Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 10, No. 9, 190-201
2026
Publisher: Learning Gate
DOI: 10.55214/2576-8484.v10i9.13593

Climate change and food security in Southern Africa: Adaptation pathways for smallholder farmers

Shingirai Mugambiwa[1]*
[1]Department of Research Administration and Development, University of Limpopo, X1106, Sovenga 0727, South Africa; shingirai.mugambiwa@ul.ac.za (S.M.).

Abstract: Climate change threatens food security in Southern Africa by disrupting rainfed production, rural incomes, dietary quality, and the stability of food supplies. This qualitative review examines these linkages and identifies adaptation pathways relevant to smallholder farmers. Database and repository searches initially identified 45 records; after screening titles, abstracts, and full texts, 20 core sources were retained for thematic analysis, while supplementary sources were used for conceptual and methodological context. The synthesis shows that rising temperatures, erratic rainfall, droughts, and floods shorten growing seasons, reduce soil moisture, damage crops and livestock, and intensify seasonal food insecurity. Farmers respond through crop diversification, drought-tolerant crops, conservation agriculture, agroforestry, water harvesting, livelihood diversification, and climate-information services. However, adoption remains uneven because finance, irrigation, extension, secure land tenure, infrastructure, markets, and usable forecasts are limited. The paper argues that no single intervention is sufficient. Effective adaptation requires coordinated packages that connect farm-level practices with inclusive institutions, climate services, rural infrastructure, and social protection. Such integration can strengthen food availability, access, utilisation, and stability without treating smallholders as a homogeneous group.

Keywords: *Adaptation, Climate change, Food security, Smallholder farmers, Southern Africa.*

1. Introduction

Climate change is one of the most acute challenges facing the world today, with far-reaching consequences for food systems, including in developing areas such as Southern Africa [1]. The region is highly vulnerable because it relies on climate-sensitive sectors, especially agriculture. Most agricultural production in Southern Africa is rain-fed and therefore highly vulnerable to climate variability [2]. Smallholder farmers are an important part of local and regional food systems but are particularly susceptible to changes in rainfall and temperature. The region has already experienced rising temperatures, shifts in rainfall patterns, and increased instances of extreme weather events in recent decades. These changes have disrupted agricultural cycles and reduced productivity [3]. They impact the four dimensions of food security: availability, access, utilisation, and stability. Climate pressures cause immediate shocks and longer-term stresses to these dimensions. This is further aggravated by decreasing agricultural productivity, which puts additional pressure on already vulnerable systems as the demand for food increases [4, 5]. Smallholder farmers usually have limited access to resources such as irrigation, improved seeds, and financial services [6]. This limits their capacity to deal with climate-related problems effectively. Food security is more difficult to improve because climate change interacts with other factors, such as land degradation and market volatility. However, there is increasing awareness of the need for adaptation strategies targeted to the needs of smallholder farmers [7, 8]. These strategies aim to improve resilience and sustain agricultural productivity. Regional and international arrangements address climate adaptation, but implementation varies from country to

History: Received: 11 June 2026; Revised: 14 August 2026; Accepted: 19 August 2026; Published: 16 September 2026
* Correspondence: shingirai.mugambiwa@ul.ac.za

country. The objective of this paper is to assess the relationship between climate change and food security in Southern Africa, with particular emphasis on adaptation pathways for smallholder farmers.

2. Literature Review

2.1. Climate Change Trends in Southern Africa

The impact of climate change in Southern Africa is well documented, and there is strong evidence of rising temperatures across the region [9]. Studies have shown that mean temperatures have been rising gradually over the last few decades, contributing to changes in agro-ecological circumstances. Increasing temperatures have caused higher rates of evapotranspiration, leading to less moisture in the soil and increased stress on crops and water resources [10]. Rainfall patterns are more erratic and less predictable. The rainy season is usually short and ends early, reducing the length of the growing period [11]. This unpredictability affects historical farming calendars and prevents farmers from planning agricultural activities. Drought is one of the most serious climate-related hazards in the region and has increased in frequency and severity [12]. Such prolonged dry periods are disastrous for crop production and livestock systems and often cause widespread agricultural losses. The effects are compounding, and communities often have little time to recover between successive drought seasons. Droughts are the most common hazard, but in some locations, floods are becoming more severe. These floods can destroy crops, damage infrastructure, and cause soil erosion, consequently reducing future agricultural productivity.

Climate change has significantly affected agricultural productivity in Southern Africa, particularly for staple crops like maize. Food production has become less reliable due to variability in rainfall and rising temperatures, which have reduced yields [13]. Crop failures are increasingly reported, especially in drought years. Phiri et al. [14], in a study of Zimbabwean smallholder farmers' cropping choices and patterns, showed that small-grain crops like sorghum and millet are often promoted as more resilient alternatives [14]. However, uptake has been patchy owing to cultural preferences, market constraints, and limited access to improved seed varieties. Maize nevertheless remains dominant, even though it is vulnerable to climate stresses. Climate change has also had a negative impact on livestock production. The reduction in available pasture due to drought and land degradation has reduced livestock health and productivity. Water shortages further aggravate these problems and lead to increased mortality rates among animals [15]. Changes in crop and livestock productivity have significantly affected the resilience of agricultural systems.

2.2. Climate Change and the Four Dimensions of Food Security

Climate change has resulted in increased food insecurity in Southern Africa [16]. Millions of people experience periodic food shortages, particularly in drought years. These shortages have serious consequences for nutrition, health and general well-being. The most vulnerable are smallholder farmers, who depend mainly on rain-fed agriculture [17]. Limited access to financial resources, technology and infrastructure reduces their ability to adjust to fluctuating climatic conditions, and they are disproportionately affected by climate shocks [18]. The impacts of climate change on the four dimensions of food security—availability, access, utilisation and stability (Figure 1)- are variable. Food availability is limited by falling agricultural productivity, while access is constrained by falling incomes. Household diets are less diverse, which reduces their nutritional quality. This vulnerability is exacerbated by socio-economic factors such as poverty, inequality, and limited market access [19]. These factors are interconnected with climate change and pose complex challenges requiring integrated solutions to improve food security outcomes.

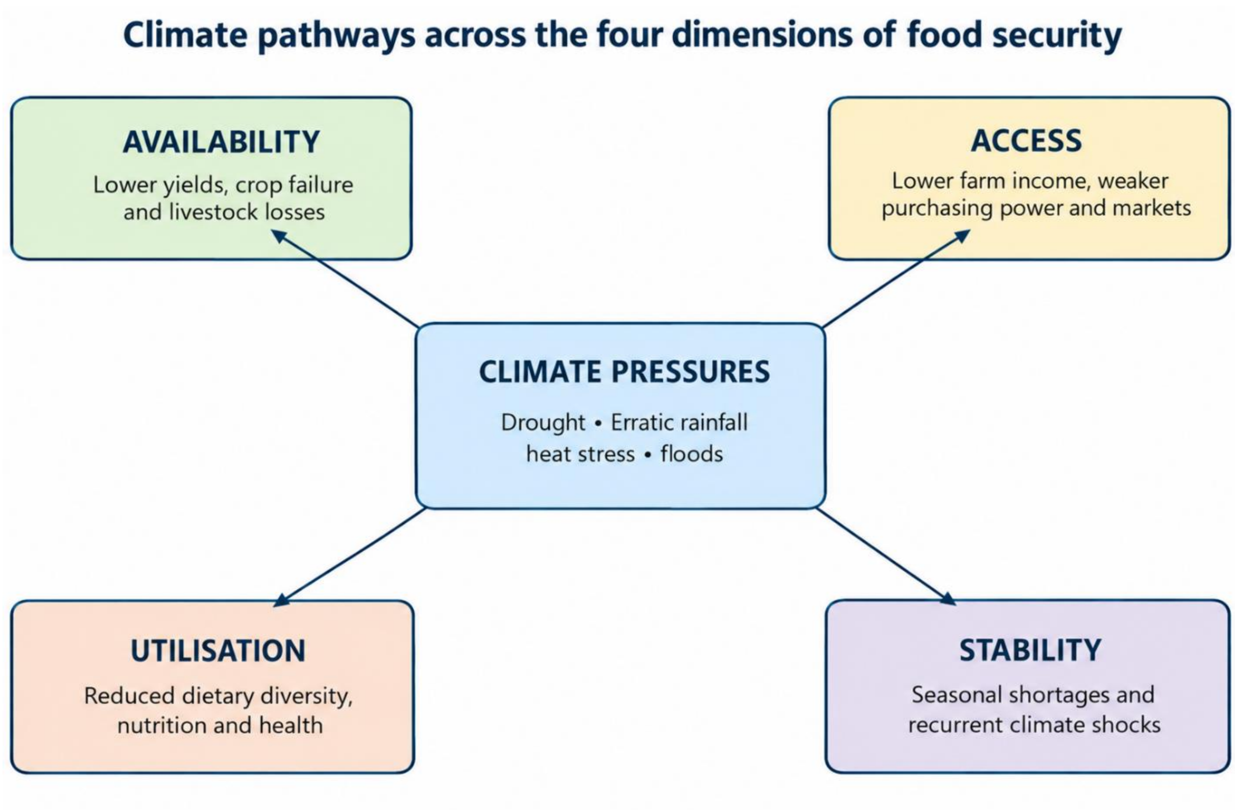

Figure 1.
Climate pathways across the four dimensions of food security in Southern Africa.

To address climate change impacts in Southern Africa, adaptation strategies have been a major focus. Farmers have increasingly adopted practices such as crop diversification, conservation agriculture, and water harvesting to improve resilience [20]. These strategies are intended to reduce risk and stabilise production in a changing climate. Indigenous knowledge systems have important implications for climate change adaptation. Some farmers rely on traditional indicators, such as animal behaviour and plant phenology, to forecast weather and guide farming decisions [21]. This knowledge, built over generations, is still useful in the local setting. Indigenous knowledge remains valuable, but its practical reach can be strengthened when it is combined with accessible scientific forecasts and appropriate agricultural technologies [21, 22]. The literature stresses the urgency of developing integrated adaptation strategies that harness local knowledge and scientific innovation [7, 23]. Strengthening institutional support, improving access to information, and promoting climate-smart agriculture are key steps towards building resilience and ensuring food security in the region.

3. Methodology

This study employed a qualitative desktop-review design based on the analysis of secondary sources. Qualitative review techniques support the synthesis of existing knowledge, identification of recurring themes, and development of a deeper understanding of social, environmental, and policy-related issues from already published sources [24]. The literature search was carried out in major academic databases and online repositories, including JSTOR, Scopus, Web of Science, ScienceDirect, Taylor & Francis Online, SpringerLink, Google Scholar, and institutional websites. The literature search was conducted using specific keywords and Boolean search terms. The keywords included climate change, climate variability, food security, food insecurity, Southern Africa, SADC, smallholder farmers, rainfed agriculture, agricultural productivity, drought, floods, adaptation strategies, climate-smart agriculture, resilience, vulnerability, food availability, food access, food utilisation, and food stability. To narrow the search and ensure that the selected sources were closely aligned with the objectives of the study, Boolean combinations such as "climate change" AND "food security" AND "Southern Africa", "smallholder farmers" AND "adaptation strategies", "climate variability" AND "rainfed agriculture", and "food insecurity" AND "climate change adaptation" were used.

Forty-five (45) sources were initially identified, including journal articles, policy documents, institutional reports, and other relevant grey literature. The sources were evaluated for relevance, credibility, and fit with the focus of the study. After screening the titles, abstracts, and full texts, 20 sources were retained as the core evidence base for thematic coding. Sources were included if they: focused on climate change, food security, or adaptation by smallholder farmers; were directly relevant to Southern Africa or provided insights that could be applied to the region; were published in English; were available in full text; and offered empirical, conceptual, or policy-based evidence relevant to the study. Recent publications, particularly those published from 2017 to 2026, were prioritised, but older sources were also considered when they presented basic definitions or conceptual insights. Sources were excluded if they did not address climate change, food security, or smallholder agriculture directly; focused on regions of limited relevance to Southern Africa; lacked academic or policy credibility; were opinion-based without supporting evidence; duplicated other sources retrieved; or were not available in full text. Content analysis is suitable for documentary and secondary-data research because it enables the researcher to identify patterns, meanings, and repeated themes in textual data [25, 26]. The selected sources were read several times to identify key issues related to climate change impacts, smallholder vulnerability, food security outcomes, and adaptation strategies. Relevant information was coded and placed into thematic categories. The major thematic areas of analysis were: climate change impacts on food security, vulnerability of smallholder farmers, adaptation strategies, constraints to adaptation, and policy responses for resilience building. The analysis was interpretive: similarities, differences, and recurring arguments across the selected sources were compared and synthesised. Supplementary sources cited elsewhere in the paper provide conceptual, methodological, and regional context and were not counted among the 20 core sources. Figure 2 summarises the evidence-selection process.

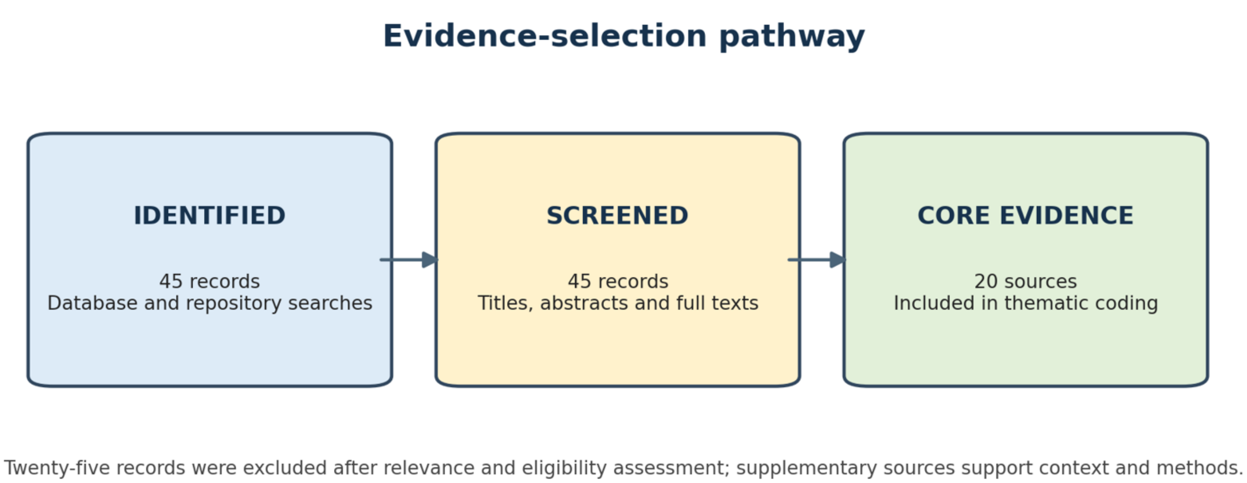

Figure 2.
Evidence-selection pathway for the qualitative desktop review.

3.1. Thematic Synthesis

The coding framework organised evidence into five themes: climate impacts on food security, smallholder vulnerability, adaptation strategies, barriers to adaptation, and policy responses. The analysis compared convergence, divergence, and causal pathways across empirical studies, policy documents, and credible grey literature. Because the included sources differed in design, setting, and outcome measurement, findings were synthesised qualitatively rather than pooled statistically. Table 1 presents the resulting thematic matrix.

Table 1.
Summary of thematic findings, food-security implications and priority responses.

Theme	**Key finding**	**Food-security implication**	**Priority response**
Climate impacts	Erratic rainfall, drought, heat, and floods disrupt planting, yields, livestock, and soils.	Availability, income, diets, and seasonal stability deteriorate.	Climate-resilient production and early warning.
Smallholder vulnerability	Dependence on rainfed farming combines with limited access to finance, irrigation, tenure security, markets and information.	Repeated shocks reduce recovery capacity and deepen household food insecurity.	Finance, irrigation, extension, tenure and market support.
Gender and inequality	Women and marginalised groups often have less access to land, credit, extension services, and decision-making.	Unequal resources weaken household and community resilience.	Gender-responsive and inclusive programmes.
Farm adaptation	Diversified crops, drought-tolerant seeds, conservation agriculture, agroforestry, water harvesting, and livelihood diversification.	Risk is spread and production can become more stable.	Scale locally appropriate packages and connect local and scientific knowledge.
Barriers	Weak institutions, poor infrastructure, limited extension services, unusable forecasts, land degradation, and policy inconsistency.	Adaptation remains uneven, and vulnerability persists.	Coordinated institutions, infrastructure, services, and targeted protection.
Overall synthesis	Climate pressures interact with structural and socioeconomic constraints.	Food insecurity persists when support is fragmented or inaccessible.	Integrated action across production, livelihoods, infrastructure, governance and social protection.

4. Results and Discussion

4.1. Climate Change Impacts on Food Security

Climate change has significantly impacted food production systems in Southern Africa, making agriculture less reliable and sustainable. The region is highly dependent on rainfed agriculture, making it highly vulnerable to climatic changes [27]. Increasingly volatile environmental conditions make consistent agricultural production difficult to sustain Mugambiwa et al. [8]. Yeleliere et al. [28] found that, in rainfed farming systems, unpredictable rainfall disrupts planting schedules, making it challenging for farmers to identify the right time to plant crops. Common consequences include shortened growing seasons due to the late onset of rains and reduced overall crop performance due to uneven rainfall distribution. Droughts are becoming more frequent and severe, posing a major threat to food security. These prolonged dry spells cause large-scale crop failure and significant livestock losses [29]. Many households lose sources of food and income during droughts, making them more vulnerable. Higher temperatures also increase the rate of evapotranspiration, compounding agricultural stress. This process reduces soil moisture and crop water availability, negatively affecting crop growth [30]. Heat stress also lowers crop yields and affects livestock productivity. Extreme weather events, such as floods, have also contributed to food insecurity [31].

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 10, No. 9: 190-201, 2026
DOI: 10.55214/2576-8484.v10i9.13593

Floods are not as common as droughts, but they can be very damaging to crops, farmland, and rural infrastructure. Soil erosion and nutrient loss following floods reduce agricultural productivity in subsequent seasons [31]. This combination of climate factors has led to reduced food availability across wide parts of southern Africa. Fewer agricultural products mean fewer foods for households to eat or sell and greater reliance on external aid. Agricultural incomes continue to fall, and access to food has been negatively affected. In a study on adaptation to climate change and its impact on smallholder farmers' food security in South Africa, Ogundeji [32] found that smallholder farmers who depend on crop and livestock production for both subsistence and income experience reduced purchasing power. This limits their ability to buy food, particularly when they are in need. Dietary diversity has diminished, and nutritional outcomes have worsened. Households tend to shift to less diverse diets consisting of cheaper and less nutritious food options [33]. This has serious health consequences, particularly for vulnerable groups such as children and pregnant women. In many rural areas, seasonal hunger is common. Many households face food shortages during the lean season [34]. These spells of scarcity are becoming longer and more intense, and climate variability is playing a greater role. "Climate change is a serious threat to the stability of food systems in Southern Africa. The effects extend beyond production to food access, utilisation, and stability, indicating the need for holistic strategies to tackle food insecurity in the region."

4.2. Vulnerability of Smallholder Farmers

Smallholder farmers in southern Africa are among the most vulnerable to the effects of climate change, mainly due to their limited access to critical resources. Such farmers typically have low financial capacity to invest in adaptive measures or improved farming technologies [35]. This limits their ability to respond effectively to climate shocks. They depend heavily on rain-fed agriculture and are therefore more vulnerable. Smallholder farmers rely on seasonal rains, which are becoming increasingly erratic in the absence of dependable irrigation systems. Their reliance on agriculture exposes them to climate risks such as droughts and erratic rainfall, leading to fluctuations in agricultural output. Smallholder farmers' capacity to adapt is constrained by limited access to credit. Financial institutions tend to regard small-scale farmers as risky borrowers, so they find it difficult to access loans. Farmers lack credit to purchase important inputs such as improved seeds, fertiliser and water technologies to help them become more resilient [36, 37]. Education and access to information also play a role in determining vulnerability. Many smallholder farmers have low levels of formal education and are unable to access timely and accurate climate information. This limits their knowledge of climate-smart agricultural methods and constrains their ability to make informed decisions about farming activities.

Gender inequalities compound the vulnerability of smallholder farmers. Women, who constitute a substantial share of the agricultural labour force, generally have limited access to land, credit and extension services [38]. These constraints limit their ability to implement adaptation strategies and increase their exposure to climate-related risks. Land tenure insecurity is another key issue affecting smallholder farmers. In many parts of Southern Africa, farmers do not own the land they cultivate [35]. This discourages investment in soil conservation, irrigation infrastructure and other long-term sustainability practices, as farmers cannot be sure of receiving returns on such investments. Smallholder farmers' resilience is also affected by market access challenges. Poor road networks, high transportation costs and limited market information limit their capacity to sell produce at competitive prices [39]. This reduces opportunities for income and limits their ability to diversify livelihoods away from agriculture. Infrastructure deficits, such as poor storage facilities, irrigation systems, and transportation networks, limit resilience-building efforts [23]. Lack of adequate infrastructure results in post-harvest losses, limited water access, and challenges in accessing inputs and markets, thus further aggravating farmers' vulnerability. Health challenges are also a major factor contributing to vulnerability. Diseases such as malaria and waterborne diseases impact agricultural productivity by reducing the availability of household labour [40]. These challenges are exacerbated by limited access to healthcare services, particularly in rural areas. These factors lead to a cycle of vulnerability that heightens smallholder farmers' susceptibility to food insecurity [41]. Meeting these challenges demands integrated interventions to improve access to resources, bolster institutional support, and foster inclusive development to build resilience among smallholder farming communities.

4.3. Adaptation Strategies

In response to the impacts of climate change, Southern African smallholder farmers have gradually adopted a variety of adaptation strategies [42]. These strategies aim to enhance resilience to unpredictable climatic conditions and stabilise agricultural production while reducing vulnerability. Their effectiveness varies, but they represent important efforts by farmers to adjust to evolving environmental realities [43]. One of the most popular strategies is crop diversification. Farmers grow different crops rather than only one staple, allowing them to spread risk across species with different tolerances to climate stress [44]. This strategy increases the chances that at least some crops will survive adverse conditions and therefore ensures some food security, even in years when harvests are poor. There is increasing interest in promoting drought-resistant crops such as sorghum, millet and cowpeas in many parts of the region. These crops are better adapted to low rainfall and high temperatures than traditional staples such as maize [45]. Adoption has been slow, but these crops provide a realistic alternative for sustaining agricultural productivity in areas where water is scarce. Conservation agriculture is a major adaptation practice [46]. Minimum tillage, mulching, and crop rotation help conserve soil moisture, improve soil structure, and reduce erosion. These practices improve water-use efficiency and maintain soil fertility over time, leading to more resilient farming systems. Agroforestry is another important strategy that combines trees with crops and livestock systems [47]. Trees provide many benefits, including shade, nitrogen fixation to enhance soil fertility, and protection from wind and water erosion. This approach promotes environmental sustainability and increases agricultural productivity.

Water harvesting techniques have been adopted to address water scarcity challenges. Farmers use methods such as rainwater collection, contour ridging, and small-scale storage systems to capture and conserve water. These techniques support supplemental irrigation and help sustain crops during dry spells. Livelihood diversification is also a critical adaptation strategy. Many households engage in non-agricultural activities such as small-scale trading, artisanal work, or informal employment to supplement their income [6]. This reduces dependence on agriculture and provides a buffer against climate-related crop failures. Migration has become an increasingly common coping mechanism among rural households. Household members may migrate to urban areas or neighbouring countries and send remittances home [48]. These financial resources help households manage food shortages and invest in farming activities. Community-based adaptation initiatives have also played a significant role in enhancing resilience. Farmers collaborate through local groups to share knowledge, pool resources, and implement collective strategies such as water management and soil conservation [8]. These initiatives strengthen social networks and improve adaptive capacity at the community level. The use of climate information services, including seasonal weather forecasts and early warning systems, is gradually increasing [22]. Access to timely and accurate information enables farmers to make better decisions regarding planting, harvesting, and resource management. However, despite the availability of various adaptation strategies, adoption remains uneven due to constraints such as limited financial resources, inadequate institutional support, and a lack of access to technology and information.

4.4. Barriers to Adaptation

Although there are various adaptation strategies, smallholder farmers in Southern Africa face many barriers that constrain their effective implementation [49]. These barriers are interlinked and often reinforce each other, making it difficult for farmers to build resilience to climate change [50]. Resolving these issues is important for improving food security and agricultural sustainability. Financial barriers are among the most important obstacles to adaptation. Smallholder farmers often lack access to credit or savings, which prevents them from investing in technologies such as irrigation systems, improved seeds,

ISSN: 2576-8484
Vol. 10, No. 9: 190-201, 2026
DOI: 10.55214/2576-8484.v10i9.13593

and farm inputs [51]. However, without financial resources, even well-informed farmers cannot implement practices that could improve productivity and resilience. Weak institutional support further hampers adaptation efforts. In many instances, government policies and programmes aimed at supporting farmers are poorly coordinated or implemented [52]. Limited institutional capacity hinders the effectiveness of agricultural interventions and limits the outreach of support services to rural communities. Another important barrier to adaptation is poor infrastructure [31]. Poor road networks, storage facilities, and irrigation systems limit farmers' access to markets, inputs, and water resources. This constrains income opportunities, increases post-harvest losses, and reduces overall agricultural efficiency [53]. The lack of extension services constrains the dissemination of knowledge and skills related to climate-smart agriculture. Many farmers do not have access to trained extension officers who can guide adaptive practices. Therefore, awareness and adoption of modern farming practices remain low in many rural areas.

A further key challenge is access to reliable climate information. Farmers often lack access to weather forecasts and early-warning systems, or the forecasts are not understandable. This limits their ability to make informed decisions regarding planting, harvesting, and risk management [22]. Traditional beliefs and cultural practices can also affect adaptation outcomes. Indigenous knowledge is dynamic and valuable, but institutional programmes can fail if they either romanticise local practices or dismiss them in favour of externally designed technologies [54]. Policy inconsistencies create uncertainty and reduce farmers' confidence in long-term investment. Frequent changes in agricultural policies, pricing systems and support programmes may interfere with planning and discourage farmers from adopting new practices that require sustained commitment. Land degradation also compromises the effectiveness of adaptation strategies. Soil erosion, nutrient depletion and desertification reduce agricultural productivity and farmers' ability to benefit from improved practices. Restoring degraded land requires additional investment, which is unaffordable for many farmers [55]. Social inequalities, such as gender, income and access to resources, also influence adaptation capacity. Marginalised groups are often more vulnerable to climate change because of limited access to land, credit and information [56]. These inequalities will have to be addressed to ensure inclusive and effective adaptation. These barriers highlight the complexity of climate adaptation in Southern Africa [57]. Concerted action to address them needs to be holistic, addressing financial, institutional, social and environmental obstacles to create an enabling environment for successful adaptation by smallholder farmers. The synthesis therefore indicates that adaptation should be understood as a pathway rather than a menu of isolated techniques. As Figure 3 shows, farm-level responses can improve food-security outcomes only when finance, infrastructure, extension, climate information, markets, secure tenure and inclusive institutions make sustained adoption possible.

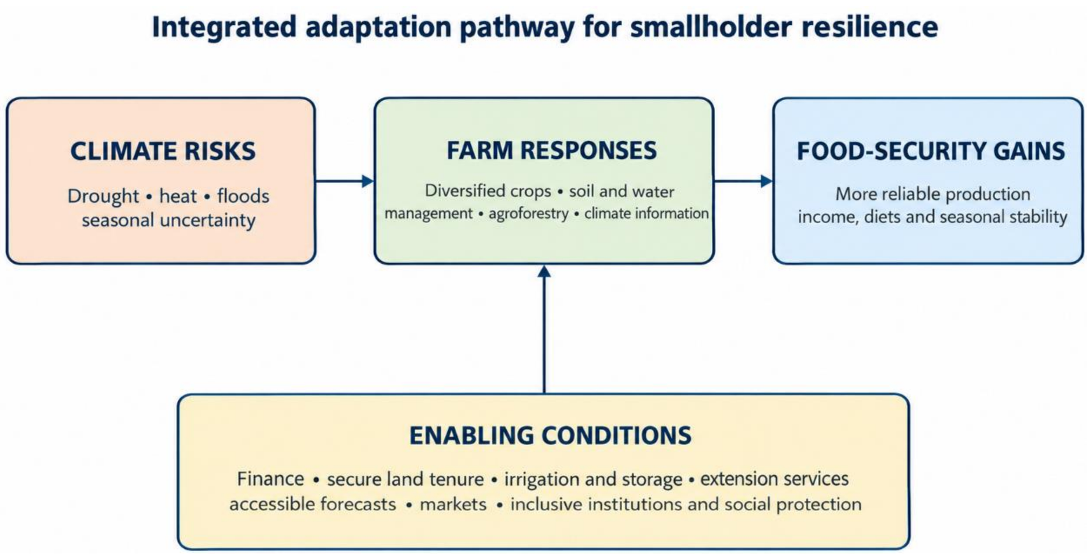

Figure 3.
Integrated adaptation pathway for smallholder resilience and food security.

5. Policy and Practice Implications

Policy should prioritise coordinated adaptation packages tailored to local agroecological and socioeconomic conditions. Extension programmes can combine seasonal forecasts with indigenous indicators and translate both into timely decisions about planting, crop choice, water allocation, and livestock management. Public investment in small-scale irrigation, water harvesting, storage, roads, and market information can reduce exposure across production and post-harvest stages. Financial services should be designed around the risk profiles of smallholders rather than conventional collateral alone, while land-tenure security is needed to encourage long-term investment in soil and water conservation. Gender-responsive implementation is essential because access to land, credit, information, and decision-making remains uneven. Social protection and disaster-risk financing should complement agricultural interventions where repeated shocks exceed households' capacity to adapt incrementally.

6. Conclusion

Climate change is undermining food security in Southern Africa through interacting effects on production, income, nutrition, and the reliability of food supplies. Smallholder farmers are highly exposed because rainfed agriculture intersects with limited finance, irrigation, infrastructure, extension services, secure tenure, and market access. Farmers already use diverse responses, including crop diversification, drought-tolerant crops, conservation agriculture, agroforestry, water harvesting, climate information, and livelihood diversification. The review nevertheless shows that farm-level practices cannot carry the burden of adaptation alone. Resilience depends on whether institutions make these practices affordable, accessible, and sustainable. A coordinated pathway linking local knowledge, scientific climate services, productive infrastructure, inclusive finance, social protection, and accountable governance offers a stronger basis for protecting all four dimensions of food security. Future empirical research should evaluate which combinations of interventions work for different groups and agroecological settings, using transparent indicators of adoption, distributional equity, and food-security outcomes.

Transparency:

The author confirms that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

Copyright:

References

[1] L. Gebeyehu, A. Gemechu, and A. Bedemo, "Effects of climate change on food security in Africa: Meta-analysis," *Journal of Agriculture and Food Research*, vol. 23, p. 102214, 2025. https://doi.org/10.1016/j.jafr.2025.102214

[2] F. Rusere *et al.*, "Rural households' vulnerability to drought and implications for resilience: Insights from Bushbuckridge, Mpumalanga, South Africa," *Progress in Disaster Science*, vol. 29, p. 100520, 2026. https://doi.org/10.1016/j.pdisas.2026.100520

[3] S. Shikwambana, N. Malaza, and K. Shale, "Impacts of rainfall and temperature changes on smallholder agriculture in the Limpopo Province, South Africa," *Water*, vol. 13, no. 20, p. 2872, 2021. https://doi.org/10.3390/w13202872

[4] B. Vilakazi, A. O. Odindo, M. M. Phophi, and P. L. Mafongoya, "Socioeconomic factors influencing crop diversification among smallholder farmers in Bergville, South Africa," *Agriculture*, vol. 15, no. 9, p. 914, 2025. https://doi.org/10.3390/agriculture15090914

[5] S. Mugambiwa and A. Upe, "Towards an inclusive climate governance system: Indigenous knowledge and state policy synergies in rural Zimbabwe," *International Journal of Qualitative Research*, vol. 5, no. 3, pp. 200-208, 2026. https://doi.org/10.47540/ijqr.v5i3.2294

[6] V. Touch *et al.*, "Smallholder farmers' challenges and opportunities: Implications for agricultural production, environment and food security," *Journal of Environmental Management*, vol. 370, p. 122536, 2024. https://doi.org/10.1016/j.jenvman.2024.122536

[7] T. Begna and R. B. Wakweya, "Mitigating climate change impacts on food security via climate-smart agriculture," *Plant Stress*, vol. 19, p. 101152, 2025. https://doi.org/10.1016/j.stress.2025.101152

[8] S. Mugambiwa, M. Kwakwa, and F. Rapholo, "The contribution of social work in climate resilience and environmental justice: A green social work perspective," *International Journal of Development and Sustainability*, vol. 13, no. 8, pp. 673–684, 2024.

[9] Centre for Environmental Rights, *Climate impacts in South Africa*. Johannesburg, South Africa: Centre for Environmental Rights, 2021.

[10] M. F. Olabanji and M. Chitakira, "A review of climate change impacts on water resources, crop production and adaptation strategies in South Africa," *World*, vol. 7, no. 5, p. 73, 2026. https://doi.org/10.3390/world7050073

[11] W. A. Atiah, F. K. Muthoni, B. Kotu, F. Kizito, and L. K. Amekudzi, "Trends of rainfall onset, cessation, and length of growing season in Northern Ghana: Comparing the Rain Gauge, satellite, and farmer's perceptions," *Atmosphere*, vol. 12, no. 12, p. 1674, 2021. https://doi.org/10.3390/atmos12121674

[12] K. A. Mbunda and F. E. Ndunguru, "Climate change adaptation practices and challenges among women maize farmers in rural Tanzania: A case study of Nyasa district," *Cogent Food & Agriculture*, vol. 11, no. 1, p. 2600127, 2025. https://doi.org/10.1080/23311932.2025.2600127

[13] P. D. Semosa, "The impact of climate change on the agricultural sector in SADC countries," *Sustainability*, vol. 17, no. 11, p. 5177, 2025. https://doi.org/10.3390/su17115177

[14] K. Phiri, T. Dube, P. Moyo, C. Ncube, and S. Ndlovu, "Small grains "resistance"? Making sense of Zimbabwean smallholder farmers' cropping choices and patterns within a climate change context," *Cogent Social Sciences*, vol. 5, no. 1, p. 1622485, 2019. https://doi.org/10.1080/23311886.2019.1622485

[15] D. W. Sintayehu *et al.*, "Effects of drought on livestock production, market dynamics, and pastoralists' adaptation strategies in semi-arid Ethiopia," *Climate*, vol. 13, no. 4, p. 65, 2025. https://doi.org/10.3390/cli13040065

[16] T. Masipa, "The impact of climate change on food security in South Africa: Current realities and challenges ahead," *Jàmbá: Journal of Disaster Risk Studies*, vol. 9, no. 1, pp. 1-7, 2017. https://hdl.handle.net/10520/EJC-a876c549f

[17] P. Lombe, E. Carvalho, and P. Rosa-Santos, "Drought dynamics in sub-Saharan Africa: Impacts and adaptation strategies," *Sustainability*, vol. 16, no. 22, p. 9902, 2024. https://doi.org/10.3390/su16229902

[18] P. D'Orazio, "Addressing climate risks through fiscal policy in emerging and developing economies: What do we know and what lies ahead?," *Energy Research & Social Science*, vol. 119, p. 103852, 2025. https://doi.org/10.1016/j.erss.2024.103852

[19] D. Marino, D. Bernaschi, F. B. Felici, F. Scannavacca, and B. Minotti, "Measuring local poverty and food insecurity: Developing an affordability index for healthy diets," *Regional Science Policy & Practice*, vol. 17, no. 12, p. 100244, 2025. https://doi.org/10.1016/j.rspp.2025.100244

[20] B. A. Magesa, G. Mohan, H. Matsuda, I. Melts, M. Kefi, and K. Fukushi, "Understanding the farmers' choices and adoption of adaptation strategies, and plans to climate change impact in Africa: A systematic review," *Climate Services*, vol. 30, p. 100362, 2023. https://doi.org/10.1016/j.cliser.2023.100362
[21] Z. Kom, N. S. Nethengwe, S. Mpandeli, and H. Chikoore, "Indigenous knowledge indicators employed by farmers for adaptation to climate change in rural South Africa," *Journal of Environmental Planning and Management*, vol. 66, no. 13, pp. 2778-2793, 2023. https://doi.org/10.1080/09640568.2022.2086854
[22] Z. Ncoyini, M. Savage, and S. Strydom, "Limited access and use of climate information by small-scale sugarcane farmers in South Africa: A case study," *Climate Services*, vol. 26, p. 100285, 2022. https://doi.org/10.1016/j.cliser.2022.100285
[23] O. O. Olarewaju, O. A. Fawole, L. J. Baiyegunhi, and T. Mabhaudhi, "Integrating sustainable agricultural practices to enhance climate resilience and food security in Sub-Saharan Africa: a multidisciplinary perspective," *Sustainability*, vol. 17, no. 14, p. 6259, 2025. https://doi.org/10.3390/su17146259
[24] H. Snyder, "Literature review as a research methodology: An overview and guidelines," *Journal of Business Research*, vol. 104, pp. 333-339, 2019. https://doi.org/10.1016/j.jbusres.2019.07.039
[25] G. A. Bowen, "Document analysis as a qualitative research method," *Qualitative Research Journal*, vol. 9, no. 2, pp. 27-40, 2009. https://doi.org/10.3316/QRJ0902027
[26] K. Krippendorff, *Content analysis: An introduction to its methodology*, 4th ed. Los Angeles, CA: SAGE Publications, Inc, 2018.
[27] L. Dlamini, O. Crespo, J. van Dam, D. V. Gaso, and A. de Wit, "Climate change impacts on rainfed maize production of small-scale cropping systems in Eastern Cape, South Africa," *Agricultural Systems*, vol. 233, p. 104627, 2026. https://doi.org/10.1016/j.agsy.2025.104627
[28] E. Yeleliere, P. Antwi-Agyei, and L. Guodaar, "Farmers response to climate variability and change in rainfed farming systems: Insight from lived experiences of farmers," *Heliyon*, vol. 9, no. 9, p. e19656, 2023. https://doi.org/10.1016/j.heliyon.2023.e19656
[29] L. Wang and W. Ren, "Drought in agriculture and climate-smart mitigation strategies," *Cell Reports Sustainability*, vol. 2, no. 6, p. 100386, 2025. https://doi.org/10.1016/j.crsus.2025.100386
[30] X. Yuan *et al.*, "Impacts of global climate change on agricultural production: A comprehensive review," *Agronomy*, vol. 14, no. 7, p. 1360, 2024. https://doi.org/10.3390/agronomy14071360
[31] B. E. Mthembu, T. Cele, and X. Mkhize, "Climate change impacts on agricultural infrastructure and resources: Insights from communal land farming systems," *Land*, vol. 14, no. 6, p. 1150, 2025. https://doi.org/10.3390/land14061150
[32] A. A. Ogundeji, "Adaptation to climate change and impact on smallholder farmers' food security in South Africa," *Agriculture*, vol. 12, no. 5, p. 589, 2022. https://doi.org/10.3390/agriculture12050589
[33] M. E. Morales and S. A. Berkowitz, "The relationship between food insecurity, dietary patterns, and obesity," *Current Nutrition Reports*, vol. 5, no. 1, pp. 54-60, 2016. https://doi.org/10.1007/s13668-016-0153-y
[34] S. Tojo-Mandaharisoa *et al.*, "Drivers of food and nutrition security during the lean period in southeastern Madagascar," *Journal of Agriculture and Food Research*, vol. 14, p. 100881, 2023. https://doi.org/10.1016/j.jafr.2023.100881
[35] M. Maziya, B. Nkonki-Mandleni, N. Mbizana, and P. Tirivanhu, "The perceived impact of climate change on the livelihoods of smallholder farmers in KwaZulu-Natal Province, South Africa," *Sustainability*, vol. 16, no. 7, p. 3013, 2024. https://doi.org/10.3390/su16073013
[36] N. Jonas and M. Christian, "Transforming South African agriculture: The role of credit in supporting value chain sustainability," *Agriculture*, vol. 15, no. 6, p. 620, 2025. https://doi.org/10.3390/agriculture15060620
[37] F. U. Khan, M. Nouman, L. Negrut, J. Abban, L. M. Cismas, and M. F. Siddiqi, "Constraints to agricultural finance in underdeveloped and developing countries: A systematic literature review," *International Journal of Agricultural Sustainability*, vol. 22, no. 1, p. 2329388, 2024. https://doi.org/10.1080/14735903.2024.2329388
[38] Y. F. Maulida, G. Palaniappan, and S. van Bommel, "What impact do gender differences have on agricultural extension organizations? A critical review," *Gender, Technology and Development*, vol. 29, no. 3, pp. 414-437, 2025. https://doi.org/10.1080/09718524.2025.2563819
[39] C. N. Mbatha and B. Charuka, "Improving market access for vulnerable small-scale farmers in the Eastern Cape province, South Africa: Some policy lessons," *Journal of Contemporary African Studies*, vol. 44, no. 1, pp. 82-102, 2026. https://doi.org/10.1080/02589001.2026.2645840
[40] C. M. Godde, D. Mason-D'Croz, D. E. Mayberry, P. K. Thornton, and M. Herrero, "Impacts of climate change on the livestock food supply chain; a review of the evidence," *Global Food Security*, vol. 28, p. 100488, 2021. https://doi.org/10.1016/j.gfs.2020.100488
[41] E. M. Allen, L. Munala, A. J. Frederick, C. Quito, A. Enayat, and A. S. Ngunjiri, "Climate change and health: Impacts across social determinants in Kenyan agrarian communities," *Climate*, vol. 13, no. 8, p. 169, 2025. https://doi.org/10.3390/cli13080169

[42] S. Roffe *et al.*, "Identifying climatic risks and relevant adaptation strategies for selected smallholder farming regions, Limpopo Province, South Africa," *South African Geographical Journal*, vol. 107, no. 2, pp. 262-281, 2025. https://hdl.handle.net/10520/ejc-sageo_v107_n2_a262

[43] M. Rwema, B. Safari, M. B. Sylla, L. Roininen, and M. Laine, "Understanding farmers' knowledge, perceptions, and adaptation strategies to climate change in eastern Rwanda," *Sustainability*, vol. 17, no. 15, p. 6721, 2025. https://doi.org/10.3390/su17156721

[44] T. O. Ariom, E. Dimon, E. Nambeye, N. S. Diouf, O. O. Adelusi, and S. Boudalia, "Climate-smart agriculture in African countries: A Review of strategies and impacts on smallholder farmers," *Sustainability*, vol. 14, no. 18, p. 11370, 2022. https://doi.org/10.3390/su141811370

[45] A. Porcuna-Ferrer, L. Calvet-Mir, N. F. Faye, B. Klappoth, V. Reyes-García, and V. Labeyrie, "Drought-tolerant indigenous crops decline in the face of climate change: A political agroecology account from south-eastern Senegal," *Journal of Rural Studies*, vol. 105, p. 103163, 2024. https://doi.org/10.1016/j.jrurstud.2023.103163

[46] A. Sithole and O. D. Olorunfemi, "Sustainable agricultural practices in Sub-Saharan Africa: A review of adoption trends, impacts, and challenges among smallholder farmers," *Sustainability*, vol. 16, no. 22, p. 9766, 2024. https://doi.org/10.3390/su16229766

[47] D.-C. Ţopa, S. Căpşună, A.-E. Calistru, and C. Ailincăi, "Sustainable practices for enhancing soil health and crop quality in modern agriculture: A review," *Agriculture*, vol. 15, no. 9, p. 998, 2025. https://doi.org/10.3390/agriculture15090998

[48] S. Mugambiwa, "Rural–urban migration under conditions of drought and displacement: A case study of the Midlands Province of Zimbabwe," *International Journal of Population Studies*, vol. 12, no. 3, p. 025310131, 2025. https://doi.org/10.36922/IJPS025310131

[49] J. Thobane *et al.*, "A review on the adoption of sustainable agricultural practices in Southern Africa: focus on smallholder farmers," *Agriculture*, vol. 15, no. 20, p. 2125, 2025. https://doi.org/10.3390/agriculture15202125

[50] F. A. Kitole and C. Komba, "Challenges and opportunities of climate change adaptation strategies among smallholder horticultural farmers in rural Tanzania," *Cogent Food & Agriculture*, vol. 11, no. 1, p. 2554247, 2025. https://doi.org/10.1080/23311932.2025.2554247

[51] M. E. Lesala, N. Mujuru, L. Mdoda, and A. Obi, "Evaluating the economic impact of market participation on the well-being of smallholder irrigators: Evidence from the eastern cape province, South Africa," *Sustainability*, vol. 17, no. 8, p. 3390, 2025. https://doi.org/10.3390/su17083390

[52] J.-C. Baraka Munyaka *et al.*, "Institutional pathways to climate-resilient agriculture: Comparative adaptation governance in Kenya and Zimbabwe," *Climate and Development*, pp. 1-20, 2026. https://doi.org/10.1080/17565529.2026.2615652

[53] S. N. Mwamakamba *et al.*, "Irrigating Africa: Policy barriers and opportunities for enhanced productivity of smallholder farmers," *International Journal of Water Resources Development*, vol. 33, no. 5, pp. 824-838, 2017. https://doi.org/10.1080/07900627.2017.1321531

[54] Z. Mekonnen *et al.*, "Traditional knowledge and institutions for sustainable climate change adaptation in Ethiopia," *Current research in Environmental sustainability*, vol. 3, p. 100080, 2021. https://doi.org/10.1016/j.crsust.2021.100080

[55] M. Elhini *et al.*, "The land degradation and desertification-socioeconomic nexus in Egypt's delta region: A case study on Alexandria and Beheira," *Heliyon*, vol. 10, no. 10, p. e31165, 2024. https://doi.org/10.1016/j.heliyon.2024.e31165

[56] N. R. Chikowore, I. Barber, N. Chanza, C. Ngan, and S. A. Yam, "Climate change vulnerabilities and adaptation strategies in rural communities: An intersectional approach in the Baham sub-division of Cameroon," *African Geographical Review*, vol. 45, no. 2, pp. 99-115, 2026. https://doi.org/10.1080/19376812.2025.2504159

[57] N. P. Sibiya *et al.*, "Overcoming bureaucratic resistance: An analysis of barriers to climate change adaptation in South Africa," *Climate*, vol. 11, no. 7, p. 145, 2023. https://doi.org/10.3390/cli11070145