infrastructure such as flood-resistant water-management systems. Meanwhile, public and quasi-public finance institutions

structure co-funding arrangements that de-risk investments and leverage indigenous knowledge, as [Fry et al. \(2024\)](#) illustrate through partnerships with established local organizations.

Despite this promise, persistent governance bottlenecks, capacity constraints, and inequitable fund distribution hamper co-funding mechanisms at the local level. [Cabannes \(2021\)](#) shows that weak institutional frameworks can stall participatory budgeting initiatives, skewing resources away from the most vulnerable. Studies underscore that the countries facing the highest climate risks often receive insufficient support ([Betzold and Weiler, 2017](#); [Moser et al., 2019](#)), underscoring the urgent need to recalibrate funding mechanisms. Aligning investment flows with detailed vulnerability assessments enables targeted financial assistance, supporting local government initiatives, empirical research, and capacity-building programs that empower communities to manage climate impacts effectively ([Adisa et al., 2024](#); [Sarfo-Adu and Kokofu, 2023](#); [Stender et al., 2019](#)).

Embedding these innovative financing tools within collaborative governance models amplifies their impact. [Bosma and Hein \(2023\)](#) emphasize that effective adaptation and conservation investment strategies can only materialize through the integration of various stakeholders in the governance processes. Advanced technologies such as remote sensing, high-resolution climate analytics, and early-warning systems further lower costs and risks, providing actionable insights for resource allocation ([Sherbinin et al., 2019](#)). Participatory action research, as documented by [Egah et al. \(2023\)](#), ensures that these financial mechanisms reflect community-identified needs and leverage indigenous knowledge, creating a resilient, climate-smart future for Africa. Table 6 presents a concise summary of Section 5.3, highlighting the main themes, key details, and supporting references for innovative financing.

6 Conclusion

Africa stands at a pivotal juncture: climate projections now signal a continent-wide temperature increase of at least 1.5 °C, ranging from 1.15 to 1.50 °C in the south and 1.05 to 1.50 °C in the east, accompanied

TABLE 6 Overview of key themes, detailed approaches, and supporting references for innovative financing mechanisms.

Theme	Details	References
Funding gap and priorities	Africa needs US \$293 bn - US \$2.5 tn by 2030; diverse funding sources required to support resilience and smart practices	Betzold and Weiler (2017), Abegunde et al. (2019), Berrang-Ford et al. (2014), Kurgat et al. (2020), Moser et al. (2019)
Innovative financial instruments	Green bonds; climate insurance; blended finance offer risk sharing and mobilize private and public capital	Cutter et al. (2003), Ayodotun et al. (2019), Brooks et al. (2005), Fry et al. (2024)
Local governance challenges	Governance bottlenecks, capacity constraints, and inequitable distribution impede co-funding mechanisms	Adisa et al. (2024), Cabannes (2021), Sarfo-Adu and Kokofu (2023), Stender et al. (2019), Moser et al. (2019)
Collaborative governance and technology	Multistakeholder frameworks, remote sensing, climate analytics, and participatory research drive adaptive finance	Bosma and Hein (2023), Sherbinin et al. (2019), Egah et al. (2023)

by more intense heatwaves, cyclones, floods, and droughts. These oscillating extremes devastate rain-fed agriculture, erode livelihoods, and inflict massive losses in property, food production, and livestock. Semi-arid lowlands are especially vulnerable, undermining irrigation initiatives and exacerbating chronic water scarcity, while persistent warming intensifies pest and disease outbreaks that threaten to overwhelm coping capacities. Health systems buckle under new burdens of vector-borne and heat-related illnesses, coastal settlements face rising seas, and energy infrastructures strain under hotter, drier conditions. With up to 70 percent of the population reliant on rain-fed farming and adaptation finance falling short by nearly \$486 billion, no nation can manage these compounded risks alone.

To build resilience, Africa must establish a robust, continent-wide climate-risk management architecture that continuously monitors hazards, forecasts emerging threats, and directs resources where they are needed most. This includes creating a pan-African Climate Resilience Observatory integrating satellite data, ground sensors, and community reporting; scaling climate-smart agriculture through drought-resistant seeds, efficient irrigation, and watershed restoration; and mobilizing innovative financing such as green bonds, climate funds, and debt-for-nature swaps, to close the adaptation financing gap. Strengthening governance and institutional capacity at national and subnational levels will ensure that policies remain adaptive as socio-economic and environmental conditions evolve.

Equally critical is forging an equitable global response that couples deep, early emissions reductions with technology transfer and safeguards against long-term risks. Aligning national commitments with the Paris Agreement's equity frameworks will protect Article 2's goal of limiting warming to well below 2 °C. Africa's resilience agenda must be underpinned by collaborative research, Indigenous knowledge integration, and regional cooperation among policymakers, scientists, local communities, and the private sector. Only through this holistic, multi-stakeholder approach can Africa transform the threats of climate change into opportunities for sustainable development and lasting innovation.

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Supplementary material

The Supplementary material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fclim.2025.1619799/full#supplementary-material>

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