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RESEARCH ARTICLE

A REVIEW OF CLIMATE CHANGE MITIGATION MEASURES AND THEIR IMPACT ON AGRICULTURAL SUSTAINABILITY IN RURAL AFRICA

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ABSTRACT

Agriculture is the backbone of rural Africa, with nearly 70% of the population relying on it for their livelihoods. It goes beyond food and income. farming is deeply rooted in tradition and cultural identity. However, climate change is increasingly threatening this way of life. Irregular rainfall patterns, extreme heat, droughts, and floods are damaging crops and decreasing livestock productivity, particularly in areas heavily dependent on rainfall. Smallholder farmers, already disadvantaged by poor infrastructure, degraded land, and limited resources, are especially vulnerable. Women and marginalized groups face greater risks, often lacking access to land, finance, and climate adaptation tools. The challenges are compounded by the spread of pests like fall armyworms and desert locusts, which destroy crops and intensify food insecurity. Water scarcity is also growing, making it more difficult for communities to sustain farming. Despite these obstacles, many farmers are adopting innovative, climate-smart solutions to adapt. Agroforestry, where trees are planted alongside crops, helps improve soil health and strengthens resilience against weather shocks. Conservation farming methods such as crop rotation and use of cover crops are restoring degraded land and increasing yields. Integrated crop-livestock systems, which combine plant and animal production, are improving farm efficiency and reducing emissions. Nonetheless, widespread adoption of these practices is slowed by financial constraints, weak governance, limited infrastructure, and cultural resistance to new methods. Addressing these barriers requires targeted support enhancing access to credit, empowering local leaders, and investing in rural development. As climate change accelerates, scaling up proven strategies and promoting locally appropriate solutions is crucial. Ensuring Africa's farmers can adapt not only safeguards food security but also protects livelihoods, traditions, and the long-term stability of rural communities across the continent.

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INTRODUCTION

In most of rural Africa, farming is more than just a job. It is a way of life. It provides food, income, and identity for millions of people in this area. Nearly 70% of the continent's workforce is involved in agriculture, and the sector plays an important role in feeding families and supporting national economies (1). In many communities, the land holds cultural meaning, and farming traditions are passed down from generation to generation. However, this lifeline is under growing threat due to climate change. Most farming in Africa depends on rain. That means when the weather changes, when the rains come late or not at all, everything is at risk. And with climate change, these disruptions are becoming more frequent and severe, especially affecting rural farmers. Rising temperatures, unpredictable rainfall, long dry periods, and flooding are already taking a toll. Crops like maize, millet, and sorghum, which are staples for millions of people across the continent, are producing less because of heat stress and water shortages (2). Farmers who raise animals are also struggling. Droughts have dried up pastures and water sources, leading to livestock deaths and lower production of meat and milk (3). On top of these climate-related challenges, many farmers face other long-standing issues like soil degradation, limited access to good seeds or farming tools, and poor infrastructure (4). For smallholder farmers, especially women and marginalized groups, these combined pressures can be overwhelming. They often have fewer resources, less access to credit, and limited influence over the decisions that affect their farms (5). Climate change also brings new problems, like pest outbreaks. In recent years, invasive species such as fall armyworms and desert locusts have destroyed crops in parts of East and Southern Africa (6). Water scarcity is becoming an even bigger concern. With over 95% of African agriculture relying on rainfall, erratic weather patterns threaten not only day-to-day farming but the future of agricultural sustainability itself (6). In response, a growing number of farmers, governments, and organizations are turning to innovative solutions. These include climate-smart practices like agroforestry, using drought-tolerant seeds, improving irrigation, and sharing up-to-date weather information (1). Efforts are also being made to train farmers, provide insurance, and set up early warning systems (7). Still, many of these initiatives face hurdles from lack of funding to weak infrastructure and limited political support. This review, therefore, explores the climate change mitigation strategies they are using, whether through new techniques, traditional knowledge, or external support, and assesses how effective these efforts are in keeping farming sustainable. The focus is on smallholder and subsistence farmers working in different environments, from drylands to wetter regions, and covering both crop and livestock systems. With climate threats mounting, understanding what works and what doesn't is crucial for shaping future agricultural policies and investments that support Africa's farmers where it matters most (8, 9, 7). The review will highlight the key mitigation strategies used by rural farmers, their role in promoting agricultural sustainability, and the challenges that hinder their successful implementation.

Climate change mitigation strategies and their contribution to agricultural sustainability: Climate change mitigation strategies play a crucial role in enhancing agricultural sustainability by helping farmers adapt to and reduce the impacts of changing climate patterns, ensuring the long-term viability of food production systems. Different strategies are employed in various regions, each with unique approaches and impacts, depending on local environmental conditions and agricultural practices. This section examines these diverse strategies and assesses their effectiveness in promoting sustainable farming across different contexts.

Blending Trees with Farming: Blending trees with farming, also known as agroforestry, has emerged as an important strategy for addressing the challenges of climate change in Africa. This practice, which integrates trees alongside crops, offers a range of benefits for both the environment and the people who rely on agriculture for their livelihoods. In Africa, where agriculture is both a source of income and food, yet highly vulnerable to climate shifts, agroforestry provides a sustainable and adaptable solution that can help farmers cope with the unpredictable impacts of climate change. In Kenya's Nakuru County, for example, small-scale farmers have begun adopting agroforestry, along with other sustainable farming practices, to adapt to increasingly erratic weather patterns. By planting trees alongside crops, farmers are able to rejuvenate soils, restore local biodiversity, and increase the resilience of their farms to unpredictable weather events. These trees not only help protect the soil from erosion and enhance water retention but also contribute to better air quality by absorbing carbon dioxide and converting it into oxygen during photosynthesis (9). In South Africa's North West Province, the likelihood of adopting agroforestry is influenced by factors like age, education, and access to farming advice (10). This emphasizes the need for targeted support to encourage more farmers to take up agroforestry practices. In Kenya and Rwanda, farmers are planting trees like Faidherbia albida and Gliricidia sepium to naturally replenish nitrogen in the soil. These trees act as natural fertilizers, reducing the need for costly chemical inputs and improving soil fertility, even during dry years with limited rainfall (10). Research has shown that agroforestry provides significant environmental benefits across the continent. Meyfroidt *et al*. (2018) found that agroforestry can improve soil fertility, conserve water, and reduce soil erosion—issues that are especially important for farmers in drought-prone areas. In regions like the Sahel, where the land is often harsh and degraded, agroforestry has proven to be a key strategy for stabilizing the soil and boosting crop yields, helping farmers become more resilient to climate challenges (11). Similarly, Giller *et al*. (2017) found that trees in farming systems can create microclimates that protect crops and livestock from extreme temperatures. Additionally, trees provide economic benefits by offering timber, fruit, and fuelwood, which farmers can sell for extra income. This dual benefit of environmental health and economic opportunity makes agroforestry a valuable practice for improving rural livelihoods (9). A study by Kiptot *et al*. (2016) in Kenya highlighted how agroforestry helps farmers cope with climate extremes like droughts and floods. By conserving moisture in the soil, trees provide crops with the necessary resources during tough weather conditions. This ability to withstand climate shocks has made agroforestry an essential tool for increasing the resilience of farmers to climate change (10).

However, despite the many advantages, adopting agroforestry is not without its challenges. Njuki *et al*. (2019) identified several barriers preventing farmers from fully embracing agroforestry, such as limited access to tree seedlings, lack of knowledge, and land tenure issues. The study stresses that agroforestry can succeed when farmers receive the right kind of support, such as training, resources, and policy initiatives.

Agroforestry offers great potential for enhancing agricultural sustainability in Africa. It improves soil health, boosts biodiversity, and provides farmers with additional sources of income. However, to unlock the full potential of agroforestry, there is a need for continued support in the form of research, training, and targeted policies that can help overcome the challenges that farmers face.

Smarter ways to farm: climate-smart agriculture and conservation practices: In the face of climate change, many farmers in Africa are increasingly turning to smarter, more sustainable farming practices to ensure their farms remain productive and resilient. One of the key approaches gaining traction is conservation farming, which involves methods like crop rotation, reducing plowing, and using cover crops to protect the soil. These practices not only help farmers reduce harmful emissions but also improve the long-term health of their land. In countries such as Namibia and Uganda, these conservation techniques are becoming more widespread as farmers seek ways to adapt to unpredictable weather patterns. Alongside conservation farming, another powerful strategy that is gaining ground is climate-smart agriculture (CSA). CSA combines sustainable practices with efforts to increase food production and adapt to climate challenges, addressing the need for both environmental stewardship and enhanced productivity (16).

In many regions of Africa, CSA is helping farmers make small but meaningful changes that lead to significant improvements. For example, by rotating crops, minimizing deep plowing, and covering the soil with mulch, farmers are able to retain moisture, prevent erosion, and even reduce carbon emissions. These adjustments ensure that the land can better withstand droughts and other climate-related shocks, while also improving food production. CSA practices are especially beneficial for smallholder farmers who are feeling the impacts of climate change more acutely, helping them maintain stable yields despite erratic weather patterns (15). Furthermore, farmers are planting more resilient crop varieties, improving their water management practices, and increasing the efficiency of their irrigation systems, making their farming systems more adaptive to changing climate conditions. In Kenya, research by Thornton *et al*. (2018) found that smallholder farmers who implemented CSA practices such as intercropping, mulching, and crop diversification experienced higher yields and more stable incomes. These farmers were better equipped to cope with extreme weather events like droughts and floods, showing how even small changes in farming practices can significantly increase resilience. Similarly, Garrity *et al*. (2017) emphasized that CSA plays a dual role in both mitigating climate change and adapting to it. They highlighted the restoration of degraded lands and the integration of trees into farming systems, which not only help sequester carbon but also improve soil fertility, water retention, and biodiversity. These practices have proven especially valuable in areas affected by land degradation, where soil health is a major concern (19). While the benefits of CSA are clear, Mwongera *et al*. (2017) identified several barriers that hinder its widespread adoption. These include limited access to climate information, inadequate infrastructure, and a lack of financial support for smallholder farmers. Despite these challenges, the study emphasized that CSA can thrive when farmers receive the necessary support, including access to resources, knowledge, and training. The key to increasing the adoption of CSA lies in overcoming these barriers through targeted interventions that address the specific needs of farmers.

Smarter farming practices, including climate-smart agriculture and conservation farming, offer vital solutions for enhancing agricultural sustainability in Africa. These approaches help improve soil health, boost food production, and increase resilience to climate change. However, for these practices to reach their full potential, more support is needed to address the barriers limiting their adoption. With continued investment in research, capacity-building, and policy support, CSA and conservation farming can help secure a more sustainable future for Africa's farmers, ensuring food security and environmental health for generations to come.

Making the Most of Livestock and Crops Together: Integrating livestock with crop farming has emerged as a sustainable and effective approach to adapting to and mitigating the impacts of climate change in many African communities. Integrated crop-livestock systems, which combine both livestock and crop farming on the same land, are becoming increasingly popular because they allow farmers to optimize their resources, boost productivity, and reduce greenhouse gas emissions. The main advantage of these systems lies in their ability to recycle nutrients and improve soil fertility, which helps to ensure farm sustainability and climate resilience (20). A key benefit of integrated systems is the use of manure from livestock as a natural fertilizer, which reduces the reliance on synthetic fertilizers that contribute to high carbon emissions. Manure helps enrich the soil, improving its fertility and reducing the need for chemical inputs (21). Additionally, crop residues can be fed to livestock, closing the nutrient loop and minimizing waste. This integrated approach not only helps sequester carbon in the soil but also reduces methane emissions through improved manure management and enhanced feed quality, contributing to both climate change mitigation and more sustainable farming practices (20). For example, in South Kivu, Democratic Republic of Congo (DRC), farmers are combining livestock with crop farming and employing strategies like better animal feed, soil erosion control, and income diversification. This integrated approach enables farmers to recycle waste into fertilizer, optimize land use, and create multiple income streams, which helps them build resilience against the impacts of climate change (21). By diversifying their income sources, these farmers are better able to withstand climate shocks, such as droughts and pest outbreaks, that might otherwise threaten their livelihoods. Studies across sub-Saharan Africa have shown that integrated crop-livestock systems tend to be more efficient in land use and better able to adapt to climate variability than monoculture systems. Research by Makate *et al*. (2016) found that farms practicing integrated systems have higher land productivity and improved resilience to adverse weather patterns. In regions affected by drought or erratic rainfall, such as parts of Kenya and Tanzania, integrated systems help stabilize food production by providing both crop and livestock products. This diversification reduces farmers' vulnerability to climate shocks and ensures a more stable income over time (22). To scale up the adoption of integrated crop-livestock systems, policy and institutional support are essential. Governments and non-governmental organizations (NGOs) must invest in farmer education and provide better access to resources, including improved livestock breeds, quality seeds, and knowledge about climate-smart practices. Inadequate infrastructure and a lack of financial support often limit the capacity of farmers to adopt these practices, despite the clear benefits (21). With the right support, integrated crop-livestock farming can become a key component of climate-smart agriculture, offering a solution that addresses both food security and environmental sustainability across Africa.

In conclusion, integrated crop-livestock systems are a promising strategy for enhancing agricultural resilience to climate change in Africa. These systems offer multiple benefits, including improved soil health, reduced carbon emissions, and diversified income sources. However, for these practices to become widespread, concerted efforts from governments, NGOs, and agricultural institutions are needed to address barriers such as lack of knowledge, access to resources, and insufficient infrastructure. Continued research, capacity-building, and policy support will be crucial to realizing the full potential of integrated farming systems in building climate resilience and sustainable agricultural practices across Africa.

Powering up with the sun: solar energy in rural farming communities: In many parts of rural Africa, solar energy is becoming a game-changer, providing a cleaner, more reliable energy source that is helping to transform farming practices. In countries like Kenya and Nigeria, solar mini-grids are offering a way out of the dependence on polluting fuels like kerosene, which are harmful to both the environment and the health of those who use them. By supplying dependable electricity to farming communities, these solar mini-grids are supporting essential activities such as irrigation, food storage, and even small-scale businesses. This shift not only helps reduce the reliance on fossil fuels but also supports greater productivity, giving farmers a sustainable and affordable energy source for their day-to-day needs (23). A growing example of how solar energy is supporting farming comes from Uganda, where solar-powered smart irrigation systems are helping farmers make the most of their water resources. These systems, which are connected to mobile networks, allow farmers to monitor soil moisture levels and adjust irrigation schedules accordingly. This technology enables farmers to irrigate their crops efficiently, saving water, and ultimately improving productivity while combating water scarcity—a growing issue in many parts of Africa (24). These systems are not just boosting agricultural yields but are also making farming practices more sustainable in regions where water is limited and erratic rainfall patterns can severely impact crop production.

In addition to enhancing irrigation efficiency, solar energy is also providing critical support for food storage and processing. Solar-powered systems are being used to run cooling units and drying systems, which significantly reduce post-harvest losses—an issue that farmers across Africa often face. By improving the shelf life of crops, solar energy helps ensure that food remains available even after harvest, reducing waste and contributing to food security. For instance, in Kenya, farmers are using solar-powered coolers to store fresh produce, allowing them to sell their products over a longer period, improving their incomes (25). Solar energy also plays a crucial role in improving farmers' economic stability. With reliable access to power, farmers are able to run small businesses, such as processing crops or producing dairy products, which adds an additional income stream. The widespread use of solar power for farming activities supports both the environment and the economy by offering a sustainable way to increase agricultural production while decreasing reliance on fossil fuels (23).

The environmental benefits of solar energy are not limited to its use in irrigation and storage. Solar energy reduces greenhouse gas emissions by cutting the need for kerosene and other polluting fuels, making it an essential part of the broader effort to mitigate climate change. According to Thornton *et al.* (2018), solar mini-grids and related technologies have helped farmers transition from high-emission sources of energy to cleaner alternatives, supporting both climate change mitigation and the resilience of farming communities (26). However, there are still challenges to widespread solar adoption, particularly in remote areas where the initial investment in solar infrastructure can be prohibitive. Moreover, many farmers lack the technical knowledge required to maintain solar systems effectively. To overcome these challenges, ongoing support, including access to financing, technical training, and infrastructure development, will be critical in expanding solar energy use across rural Africa (27). With continued investment and policy support, solar energy can play a key role in making African farming more resilient to climate change, while improving both food security and environmental sustainability. Solar energy is transforming agriculture in rural Africa by providing clean, reliable energy for irrigation, storage, and small businesses. Solar mini-grids help increase productivity, reduce waste, and boost farmers' income, while also contributing to climate change mitigation. As technology advances and resources expand, solar energy has the potential to make farming more sustainable, helping communities better adapt to climate challenges.

Old Wisdom for New Challenges: leveraging traditional knowledge in modern farming: Traditional knowledge remains a vital component of farming practices in many rural areas, particularly in regions of Africa where climate change poses significant challenges to agricultural productivity. Across the continent, time-honored techniques such as intercropping, crop diversification, and the use of natural fertilizers have been passed down through generations, providing a sustainable and cost-effective way for farmers to adapt to changing climatic conditions. In Zimbabwe's Nyanga District, for instance, local communities have preserved practices like planting drought-resistant crops such as millet and sorghum. These grains have long been used to withstand dry spells, making them crucial for farmers facing increasingly erratic rainfall patterns (28). Additionally, farmers in Nyanga have continued the practice of building terraces to prevent soil erosion, a technique that not only conserves soil but also helps in water retention, ensuring that the land remains productive even in challenging conditions.

These traditional practices are especially valuable in areas where modern technologies and external support may not be readily available. Intercropping, for example, involves growing multiple crops in the same space, which can help in improving soil fertility, reducing the spread of pests, and increasing overall farm resilience to environmental stress (28). By working with nature rather than against it, these methods foster a balance that enables farmers to maintain the productivity of their land while reducing the need for synthetic inputs that can be costly and harmful to the environment. Research also shows that traditional farming methods, when combined with modern scientific knowledge, can greatly enhance agricultural sustainability. For example, studies have found that integrating indigenous agricultural practices with modern climate-smart approaches can create more resilient farming systems (29). This blending of old and new is seen in various parts of Africa, where farmers are increasingly looking to their ancestors' knowledge to solve new challenges posed by climate change. However, despite the effectiveness of these traditional techniques, challenges remain in scaling them up and integrating them into national policies. Limited access to financial resources and technical support often hinders the widespread adoption of these practices (28). As a result, there is a need for greater investment in supporting rural farmers with the necessary tools and knowledge to integrate these traditional methods with modern innovations. Traditional farming knowledge offers valuable lessons for building climate-resilient agricultural systems in Africa. Practices like intercropping, crop diversification, and soil conservation techniques have stood the test of time, providing cost-effective and sustainable ways to cope with climate variability. With increased support and recognition, these traditional methods can be enhanced and integrated into broader agricultural strategies, ensuring that they continue to serve as a cornerstone of food security and sustainability for future generations.

Challenges and Barriers to Implementing Mitigation Measures: Rural communities across Africa face multiple challenges when trying to implement climate change mitigation strategies, and one of the biggest obstacles is financial constraints. Limited access to funding makes it difficult for these communities to invest in modern tools, improve infrastructure, and adopt sustainable practices that can help them adapt to and mitigate the impacts of climate change.

Financial Constraints: Financial limitations are a major barrier to effective climate action in Africa. Many countries across the continent, like South Africa, face challenges in securing the necessary climate finance to support mitigation efforts. This lack of funding restricts rural communities' ability to implement essential climate-resilient strategies, such as the use of renewable energy or the adoption of climate-smart agriculture. Without sufficient financial resources, farmers cannot invest in technologies like solar-powered irrigation or water-efficient systems that could enhance productivity and reduce environmental impacts (30).

Additionally, many African nations, including Zimbabwe, struggle with energy poverty, which further compounds the financial difficulties. With limited access to reliable and affordable energy, rural communities are unable to take full advantage of climate-smart technologies. This reliance on outdated farming methods without financial support keeps communities vulnerable to the impacts of climate change, such as droughts, floods, and erratic weather patterns (31). Research in Zimbabwe has shown that without proper financial backing, rural farmers are unable to transition to more sustainable farming practices. This makes it harder for them to adapt to climate change and limits their capacity to improve agricultural yields in the face of increasingly unpredictable weather patterns (28).

Financial constraints significantly hinder the implementation of climate change mitigation strategies in rural African communities. Limited access to climate finance, energy poverty, and the absence of sufficient public and private investment prevents farmers from adopting sustainable practices that could improve their resilience to climate impacts. Addressing these financial barriers through better access to funding, government policies, and international support is critical to enabling African farmers to cope with the challenges posed by climate change.

Institutional and Governance Limitations: Institutional and governance challenges are significant barriers to implementing effective climate change mitigation measures in many rural African communities. A key issue is the weakness of institutions tasked with addressing climate change. In several African countries, local governments often struggle with outdated systems, a lack of technical expertise, and insufficient political will to prioritize climate change initiatives. For example, in Zimbabwe, the implementation of climate adaptation strategies is frequently delayed due to poor coordination among government bodies, non-governmental organizations, and local communities. This lack of alignment hampers efforts to tackle the pressing climate challenges in rural areas (35). Uganda faces similar difficulties. The disconnect between the central government and local communities results in ineffective implementation of climate policies and programs. The central government's inability to engage meaningfully with local farmers and community leaders prevents tailored solutions that address specific local climate vulnerabilities. Without strong leadership and collaborative governance, efforts to mitigate climate change in rural areas are often fragmented and inefficient (35). Moreover, institutional constraints extend beyond coordination challenges. A lack of technical expertise in local government bodies often means that there is insufficient capacity to implement modern climate adaptation technologies, such as renewable energy solutions or sustainable agricultural practices. In southern Africa, many local institutions face infrastructure deficits that hinder their ability to implement climate-resilient strategies effectively. This further exacerbates vulnerabilities to climate shocks, such as droughts and floods (36). To make meaningful progress, strong institutional frameworks and effective governance are critical. Governments must prioritize capacity building in local institutions, enhance coordination between stakeholders, and ensure that policies are aligned with the needs of rural communities. Additionally, strengthening the relationship between central and local governments will foster a more coordinated and comprehensive approach to addressing climate challenges.

Technological and Infrastructure Deficits: A significant barrier to addressing climate change in many rural African communities is the lack of adequate infrastructure and technology. Many areas across the continent lack basic infrastructure such as roads to connect farms to markets, electricity, and reliable water systems all essential for supporting even the most basic climate change mitigation efforts (32). This lack of infrastructure limits the ability of rural farmers to implement more advanced and sustainable agricultural practices that could improve their resilience to climate challenges (33).

Beyond the absence of infrastructure, the issue extends to the lack of access to climate-friendly technologies. Many communities do not have the technical training or exposure needed to utilize available natural resources efficiently. For instance, solar-powered irrigation systems, which have proven to be effective in improving water management and enhancing resilience in farming systems, are still unavailable in many rural areas (37). Similarly, improved storage facilities and weather forecasting tools, which can significantly reduce crop losses and help farmers prepare for extreme weather events, remain out of reach for many (23). Further compounding the problem is the widespread digital illiteracy and poor internet connectivity in rural areas. These technological gaps make it difficult for farmers to access online extension services, climate information platforms, and agricultural training, all of which are critical for adapting to and mitigating the effects of climate change (34). Without access to modern technologies and the necessary skills to use them, rural farmers are unable to take full advantage of innovations that could help them better manage climate risks and improve productivity (33). The lack of technological access and infrastructure not only hampers climate adaptation efforts but also keeps farmers trapped in traditional, less efficient practices that are less resilient to climate shocks. Addressing these deficits by improving infrastructure, increasing access to climate-smart technologies, and providing training in their use is crucial to enhancing the capacity of rural communities to deal with climate change.

Sociocultural and Educational Barriers: Social and cultural factors play a significant role in hindering the adoption of climate change mitigation strategies in rural Africa. In some communities, traditional beliefs and cultural practices can conflict with modern approaches to land management, conservation, or climate adaptation. For instance, practices like tree planting, which is often promoted as a key climate change mitigation strategy, may be seen as disrupting sacred land uses or conflicting with local customs. In Ghana, for example, some rural farmers view the introduction of new crops or agricultural practices as a threat to traditional food systems or cultural practices (40). This resistance to change is compounded by a lack of trust in unfamiliar farming methods, particularly among older farmers, who are more likely to hold onto traditional practices passed down through generations. Additionally, women, who make up a significant portion of the agricultural workforce in Africa, often face socio-cultural barriers that limit their ability to implement climate change mitigation measures. These barriers include restricted access to land ownership, limited financial services, and inadequate access to agricultural training, which hinders their involvement in modern farming practices. In some regions, women are also excluded from decision-making processes related to agricultural and environmental policy, further limiting their capacity to contribute to climate adaptation efforts (13).

These gender-based challenges need to be addressed to empower women farmers and increase the adoption of climate-smart agricultural practices across the continent. Moreover, many rural farmers, particularly in sub-Saharan Africa, lack formal education, which can be a significant barrier to adopting new technologies or methods. Educational constraints often lead to a lack of awareness about climate change and available adaptation strategies. Without proper education and training, farmers may be hesitant to invest in unfamiliar technologies or practices, even when they are proven to be beneficial in enhancing resilience to climate-related challenges (42). Thus, there is an urgent need for both educational interventions and policies that consider socio-cultural dynamics to foster greater acceptance of climate change mitigation measures.

Policy and Funding Gaps: While climate change has become a global priority, many African countries continue to face significant gaps between high-level climate policies and their practical implementation at the local level. Although several African nations have developed national climate strategies, these are often not backed by adequate funding or clear plans for local execution. This disconnect can limit the effectiveness of the strategies, leaving rural communities vulnerable to the impacts of climate change. A study by Mbow *et al.* highlighted that despite the adoption of national climate frameworks, insufficient funding often results in the stagnation of climate change adaptation efforts, particularly in rural regions where resources are already scarce (16).

Moreover, poor coordination between various government ministries, non-governmental organizations (NGOs), and private sector actors further exacerbates the problem. Without effective collaboration, efforts are sometimes duplicated, or opportunities are missed to consolidate resources and expertise. For example, climate-smart agriculture projects may initially show promise, but they often fail to scale up or lack long-term support, as noted in the work of Nyahunda and Tirivangasi. These projects can falter when local governments do not prioritize them or fail to provide the necessary resources to sustain them over time. Without stable and reliable funding mechanisms, many climates adaptation and mitigation projects stall before they reach their full potential (31). The absence of reliable policy frameworks and continuous funding leaves rural communities in a perpetual state of vulnerability, unable to address long-term climate risks. It is evident that for climate change mitigation and adaptation strategies to succeed, there must be an improvement in policy design, coordination, and sustainable funding mechanisms. This includes aligning international climate finance with local needs and ensuring that policies are implemented effectively at the grassroots level.

DISCUSSION

The findings from this review highlight a range of strategies and challenges that shape the agricultural sustainability of rural communities in Africa, with a particular focus on climate change mitigation efforts. Among the strategies discussed, agroforestry stands out as a powerful tool for increasing resilience and sustainability. Research from Kenya, South Africa, and Rwanda shows that integrating trees with farming not only improves soil health and enhances biodiversity but also contributes to better water retention and carbon sequestration (14); (10). However, the adoption of agroforestry is hindered by barriers such as limited access to tree seedlings, lack of technical knowledge, and land tenure issues (13). This contrasts with findings from studies on climate-smart agriculture (CSA), which emphasize crop rotation, minimal plowing, and water-efficient practices. CSA has shown promise in countries like Uganda and Namibia, where these methods help farmers adapt to droughts and other climate-related shocks (16). CSA is particularly beneficial for smallholders who are most vulnerable to climate change, but challenges such as limited access to resources and infrastructure remain (15).

The discussion of integrated crop-livestock systems also reveals their potential in increasing land productivity and reducing greenhouse gas emissions. The combination of livestock and crops optimizes the use of resources, improves soil fertility, and enhances resilience to climate change (23); (22). This integrated approach has been found to be more efficient than monoculture farming, particularly in regions like South Kivu and sub-Saharan Africa (20); (21). While the benefits are clear, the adoption of such systems is constrained by financial limitations and the lack of adequate policy support (22). Furthermore, solar energy emerges as a game-changer for rural farmers, offering a cleaner and more reliable source of energy for irrigation, storage, and small businesses. Solar-powered technologies, such as irrigation systems and storage coolers, have the potential to boost productivity, reduce waste, and support smallholder incomes (25); (16). However, the lack of infrastructure, high initial investment costs, and technical knowledge prevent widespread adoption (15).

Despite these promising strategies, several challenges continue to hinder progress. Financial constraints are perhaps the most pressing issue, with limited access to climate finance, energy poverty, and insufficient funding for climate resilience initiatives (30); (31). Institutional weaknesses, such as poor coordination between government ministries and lack of technical expertise, further exacerbate the situation (35). Technological deficits, including poor infrastructure and limited access to climate-smart technologies, also present significant barriers (32); (33). Socio-cultural factors, such as resistance to change and gender-based constraints, add another layer of complexity, particularly for women and older farmers who are less likely to embrace new farming practices (13); (40). The gap between national climate policies and local implementation is another critical issue, with many countries lacking the resources and governance structures needed to effectively execute climate strategies at the grassroots level (16). While there are promising strategies to tackle climate change and support sustainable farming, these efforts are still held back by challenges like limited funding, weak institutions, poor infrastructure, and cultural barriers. The success of climate-smart strategies relies not only on adopting new technologies but also on overcoming these obstacles. Addressing these issues will be crucial for creating more resilient farming systems in Africa.

CONCLUSION

In conclusion, while Africa has made progress in adopting climate change strategies to help farming become more sustainable, there are still significant barriers that prevent these efforts from reaching their full potential. Techniques like agroforestry, climate-smart agriculture, and solar energy have shown promise in improving resilience to climate change, but challenges such as lack of funding, weak institutions, poor infrastructure, and cultural resistance continue to hinder their widespread use. The key to success lies not just in introducing new technologies, but also in addressing these challenges. Farmers need better access to financial support to invest in sustainable practices, and there's a need for stronger coordination between governments, NGOs, and local communities. Socio-cultural barriers, such as resistance to change and limited education, also need to be overcome. Furthermore, rural areas often lack the infrastructure needed to support modern climate-smart technologies. To make these strategies work on a larger scale, policies must be better aligned with local needs. Governments, organizations, and private sectors must invest in infrastructure, provide easier access to climate finance, and offer education and training to farmers. It's also important to involve communities in ways that respect their cultural beliefs. By addressing these gaps, Africa can create more resilient farming systems that will be better equipped to face climate challenges in the future.

Recommendations to improve climate mitigation and support for farmers: To address the challenges facing climate change mitigation and agricultural sustainability in rural Africa, several recommendations can be proposed. These recommendations aim to support the adoption of effective strategies and overcome the barriers identified in the review which could be adapted by local farmers and are feasible

Increase access to climate-smart technologies: Providing farmers with affordable and accessible climate-smart technologies, such as solar-powered irrigation systems, drought-resistant crop varieties, and weather forecasting tools, is essential. Training farmers on how to effectively use these technologies will help enhance productivity and build resilience against climate challenges.

Promote knowledge sharing and farmer networks: Encouraging farmer-to-farmer knowledge sharing and creating local networks where farmers can exchange ideas on sustainable practices, such as agroforestry and conservation farming, can be highly effective. Peer learning and community-based solutions can empower farmers to adopt and adapt climate-resilient practices that suit their local conditions.

Enhance financial support for smallholder farmers: Offering microloans, subsidies, or insurance schemes specifically for smallholder farmers will enable them to invest in the technologies and practices that improve resilience. This financial support can help farmers overcome barriers to accessing the resources they need to adapt to climate change.

Strengthen training on sustainable agricultural practices: Providing farmers with consistent training on sustainable farming practices, such as crop rotation, intercropping, and soil conservation, can boost soil health, enhance biodiversity, and improve long-term agricultural productivity. Practical, hands-on training will help farmers make informed decisions and adopt new techniques confidently.

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