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TRAVERSING THE INTERCONNECTED DYNAMICS OF CLIMATE CHANGE AND FOOD SECURITY IN SUB-SAHARAN AFRICA

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Abstract:
Globally, Climate change adversely impacts people's lives. Climate change has not spared Sub-Saharan Africa in terms of farming and food security. Sub-Saharan Africa's overdependence on agriculture and farming adversely impacts the standard of living and quality of life. This study explored secondary data analysis of global institutions' reports to examine the impact of climate change on food security in Sub-Saharan Africa. The paper synthesizes themes and patterns to comprehend the effects of climate change on food supply. The data was analyzed through a thematic analysis to identify patterns and themes from the secondary data. The findings established that climate change reduces farming productivity, which causes food shortages and increases the vulnerability of farming. Food security can be improved by adopting climate-change agricultural practices and increasing investment in agricultural infrastructure. The paper concludes that climate change impacts food security. This paper recommends that the government and global institutions support Sub-Saharan African farmers. It contributes to raising awareness of measures to improve food security in Sub-Saharan Africa.

Keywords: Agriculture, Climate Change, Farming, Food Security, Impact, Sub-Saharan Africa

INTRODUCTION

Sub-Saharan Africa (SSA) faces climate change challenges that affect different spheres of life. Research indicates that the excessive reliance on farming in Sub-Saharan Africa adversely affects the living conditions and welfare of the people (Kom et al., 2022). The region's dependence on rain and the inability to adapt to unpredictable weather patterns make it vulnerable to changes in the climate (Kom et al., 2022). A study conducted by an agency called the International Panel on Climate Change (IPCC) found that Sub-Saharan Africa (SSA) is about to face an increased share of global famine (Assan, 2022). Assan's study (2022) also found that hunger in Sub-Saharan Africa accounts for about 40-50% of the global population's malnourishment by 2080. These grim statistics reveal the need to investigate the relationship between food security and climate change. This can be established by analyzing the realities and existential threats to the region.

Food security has been described as a condition that allows people to sustain physical and social access to secure food to meet their dietary needs and ensure an active and healthy life (Badolo, 2024). Baynachew et al. (2019) explain the concept of food security as encompassing four critical interdependent elements: availability, access to food, utilization of food, and stability of food supply. These elements combine to ensure an adequate food supply in circulation to sustain individuals and households. However, climate change and extreme weather (Damoah et al., 2024) affect the interplay of these four elements with their resultant effect on the Sub-Saharan region and its people (Tesfay, 2024). Climate change challenges disrupt food security and agricultural productivity and contribute to the increasing food supply in the region (Jones et al., 2021). The disruption in food supply pushed prices upward and undermined the national security and the workforce of Sub-Saharan Africa (Duran-Sandoval et al., 2023).

People and communities from sub-Saharan Africa face difficult times in terms of getting sufficient food for their sustenance. Bismark et al. (2021) assert that the changing patterns in the weather influence the temperatures, erratic rainfalls, and other weather-related events that destabilize conventional farming and the distribution network of food. The impact of climate change can be reduced through alternative farming strategies that strengthen food security and improve food distribution. Using climate-smart agricultural (CSA) practices has been identified as a strategy that helps lessen climate change's impact on food production. Chari and CSA, as described by Ngcamu (2022), is a strategy that allows farmers to grow crops that do well in arid lands and can increase crop production. CSA is reliable when there is a reliable water system for a reliable water supply (Nakalemba & Kerner, 2023). According to Nakalembe and Kerner (2023), farmers can maximize CSA for increased food production when the water supply is constant and reliable. Thus, farmers need to invest in irrigation systems that trap and channel the direction of water to farms (Quarshie et al., 2023). Kurgat et al. (2020) emphasize the need for practical training on CSA and water systems and understanding seeds that can withstand harsh climate conditions.

Globally, climate challenges contribute to increasing poverty and the widening gap in income between the poor and the rich. Food security is a dire challenge affecting the population's and communities' socioeconomic lives in the SSA region. According to Naazie et al. (2023), floods, droughts, and unpredictable weather conditions disrupt farming, decrease food supply, and threaten people’s lives. While several studies have been done about climate change and food security, a gap has been identified, which this paper will contribute to. There is limited knowledge and research on climate change in Sub-Saharan Africa to understand how food security is impacted. In addition, not many studies have been done that shed light on how communities and people's livelihoods in this region are affected. This paper aims to uncover the impact of climate change on food security in Sub-Saharan Africa. The paper then explores secondary data to gain insight into strategies that can be implemented to build a sustainable food system in the SSA region. The paper seeks to elucidate the impact of climate change on food security and strategies employed to enhance the resilience of food systems in Sub-Saharan Africa.

Climate Change Mitigation for Food Security. Climate change and weather conditions in the SSA present a serious threat that undermines food security in the region (Damoah & Khalo, 2023). Gomez-Zavaglia et al. (2020) expressed concerns about the worsening temperatures and weather conditions that disrupt the agricultural production of crops and farming practices. These climate conditions lead to declining food production and famine in the region. Kogo et al. (2021) warn farmers of their dependence on the weather and rainfall to increase food production. This approach to farming increases the vulnerability of farming and food production. Measures must be implemented to overcome the variability in the weather conditions (Kogo et al., 2021). Ofori et al. (2021) and Damoah (2023) identified possible mitigation measures to reduce the effects of climate change. These include adopting climate-smart agriculture, diversifying farming, improving rain harvesting and irrigation systems, promoting agroforestry, and strengthening early warning systems for weather-related risks. Omotoso et al. (2023) report that increased temperature exposes staple crops like maize, wheat, and rice to increased stress. These findings can jeopardize the effort of SSA towards increasing its capacity to produce more food to sustain the growing population.

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Quarshie et al. (2023) opine that the change in weather patterns has caused droughts, and unreliable rainfall affects the supply of drinking water and irrigation of farms. Qiao et al.'s (2022) findings show that increasing temperatures and weather conditions (Damoah & Khalo, 2024) contribute to poor soil for planting crops. According to Liliane and Charles (2020), poor soil quality and changes in weather and temperature patterns affect food production in Africa. However, Agostoni et al. (2023) claim that climate change conditions worsen the risk of malnutrition and famine through food reduction agricultural practices. This finding is aligned with studies that identified socioeconomic factors like poverty, infrastructure, and instability in the market as critical factors for insecurity in food production (Ahmad,2023; Raj et al., 2022; Fronda,2024). For food security to improve, governments and farmers must adopt strategies that improve food security in the face of climate change.

Food security and increased production are essential to the economy's stability and provide nutritional needs for the people. Cheng et al.'s (2022) emphasize concerns about how climate change and food security obstruct the achievement of sustainable farming practices and improved food supply. Ra et al. (2022) postulate the important role of farming in contributing to the health and well-being of the people and the community. However, a decrease in agricultural productivity threatens the communities and livelihoods of the people. This corroborates Laborde et al. (2021), the reliance on imported goods, and the inability of countries to increase their food production through farming. As a result of the high cost of importing goods to supplement local production, low-income households find it difficult to access food. Studies have shown that malnutrition, famine, and food insecurity not only affect the health of the people but also increase the poverty of individuals and communities (Alaimo et al., 2020). These challenges to food security require efforts by global institutions and national governments to implement sustainable measures that address food security.

The Impact of Climate Change on Food Production and Availability. Omotoso et al. (2023) contend that droughts, floods, and irregular rainfalls disrupt the farming cycles in Sub-Saharan Africa. These challenges, as presented, directly contribute to food insecurity in SSA. Negri et al. (2021) assert that the prolonged drought and poor rainfalls lower the soil's moisture and make the land unsuitable for food crops. In contrast to this finding, Kulkarni (2021) argues that excessive rainfall erodes the topsoil and reduces the ability of the soil to support food production. In addition, this author also emphasized that the changes in weather patterns make it difficult for farmers to decide the times for planting and harvesting. The challenges pointed out in these findings affect food production and malnutrition in children. This situation not only makes the communities and their people vulnerable but also threatens the survival of households (Damoah et al., 2024).

Quarshie et al. (2023) point out that a lack of access to infrastructure and poverty make it difficult for individuals from developing countries to access food supplies. Providing the support needed for developing countries is vital for improving access to food and infrastructure for climate resilience. Farhall and Rickards's (2021) findings show the contribution of food production and farming in African countries. Women who contribute significantly to the farming labor force and productivity in agriculture are often not supported in farming and face the risk of climate disruptions. This shows the important role of women in food security. As a result of this, their efforts must be supported to ensure food security. Escalante and Maisonnavo (2023) report that the challenges impacting food and farming production increase unemployment in the SSA. They suggested the need for local governments to support women's participation in farming to boost productivity.

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The inability of farmers to increase crop production, coupled with an increase in prices, is a major contributing factor to famine in the SSA. Fukase (2020) intimated that the cost of basic food increases because there is so much demand for food that farmers cannot produce. Most farmers in the SSA cannot increase their productivity due to the need for food for the people. According to Iller et al. (2021), the high staple food prices affect low-income households. On the contrary, Mensha et al. (2022) opine that high temperatures and poor storage for farm crops worsen the challenge of food security. The conditions that this finding has spelled out are the cause of more food spoiling. Similarly, Cheng et al. (2022) focused on how livestock are affected by increased temperature and water shortages. These challenges, as pointed out by Cheng et al., make the grazing of farmlands rugged and expose livestock to the risk of diseases. These challenges that affect crop and animal farming put farmers under intense pressure to improve food security in the SSA.

Socioeconomic and Policy Drawbacks in Achieving Food Security. Poverty and lack of access to basic infrastructure contribute to the inability of SSA to find solutions to climate change. Quarshies et al. (2023) posit that high poverty levels and a lack of infrastructure prevent access to farming communities. This situation means that farmers' produce goes rotten because they cannot transport it from the farms to where it is needed. This makes it important for the government to provide the necessary infrastructure for storing and transporting goods (Farhall & Rickards, 2021). Communities can build resilience when the government provides them with the support needed for food to be accessible (Quarshie et al., 2023). On the contrary, lacking access to infrastructure like transport and storage does not necessarily lead to decreased food production or unemployment. For instance, Escalante and Maisonnovo (2023) concluded that well-built farming systems can withstand climate change pressure, build resilience, and adapt to unpredictable weather patterns. These suggest that climate disruptions can bring about sustainable farming practices to ensure the food supply is not disrupted.

The inadequate support from the government and the implementation of appropriate policies affect governments in SSA’s efforts to ensure sustainable food security (Smith & Glauber, 2020; Damoah a& Adu, 2022). In contrast, Tacconi and Williams's (2020) perspectives show that corruption and mismanagement of agricultural resources to combat climate change in vulnerable communities do not allow the food needs of the people to be addressed. According to these authors, this challenge needs to be addressed by enhancing the implementation of policies, transparency, and fostering inclusive governance. Creating an enabling environment through transparency and partnership with the government fosters sustainable and resilient food security. Contrastingly, Zougmore et al. (2021) find inconsistencies in policy implementation as an obstruction to climate adaptation and change strategies.

Wang (2022) found that the expansion of food production to meet the needs of the communities and people are affected by an increase in population and limited land and resources to expand farming and increase food production. This study finds these factors to be the major contributing factors to the increase in food prices and famine. Raj et al.’s (2022) findings indicate that many individuals and communities cannot afford their nutritional food requirements. This is exacerbated by their inability to implement adaptation strategies to mitigate against climate change. According to Ipinnaiye and Olaniyan (2023), there is a need for a multifaceted approach to address the socioeconomic challenges that impact food security. Communities need to adopt an approach that incorporates awareness, social protection initiatives, and funding to improve the well-being of people (Ipinnaiye & Olaniyan, 2023). Zougmore et al. (2021) assert that climate change seriously challenges food security in SSA. However, it also offers an opportunity to improve food supply systems.

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Strategies to Strengthen Food System Resilience. Zheng et al. (2024) emphasize the important role a farming approach like climate-smart agriculture (CSA) can play in ensuring global sustainable food security. According to this finding, properly implementing CSA in communities experiencing climate change challenges (Damoah, 2023) can improve farmers' productivity. Improving productivity through the use of CSA assists farmers in adapting to climate change while reducing greenhouse gas emissions (Zheng et al., 2024). Mihrete and Mihretu (2025) revealed that agricultural practices like conservation, agroforestry, and diversification of crops are essential for improved farming and supply. These agricultural practices ensure that soil texture is improved and reduce the risk of reliance on single-crop farming. Contrastingly, Maity et al. (2023) argue in favor of using improved seeds that are pest and drought-resistant to enhance food security. Using this approach to farming assists farmers in coping with the adverse effects of climate change.

Wakweyas (2023) reinforces the importance of CSA as a key strategy for improving farming and food production in Africa. This finding aligns with Makate's (2020) perspectives of combining innovative technologies with indigenous knowledge systems to assist farmers in adapting to challenges from climate change. Mtega and Ngoepe (2002) claim that farmers must be supported with the training needed for these innovative technologies to be effective. This finding aligns with Sundaram (2023), who pointed out the important role that policymakers can play in procuring funding for farming infrastructure. Improving farming infrastructure can provide the necessary tools and access to enhance farming.

Mtega and Ngoepe (2020) establish the importance of irrigation systems, early warning mechanisms, and improved policies to foster resilience in farming communities. Similarly, Abiri et al. (2023) findings focused on the need for broader access and implementation of irrigation systems to reduce dependence on rainfall. However, Wakweya (2023) warns that without the early detection of climate challenges, farmers may not have the needed information to plan and adapt. An early warning system of climate change hazards can help farmers plan their activities around planting and harvesting effectively. Raj et al. (2022) contend that implementing climate change policies like subsidies to farmers and creating a ready market for farm crops can improve food security. In contrast, Kulkarni (2021) claims that forging partnerships and community-led programs is critical for enhancing resilience.

Theoretical Framework. Social-ecological systems (SES) theory, which was developed by Elinor Ostrom and colleagues in the 1990s, provides a lens for this paper (Ostrom, 2019). The theory sheds light on the interaction that exists between communities and environments that are faced with climate change challenges. According to Negri (2021), the SES theory is for sustainable science, the resilience of communities, and the management of environments. This theory assesses the approach communities use to cope, adapt, and restore environments that have been harmed due to climate change (Negri, 2021). This theory navigates vulnerability, adaptive capacity, and resilience in the distribution and food chain systems affected by climate change (Thonicke et al., 2020).

The SES theory delineates four interrelated elements that influence the effect of climate change on food security. These elements include:

- Vulnerability: Vulnerability in the SES framework shows how ecological, social, and economic systems are affected by climate change risks. The risk of these systems is determined by factors like exposure, sensitivity, and lack of coping mechanisms.
- Adaptive Capacity: These are the actions and interventions governments, communities, and individuals take to solve climate change challenges. Some strategies that can be used to combat climate change include redistribution of resources, improving farming strategies, and understanding the weather patterns and changing conditions.

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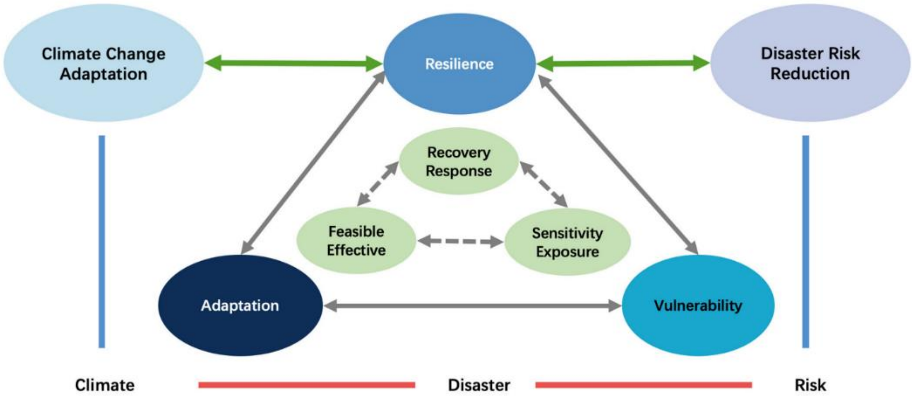
- Resilience: Refers to adaptive measures that governments, communities, and people adopt to contain and survive the potential risk of climate change. Some resilient strategies that can be adopted include diversifying crops, providing community support, and implementing policies that assist in adapting to unpredictable weather conditions.

The combination of these three factors can assist in combating the implications that climate change has on food security in SSA. This interaction between these three factors is further explained in Figure 1. In this paper, the SES theory is used to analyze secondary data on climate change and food security to gain insights into the impact of climate change on food security and strategies that can be used to enhance food distribution in SSA.



Note. Zhai and Lee (2024)

Figure 1. Links between vulnerability, adaptation, and resilience

METHODS

This paper explored the impact of climate change on food security in Sub-Saharan Africa. Secondary data from global institution reports were analyzed to gain insight into the impact of climate change on food security. The data analyzed focused on synthesizing themes and patterns to understand how climatic conditions affect food supply and some of the adaptation measures adopted to build a resilient food supply chain (Vonthron et al., 2020). Adopting this approach ensures that in-depth and evidence-based findings are achieved. Findings from these global reports contribute to finding possible solutions to support vulnerable communities and individuals.

Data from the World Bank was drawn from other reputable global institutions to ensure reliability and credibility. Themes that emerged from multiple data sources were cross-checked (Morgan & Nica, 2020). Reliability and credibility of the study were ensured by collecting data from the World Bank, which synthesized data from different reputable organizations. These sources included the Intergovernmental Panel on Climate Change (IPCC, 2022), the Food and Agriculture Organization (FAO, 2022), and the World Food Program (WFP, 2022)> Data collected from these sources provided local and global perspectives on climate change, food security, and farming and agricultural reports.

A scoping review design was used to collect secondary data by considering peer-reviewed articles, reports, and grey literature published from 2020 to 2024. The inclusion criteria were climate change, food security, agriculture, and farming adaptation in Sub-Saharan Africa. The considered sources had to show empirical data published by a recognized authority (Harris et al., 2022). In addition, these sources should show interconnectedness between environmental and socio-economic systems.

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The thematic analysis technique was used to identify patterns and themes about the impact of climate change. These sources used were guided by the SES theory. Recurring issues were coded, and policy responses from the text were considered. Identified codes were grouped into categories that link with the components of SES, such as vulnerability, adaptive capacity, system-relatedness, and resilience. The themes that emerged were reviewed across a range of sources to ensure consistency, reliability, and relevance to the paper's objective.

Emergent themes from the data were cross-validated by comparing findings from various sources, which included the World Bank, the IPCC, the WFP, and the FAO. These themes were focused on the findings and discussion of the study.

A key limitation of the paper was its reliance on secondary data sources, which do not show the development of climate change's impact on food security. This may not necessarily be context-specific and reflect on local experiences. While a rigorous search was used to gather reliable sources, the study did not follow the PRISMA protocol. This limits the reproducibility of the criteria and the process selection used in this paper.

RESULT AND DISCUSSION

Climate Change Threatens Food Production. Findings showed that climate change can affect food production in SSA. World Bank (2022), drawn from IPCC (2022), showed that climate change can lower the global crop production by 30% in SSA by 2050. This report from the World Bank and IPCC (2022) shows that agricultural models are connected to findings in the literature that underline the disruptions in traditional farming practices. In their findings, Gomez et al. (2020) and Omotoso et al. (2023) identified increasing temperatures and fluctuations in weather patterns as major disruptions in agricultural practices. As Ostrom (2019) pointed out in the SES framework, the reduction in staple food production impacts the vulnerability of societies and individuals. Omotoso et al. (2023) claim that the inherent vulnerability of the food production system to climate change shocks decreases the resilience of food production systems. Findings from Liliane and Charles and Qiao et al. (2022) concur by showing soil degradation because of patterns of harsh weather, which damage the ability of the soil to produce crops. These disruptions affect system resilience and the capacity to adopt, two main components of SES theory.

Furthermore, Ostrom (2019) indicates the importance of how the three factors of the SES framework interact. The study established how the absence of adaptive capabilities adversely contributes to communities' vulnerability and resilience to adapt to climate change challenges. On the other hand (Damoah et al., 2024), findings from Kogo et al. (2020) revealed how overreliance on rain can result in drought and flooding. The inability to predict rain worsens the vulnerabilities of farming communities in the SSA region. This is supported by Quarshie et al. (2023), who noted that the ability of communities to deal with climate change shocks depended on the weather. When there are fluctuations in the weather patterns, it makes it difficult for communities to contain environmental issues. This finding aligns with Agostoni et al. (2023), who reported that crops that depend heavily on the weather do not contribute to improved food production. This is supported by the SES theory, which shows how the inability of communities to mitigate climate change can lower their effort to improve food security (Ostrom, 2019). The SES theory emphasizes adaptive responses in challenging ecological and sociological systems (Ostrom, 2019).

Rising Food Prices Due to Climate Shocks in SSA. Research findings indicate that climate change shocks significantly contribute to rising food prices in Sub-Saharan Africa (SSA) (World Bank, 2022; Fukase & Martine, 2020; Negri, 20210). According to a World Bank (2022) analysis, 1 degree Celsius could lead to food price increases ranging from 3 to 10 percent. This finding supports

Fukase and Martine (2020) by asserting that higher food prices impact both the demand and supply. The study shows that climate change-induced food production reductions increase food prices. This conclusion aligns with Negri's (2021) conceptualization of the Socio-Ecological Systems (SES) framework, which illustrates the interplay between ecological and economic systems. The connection illustrated in SES is how ecological disruption has a ripple effect on economic systems.

Laborde et al. (2021) found that poor nutrition and food insecurity adversely affect individuals and the public's well-being in SSA. These findings highlight the vulnerabilities that can arise from climate change's impact on food security, as depicted in the SES framework. An analysis by the World Bank found that household vulnerability worsens when over 50 percent of income is spent on food consumption (FAO, 2022). This is further validated by Zhai and Lee (2024), who link household vulnerability to food security within the SES framework. This relationship illustrates how food security reflects the social dimensions of vulnerability outlined in the SES framework.

Iller et al. (2021) and Mensah et al. (2022) recognized that declines in farming productivity reduce communities' ability to afford food. In contrast, Raj et al. (2022) acknowledged that many regions in SSA struggle to afford decent meals due to poverty. These findings suggest a lack of economic opportunities and insufficient investment in adaptation strategies to climate change. To improve the socioeconomic conditions of the people, governments need to create economic opportunities and invest in programs that enhance resilience and adaptability (Damoah et al., 2023). However, Laborde et al. (20210) identified that reliance on food imports in SSA hinders communities' ability to adapt effectively. SES theory helps to understand these results as a failure of socioeconomic systems to supplement ecological stress. As shown by SES, this outcome shows an inherent challenge of structural vulnerabilities.

Conflict & Climate Change Exacerbate Hunger in SSA. Famine and hunger in Africa directly result from conflict and climate change in the region (Kulkarni, 2021; Quarshie et al., 2023; Naorem et al., 2023). This finding is confirmed by WFP (2022) statistics, which emphasize the compounding effect of climate change on food security in developing countries. This finding is corroborated by data from the World Bank (2022) and FAO (2022), which quantified that 30 percent of people in the SSA region are displaced or migrate due to famine and poverty. These findings suggest a connection between food insecurity and instability in Sub-Saharan African countries. Furthermore, analysis of data by the World Bank (2022) indicates that more than 80 percent of hunger and famine experienced globally are caused by climate change vulnerability. Most of the countries that are affected by hunger and famine are countries from SSA (World Bank, 2022). This result aligns with Ostrom's (2019) conceptualization of SES theory, which recognizes the variety of stressors that interact with complex systems. The instability, as has been referenced in the reports of the World Bank (2022), FAO (2022), WFO (2022), and IPCC (2022), contributes to the reduction in the adaptive ability of communities to food security.

Bismark et al. (2021) emphasized that climate-related disasters like droughts and floods (Damah & Khalo, 2023), coupled with conflict, put so much burden on food systems. This vulnerability, as shown in the SES framework by Zai and Lee (2024), worsens the ability of communities to absorb and survive ecological and social shocks. In contrast, Wang (2022) and Raj et al. (2022) that affects communities' ability to absorb shock is the abnormal growth of population and poverty, which pressurize the systems of food supply. As a result, communities become more susceptible to disruptions induced by climate change. This is supported by Zougmore et al. (2022)'s finding, which shows that climate change leads to critical challenges for people and their regions and contributes to a resilient and transformative food supply system. These findings support the objective of the SES theory of fostering resilience and adaptive responses capacity. In addition, this

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indicates how communities can adapt to vulnerability due to climate change, which is a key element of the SES framework.

The use of Climate-Smart Agriculture (CSA) to improve food security. Chari and Ngcamu (2022) confirmed that climate-smart agriculture (CSA), as a farming approach, can help communities improve food security. An analysis of data from the World Bank (2022) and FAO (2020) concluded that incorporating CSA into farming practices contributes to a 20 percent increase in food production and lessens gas emissions in communities. This statistic represents the need for the SSA government to implement strategies for adaptation, as shown in the SES framework (Ostrom, 2019). Zheng et al. (2024) affirm the role of CSA in increasing the production of farming to reduce the impact of climate change on food. Conversely, the findings of Mihrete and Mihretu (2025) identified that only specific practices of CSA, like agriculture conservation and agroforestry practices, enhance the quality of the soil. These findings align with SES, which focuses on adaptive capacity as a primary component of resilience. This suggests that managing the soil can enhance soil quality for improved crop production and resilience of agricultural practices.

World Bank (2022) and IPCC (2022) reports established the importance of the practical use of drought-resistant seeds, irrigation, and agroforestry practices. These practices reveal how agricultural practices can help to adapt to climate change. IPCC (2022) data corroborate this by showing how crop yields can increase by 20% to 30% due to the implementation of drought-resistant seed types in arid communities. This finding positively compares to traditional seed planting during prolonged periods of drought and provides a practical application of the adaptive capacity shown in the SES theory. This finding is contrary to the outcome of data analysis by FAO (2022), which found that using precision irrigation techniques can improve water use efficiency by 40%. As a result, whilst water use is reduced, this assists in maintaining constant food production throughout the year. Maity (2023) supports using an improved variety of seeds, whilst Wakweya (2023) points to the need to incorporate sustainable practices into farming, which are vital in sustaining resilience, as shown in SES theory.

Financial Gaps for Climate Change Adaptation in SSA. Studies show that sub-Saharan Africa faces a financial gap in adaptation to climate change (Ahmad, 2023). Quarshie et al. (2023) argue that to maintain resilience and ensure food security, there is a need for investments in adaptive measures to build resilience. World Bank (2022) findings acknowledge that developing countries need about $140 to $300 billion annually to build resilience and adapt to climate change. However, a similar finding from FAO (2022) indicated that only $20 billion had been globally allocated to agriculture. This lack of funding suggests a barrier to enhancing adaptive capacity, as shown in the SES framework. Ahmad (2023) believes there is a lack of capital among micro farmers to inject funding into farming techniques to enhance the resilience of vulnerable communities. On the other hand, Raj et al. (2022) assert that restricting access to credit facilities and insurance services does not allow farmers to bounce back from losses that emanate from climate change challenges. This lack of support to farmers shows gaps within the social ecological system, where institutional arrangements must be linked to resource needs.

Ostrom (2019) focuses on urgent public and private collaboration to improve funding for innovative farming systems. This aligns with findings from Sundaram (2023), which emphasize that for the resilience and adaptability of farming communities to be ensured, it is essential to foster partnerships between the government and farmers to ensure resilience and adaptability. Fronda (2024) advocated for governments to implement microfinance and funding programs to improve infrastructure in farming communities. Driving infrastructural development and funding to farmers improves the resilience of farming practices. Conversely, Smith and Glauber (2020) and Tacconi and

Williams (2020) find implementing policies critical in ensuring effective management of resources to bolster food security. Policy implementation can raise the level of adaptive capacity of vulnerable communities (Smith & Glauber, 2020). These findings show the financial gaps in SSA communities that make it difficult for farmers to adapt to climate change. In the framework of SES, tackling financial gaps is not only of equity concern but also a requirement for stabilizing ecological and social systems.

CONCLUSION

Climate change significantly impacts crop production and food security in Sub-Saharan Africa. This is evident from the region's declining agricultural yields and rising food prices. Increased food prices contribute to hunger and famine, highlighting the vulnerability of individuals and communities in Sub-Saharan Africa. This paper indicates that these communities' lack of adaptation and resilience underscores their vulnerability and poses a significant risk to food security. The findings reveal that a major cause of this vulnerability is rising temperatures and unpredictable weather patterns. These factors affect farmers' resilience to climate change and degrade soil quality. Soil degradation due to climate change disrupts agricultural output, making it challenging for farmers who overly depend on rainfall and do not incorporate adaptive practices. As a result, they struggle to improve food production and alleviate hunger and malnutrition in Africa.

Rising temperatures due to climate change not only contribute to famine and hunger but also lead to an increase in food prices. Farmers' difficulty predicting weather patterns worsens the region's poor agricultural production. This unpredictability destabilizes the prices of goods and heightens the vulnerability of countries in Sub-Saharan Africa (SSA). Additionally, the rising food prices make it challenging for low-income households to afford necessities for survival and health. Conflicts within SSA have been identified as contributing to the region's vulnerability to climate change and famine. This study established that hunger is a direct consequence of climate change in areas already vulnerable and affected by conflict. These findings underscore the urgent need for policy interventions to control and manage the impact of climate change on food security in Sub-Saharan Africa.

Global institutions must increase investment and funding in innovative farming practices like climate-smart agriculture in SSA. Such financial injection to support SSA should focus on initiatives that improve the adaptability and resilience of the people in underprivileged communities in SSA. Interventions such as providing farmers with drought-resistant seeds, irrigation water systems, and agroforestry practices can effectively solve climate change. Global institutions can forge partnerships and collaborations with local partners to implement warning systems and training programs for farmers. This can equip farmers to be more resilient and adapt to the impact of climate change.

Sub-Saharan African governments should integrate climate adaptation programs into their farming practices and agricultural initiatives. This can be achieved by implementing policies that address conflicts and support local farmers. For example, subsidies and access to essential farming technologies can be provided to help mitigate the impacts of climate change on agricultural production and food security. Government subsidies can enable farmers to acquire the technologies needed to withstand the region's harsh effects of climate change.

Policymakers in SSA should develop and implement policies supporting sustainable farming and stabilizing food prices. Initiatives like carbon credit schemes, climate risk insurance, and regulations can be maximized to improve the food supply in the region. Farmers must be empowered to adopt practices and measures that enhance farm soil quality. Ensuring the farming lands are arable can assist in ensuring sustainable food security.

Farmers should adopt farming practices and technologies that help reduce the effects of climate change on food security. Using drought-resistant seeds, irrigation systems, and agroforestry practices can improve food production in the SSA. Farmers can form cooperatives that enable them to access credit facilities, improve the food supply, and reach their targeted markets. Farmers can diversify from crop farming to animal farming to enhance resilience to climate change.

Limitations of the study. This study only relied on secondary data from the World Bank, IPCC, FAO, and WFP. Using only secondary data could affect the findings' adaptability and generalizability. While secondary data may provide valuable insights, using it alone can affect the validity of the study's conclusions.

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