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AGRICULTURAL ADAPTATION TO CLIMATE CHANGE THREATS IN NORTHERN GHANA: A REVIEW OF THE ISSUES

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ABSTRACT

Climate change poses a severe threat to Ghana's northern regions, particularly the savanna ecological zones. Rising temperatures, erratic rainfall, and extreme weather events have significantly reduced crop yields, degraded land, and heightened food insecurity. This study assesses adaptation strategies such as sustainable agricultural intensification, soil and water conservation, and crop improvement efforts. Additionally, it explores the potential of weather-based index insurance and post-harvest management techniques to mitigate climate-induced crop failures. However, barriers to effective implementation persist, including gender disparities and limited community advocacy. To address these challenges, policy interventions should prioritize expanding climate-resilient irrigation infrastructure and integrating climate-smart agricultural technologies. Strengthening these measures is essential for ensuring sustainable food production and consumption in Ghana's vulnerable northern regions. This paper contributes to the advancement of Sustainable Development Goal (SDG) 2 (Zero Hunger) and SDG 13 (Climate Action) by promoting climate-resilient agricultural systems that enhance food security and environmental sustainability.

Keywords: Climate Change, Agricultural Adaptation, Northern Ghana, Food Security, Sustainable Agriculture

INTRODUCTION

By 2080, temperatures in northern Ghana's savanna regions are expected to exceed 30°C, intensifying droughts and floods that have already destroyed farms and displaced thousands (Benefoh, 2020). In a future where the land itself seems to be turning against them, how will farmers adapt and survive? The Republic of Ghana is located in West Africa on the Guinea Coast and is divided into sixteen administrative zones and consists of twelve ecological zones. The northern part of Ghana encompasses five regions: Northern, Savannah, Upper East, North East, and Upper West Region. Together, the five regions' total area is 97,702 km2 (Ghana Statistical Service, 2021). Before 2018, these five regions were three regions called Upper East, Upper West, and Northern Regions. Nearly 70% of the land is for agricultural use (Benefoh, 2020). Agriculture is the backbone of the economy of Ghana and its primary source of livelihood.

Direct climate threats have dramatically impacted agriculture in this area of Ghana. The specific threats include floods, drought, unpredictable rainfall, and high temperatures that cause varying levels of land degradation and decreased crop yields. Such climate threats impact land quality and crop yields and lead to food insecurity and malnutrition in communities in Northern Ghana. This study describes existing efforts to adapt to climate threats and provides recommendations for responding to those threats adequately. Addressing these challenges is imperative for sustainable development in agriculture, as it safeguards food security, sustains economic stability, and enhances the resilience of agriculture-reliant communities in Northern Ghana.

PURPOSE & RESEARCH QUESTIONS

Despite existing adaptation strategies such as sustainable agricultural practices, soil and water conservation, and crop improvement efforts, significant challenges persist, including barriers to implementation, gender disparities, and limited community advocacy. The purpose of this review paper is to examine the multifaceted impacts of climate change on agriculture in Northern Ghana, with a focus on rising temperatures, erratic rainfall, and land degradation and their consequences for food security.

This paper addresses a critical gap in knowledge by synthesizing current climate projections, policy interventions, and adaptation measures while highlighting their effectiveness and limitations. While several studies have examined individual climate threats or adaptation strategies in isolation, we lack a comprehensive analysis that integrates these factors to provide a holistic understanding of how climate change disrupts agricultural systems in Northern Ghana. By evaluating existing policies and proposing targeted interventions such as climate-resilient irrigation and climate-smart technologies, this review will guide policymakers, researchers, and stakeholders in enhancing resilience and mitigating climate-related agricultural risks.

Research Questions:

- What are the primary climate change threats impacting agricultural productivity in Northern Ghana?
- How effective are current adaptation strategies in mitigating the negative impacts of climate change on agriculture in the region, particularly for vulnerable populations?
- What policy interventions are needed to scale up successful climate adaptation practices and advance sustainable agricultural development and long-term resilience in Northern Ghana?

METHODS

Researchers employed a systematic review approach, which is a method of finding, selecting, and synthesizing available resources. We followed the review protocol developed by Kitchenham & Charters (2007) and Keele (2007) as it is shown in Figure 1. This method was used to review studies and identify key findings on climate change threats, current adaptation strategies, and policy interventions related to agricultural productivity in Northern Ghana (Keele, 2007).

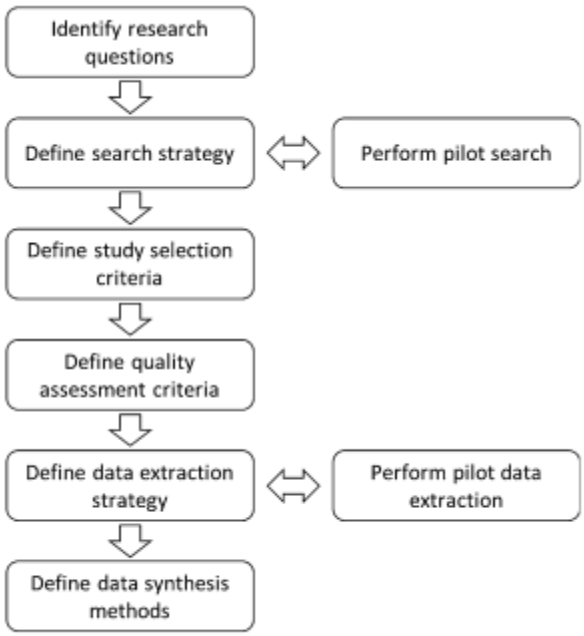

Fig. 1 Review protocol used in our study (Adapted from Kitchenham and Charters [23])

Search Strategy

This review employed a systematic literature search using Web of Science and Google Scholar, along with general Google searches, to identify relevant studies on agricultural adaptation to climate change in Northern Ghana. The search terms included "climate change," "agriculture," "Northern Ghana," "food security," "adaptation," "land degradation," and "crop yields. Boolean operators (AND, OR) were used to refine the search results. The search focused on peer-reviewed journal articles, newspaper articles, and reputable reports published between 2007 and 2024. To ensure relevance and quality, inclusion and exclusion criteria were

applied. The inclusion criteria included: studies focusing specifically on the northern regions of Ghana, peer-reviewed journal articles and reputable reports, studies addressing impacts of climate change on agricultural systems, evaluations of the effectiveness of adaptation strategies, studies published in English, and articles published between 2007 and 2024. The search prioritized studies contributing to sustainable development. Exclusion criteria included: studies focusing on regions outside Northern Ghana, articles that do not specifically address climate change and agriculture; non-peer-reviewed sources such as blogs, opinion pieces, or non-reputable websites; and studies published before 2007 unless they provided foundational background information.

Study Selection Process

In this study, our initial search identified 315 articles across the selected databases (Web of Science: 248; Google Scholar and Google Search: 67). The selection process followed a two-step screening approach: (1) In title and abstract screening, articles were screened for relevance based on titles and abstracts, resulting in 285 articles for full-text evaluation. (2) full-text review and refinement. The inclusion and exclusion criteria were applied rigorously to prioritize empirical research over theoretical discussions. This process refined the dataset to 46 studies for in-depth analysis. To ensure consistency in selection, Zotero reference management software was used for organizing and filtering the identified studies. The screening process, facilitated through Zotero's tagging and classification system, helped eliminate duplicates and irrelevant publications. The final selection of 39 articles was determined based on methodological rigor and direct relevance to the study objectives.

Data Extraction and Analysis

Data extraction focused on key themes related to climate change threats, adaptation strategies, and policy interventions. Each study was systematically coded to identify climate change threats including: key climate-related risks affecting agricultural productivity in Northern Ghana; effectiveness of adaptation strategies; findings related to measures farmers and communities use to mitigate climate impact; and policy recommendations and effectiveness (which included policy recommendations and government policies aimed at

scaling up adaptation strategies). To categorize the findings, keyword scanning and thematic coding were applied to each article.

The following keywords (and their variations) were used:

1. Climate Change Threats **(***Drought, rainfall variability, temperature rise, desertification, soil degradation, food insecurity, extreme weather, migration, crop failure, economic losses, floods, land degradation).*
2. Effectiveness of Adaptation Strategies **(***Climate-smart agriculture, irrigation, crop diversification, agroecology, community-based adaptation, indigenous knowledge, soil fertility management, reforestation, risk mitigation, agricultural insurance, conservation agriculture)*
3. Policy Interventions **(***Government policies, adaptation programs, climate finance, subsidies, training programs, farmer support schemes, national adaptation plans, sustainable land use, climate change policy frameworks, local governance).*

The extracted data were synthesized using thematic labels corresponding to the research questions, which allowed for a structured comparison of findings across studies. The analysis emphasized patterns in adaptation success and implementation challenges and provided a comprehensive perspective on agricultural resilience in Northern Ghana.

FINDINGS & DISCUSSION

The findings section first examines the sustainability implications, then various ways climate change affects agriculture in Northern Ghana by exploring key environmental threats and their consequences for food security and rural livelihoods. It then shifts focus to adaptation strategies by analysing approaches farmers and policymakers use to mitigate these impacts, including agricultural intensification, alternative farming techniques, and soil fertility management. The section also incorporates two tables to support the analysis: one evaluating policy documents that address climate-related agricultural challenges and detail the issues they target, the actions proposed, and their effectiveness and another assessing various adaptation strategies for land degradation by summarizing their implementation, outcomes, and overall impact. This structure provides a comprehensive overview of both the challenges posed by climate change and the efforts to build resilience in the region's agricultural sector.

Sustainability Implication.

The findings suggest that while adaptation efforts in Northern Ghana are growing, their long-term success depends on embedding sustainability principles that balance environmental protection, economic viability, and social inclusion. Environmentally, sustainable agricultural practices strengthen ecological resilience by improving soil fertility and conserving natural resources. Yet, inconsistent adoption and limited technical support continue to challenge widespread sustainability. Economically, climate-smart agricultural practices can enhance productivity and stabilize farmer income; however, financial constraints, poor infrastructure, and reliance on external funding undermine scalability. Socially, sustainability requires equitable

access to resources, inclusive participation, and the recognition of women and youth as key agents of resilience. Strengthening local governance, community advocacy, and knowledge-sharing systems will be crucial to sustaining progress. These implications highlight the importance of aligning adaptation and policy frameworks with SDG2 (Zero Hunger) and SDG13 (Climate Action), ensuring that agricultural transformation in Northern Ghana contributes to food security, climate resilience, and long-term sustainable development.

Impacts of Climate Change on Agriculture

Several studies have identified key climate change threats that negatively impact agricultural productivity in Northern Ghana. Drought, desertification, and declining soil fertility are reported as major concerns affecting food security and crop yields in the region (Akudugu et al., 2012; Asante & Amuakwa-Mensah, 2015; Benefoh 2020; Frieler et al., 2017). Erratic rainfall and increasing temperatures have led to reduced agricultural output and have forced farmers to rely on alternative income sources (Ahiale et al., 2020; Benefoh 2020; Chemura et al., 2020; Potsdam Climate Risk Profile, 2020). Soil erosion and land degradation also emerge as major threats, with studies highlighting how unsustainable land use practices contribute to climate vulnerability (Bawayelaazaa Nyuor et al., 2016; Danso-Abbeam et al., 2021; Appiah et al., 2018). Climate modeling projections suggest that temperature increases of up to 5.5°C by 2090 will exacerbate these challenges, further threatening crop viability and agro-ecological stability (Benefoh 2020; Potsdam Climate Risk Profile, 2020; Frieler et al., 2017).

Table 1: Climate Change Threats

Study	*Climate Change Threats Identified*	*Study Design*
Akudugu et al. (2012)	Drought, desertification, declining soil fertility, food insecurity	Survey-based study
Ahiale et al. (2020)	Soil erosion, land degradation, deforestation affecting farm productivity	Mixed methods (survey & interviews)
Alhassan et al. (2018)	Temperature increases and erratic rainfall reducing crop yields	Survey and focus group discussions
Appiah et al. (2018)	Deforestation and unsustainable land use practices contributing to climate variability	Case study on farmers' perception
Asante & Amuakwa-Mensah (2015)	Projected temperature increase, declining rainfall, desertification rate of 20,000 ha per year	Quantitative modelling study
Bawayelaazaa Nyuor et al. (2016)	Negative economic impacts on cereal production due to irregular rainfall and rising temperatures	Economic impact modelling
Benefoh (2020)	Identified climate change threats such as rising sea levels, droughts, floods, and declining agricultural productivity in Ghana.	Government report based on a policy review and national assessment
Chemura et al. (2020)	Reduction in crop suitability for maize, sorghum, cassava, and groundnut due to climate shifts	Agro-climatic modelling study
Danso-Abbeam et al. (2021)	Higher temperatures, erratic rainfall, and land degradation impacting smallholder farming	Mixed methods (survey & modelling)
Frieler et al. (2017)	Projected temperature increase of up to 5.5°C by 2090, increased dry and wet extremes	Global climate projection modelling
Potsdam Climate Risk Profile (2020)	Declining water availability, increased heat waves, and shifts in agro-ecological zones	Climate risk assessment report

Climate change projections show increasingly scarce water, collapsing agricultural yields, desertification, and damage to coastal infrastructure (Brown et al., 2008). Projections also show that rainfall will reduce up to 70%, which poses a critical challenge for farmers who need rainfall to begin sowing their crops. These changes will lead to low agricultural productivity (Wossen & Berger, 2015). Crops are mainly rain fed, and irrigation is very low across the country; therefore, crop production is low when water access and availability are low (Benefoh, 2020). Projected climatic conditions show that suitable growth conditions will reduce maize, sorghum, and cassava but not groundnuts by 2050. These are all staple crops within the country that are widely used to prepare meals, which makes them very important to maintain despite climate change threats (Chemura et al., 2020). The population of the Savannah zone (Northern regions) is the most vulnerable to climate change impacts, as it negatively affects their agricultural production (Alhassan et al., 2019). The people who are living in that region are practising subsistence agriculture, which is when farmers produce for consumption rather than for commercial use.

The negative impact of drought is direct on the agricultural sector in Northern Ghana. The farmers' production has decreased, especially sorghum, maize, groundnuts, and millet. Moreover, this reduction negatively affects the income of smallholder farmers mainly in the northern Savanna areas (Benefoh, 2020). The droughts directly affect crop production and productivity, and the smallholder farmers are primarily the most vulnerable to food access due to crop failure, according to Akudugu (2012). In Ghana, the agriculture sector is highly vulnerable due to extreme weather conditions, including droughts, hurricanes, and rising sea levels. According to Benefoh (2020), the projection shows that there will be extreme prolonged drought conditions that impact cash crop production in the future, and variegated grasshoppers will increase and destroy cassava. In addition, climate change threats such as unpredictable rainfall, drought, and flooding present a significant challenge in the northern regions of Ghana, which cause crop failure and reduced yields.

The main crops in Northern Ghana are sorghum, groundnuts, maize, and cassava, which are planted in large spaces where they occupy 83% of cultivation land (Chemura et al., 2020). Regardless of the challenges of climatic conditions, the studies showed that in the northern parts of Ghana in 2050, groundnuts would continue to be suitable in this region, while the maize production will continue to be lower than currently. The main reason for this decrease is because maize is highly affected by climate change variability compared to other crops. Cassava will decrease also but will be much better suitable than maize. The sorghum will also be suitable as it is a tolerant crop (Murken et al., 2019). Bawayelaazaa Nyuor et al. (2016) carried out a study in Northern Ghana and found the impacts of climate change on cereal production. They found that some of the varying rainfall patterns and temperature changes were beneficial to crops such as sorghum but negatively impact maize, suggesting that appropriate adaptation strategies should be promoted. Therefore, the adaptation of climatic conditions among the community population of northern Ghana should involve different actors.

Effectiveness of Current Adaptation Strategies

In response to climate change threats, farmers in Northern Ghana have adopted various adaptation strategies to mitigate climate risks. Crop-livestock diversification is frequently cited as an effective method for improving resilience and stabilizing food production in the face of climatic variability (Amankwah, 2013;

Danso-Abbeam et al., 2021; Yahaya et al., 2018). Studies also emphasize the importance of soil and water conservation techniques, such as mulching, composting, and rainwater harvesting, which have shown positive outcomes in preserving soil fertility and ensuring sustainable water use (Anafo et al., 2020; Nyamekye et al., 2018; Akoto-Danso et al., 2019). Additionally, community-based initiatives, including water resource management and ecosystem-based adaptation, have been implemented with varying levels of success in enhancing local resilience (Akolgo et al., 2020; Guodaar et al., 2021; Murken, 2020). However, despite the effectiveness of these approaches, limited access to financial resources and extension services remains a significant barrier to scaling up successful adaptation strategies (Azumah et al., 2017; Yiridomoh et al., 2021).

Table 2: Extracted Data for Research Question 2

Study	*Effectiveness of Adaptation Strategies Identified*	*Study Design*
Amankwah (2013)	Small ruminant production enhances food security and resilience	Case study on livestock production
Anafo et al. (2020)	Ecosystem-based approaches such as mulching, composting, and crop rotation mitigate soil degradation	Survey and qualitative analysis
Akoto-Danso et al. (2019)	Biochar and wastewater irrigation improve soil fertility and crop yields	Experimental agronomic study
Akolgo et al. (2020)	Community-based water management strategies enhance water security	Community-based participatory research
Azumah et al. (2017)	Contract farming enhances adoption of adaptation strategies like row planting and crop rotation	Survey on farmers' contract adoption
Danso-Abbeam et al. (2021)	Crop-livestock diversification improves food security resilience	Mixed methods (survey & modelling)
Guodaar et al. (2021)	Indigenous strategies like rainwater harvesting, crop diversification, and irrigation	Case study on indigenous adaptation
Murken (2020)	Risk assessment-based adaptation strategies for sustainable farming	Climate risk assessment study
Nyamekye et al. (2018)	Soil and water conservation measures improving resilience	Soil conservation field study
Yiridomoh et al. (2021)	Women engaging in off-farm income-generating activities as adaptation strategies	Survey-based study on gendered adaptation

Sustainable Agricultural Intensification Practices

Farmers in the Upper East, Upper West, and Northeast Region are subsistence farmers with low soil productivity because of farming practices such as mono-cropping with limited farming inputs like advanced seeds and fertiliser (Yahaya et al., 2018). The dire situation is worsened by a lack of access to credit and poor infrastructure, poverty, and an underdeveloped agriculture market (Yahaya et al., 2018). Sustainable agricultural intensification practices (SAIPs) were introduced to the Northwestern area of Ghana in 2010 to decrease natural

resource degradation, increase crop yields, increase incomes, and increase food security (Yahaya et al., 2018). SAIPs include direct seeding without ploughing, leaving crop residue, intercropping, and crop rotation with legumes. The benefits of SAIPS are to reduce the rate of declining soil fertility, improve soil structure, prevent soil erosion, and allow sustained soil fertility (Yahaya et al., 2018). In addition, Yahaya (2018) found that when farmers participated in SAIPs, they had better household security than those that did not participate.

Integrated Soil Fertility Management

Scientists and development practitioners have pushed for integrated soil fertility management (ISFM) to improve soil fertility (Adolwa et al., 2017). However, adoption by farmers has been low because of a lack of knowledge of the principles of the approach, gaps between the primary producers and end-users of the ISFM knowledge, and other gaps in the agricultural knowledge and innovation systems (AKIS) (Adolwa et al., 2017).

ISFM is a set of soil fertility management practices that include mineral fertilisers, improved germplasm, organic soil amendments, and the knowledge needed to adapt the methods to the local context. It is an intricate process involving activities such as targeted manure application, building terraces to prevent soil erosion, and using crop residue to recycle nutrients. The concept is knowledge-driven and not input-intensive and aims to replenish soil nutrients; optimise on-farm recycling of nutrients; reduce nutrient loss; improve efficiency; use local, traditional, and scientific knowledge; and integrate the technologies for sustainable natural resources management (Adolwa et al., 2017). This practice would be an excellent adaptation to break the cycle of land degradation because it addressed biophysical and socioeconomic barriers that farmers face (Adolwa et al., 2017). Soil degradation caused by human and environmental factors has adverse impacts on food security, environment, and quality of life (Wang et al., 2019). ISFM has been an agricultural strategy to promote sustainable agricultural intensification in Tamale, Northern Region of Northern Ghana, since 2008 (Adolwa et al., 2017).

According to Adolwa et al. (2017), AKISs are a set of formal or informal agricultural organisations or people and their links and interactions. They engage in the creation, transformation, storage, retrieval, integration, and utilisation of knowledge and information that support decision-making, problem-solving, innovation, and a country's agricultural sector. Despite communication gaps, policymakers and development agencies still use the AKIS approach (Adolwa et al., 2017). NGOs in Tamale, such as the Urban Agriculture Network and the Presbyterian Mile Seven, have trained farmers AKIS. Other organisations have used AKIS to share information and agricultural technology with farmers. They play a crucial role in the information system (Adolwa et al., 2017). For example, Adolwa et al. (2017) found that the reach of AKIS is a determining factor in whether information on integrated soil and fertility management will be adopted.

Soil and Water Conservation Management

Soil and Water Conservation Measures (SWCM) can also respond to runoff control, soil moisture improvement, land rehabilitation, mitigation of land degradation, and nutrient management. SWCM are applied in varying ways depending on the needs of the environment and the conditions of rainfall intensity, soil type,

and topography. This type of intervention was used successfully in Burkina Faso and improved food security, economic security, and biodiversity (Nyamekye et al., 2018).

Farmers' Strategies

According to Anafo (2020), smallholder farmers in Northern Ghana implemented four main strategies to address land degradation: composting, stone bonding, crop rotation, and mulching. Composting is a chemical response characterised by degrading organic materials into fertiliser to replenish degraded soil. Stone bonding, a mechanical strategy, consists of lining up various stones across the farms to reduce the speed of the water, trap eroded soil, and retain water in the soil. Crop rotation is a biological or agronomic solution. Farmers alternate among crops on the same piece of land because the nutrient needs are different for different crops; it allows the soil to replenish. For example, beans and groundnuts are perfect because they fix nitrogen in the soil for the next crop (Anafo et al., 2020). Crop rotation is important because the warming climate depends greatly on nitrogen fertilisation rates that cause crops to grow faster and in higher quantities (Tan et al., 2010). Finally, mulching, another mechanical response, puts different grasses over the crops to prevent evaporation and retain soil moisture (Anafo et al., 2020). The other effective adaptation practices that households in the Northern regions of Ghana have implemented include expanded cultivated area, dry season gardening, task-sharing with women, diversification into livestock rearing, and increasing fertiliser (Asante & Amuakwa-Mensah, 2015).

Technological Adaptations

Improved crop varieties can effectively raise crop yields and adapt to climate change conditions such as floods, droughts, and diseases. Improving the agricultural farming practices can be value-added to the use of improved varieties. It is necessary to adapt new breeding and improve existing crop varieties in Northern Ghana to raise crop yields. Existing crop varieties of cassava, maize, rice, and cocoa need to be developed to resist drought. The improved crop varieties are very needed in Northern Ghana to improve and secure crop yields. The farmers can use improved varieties suitable in their region to improve crop yields (Murken et al., 2019). Improved crop varieties were found to make a significant contribution in transforming agriculture (Murken et al., 2019)

Post-harvest management strategy

Effective post-harvest management prevents crop losses during the harvesting period. Due to a lack of financial resources to make a robust system of post-harvest management, farmers' production decreased in Northern Ghana (Frieler et al., 2017). Climate change causes uncertainty with crop yields, and post-harvest management can help cope (Murken et al., 2019). There is a need for capacity building and education for farmers to increase participation in this strategy. One of the effective post-harvest management technologies for maize is the Purdue Improved Cowpea Storage (PICS) that has been helpful to vulnerable farmers in northern

Ghana for storing maize (Frieler et al., 2017). The PICS bags are low-cost, triple-layered bags that provide an oxygen and insect barrier for grain storage reducing crop loss.

Rainwater harvesting and small-scale irrigation strategy

Rainwater harvesting can reduce the cost of irrigation. The conservation of water can be beneficial to farmers of Northern Ghana. This rainwater harvesting can improve cereal crop yields and benefit the women who spend time fetching water and, along with small-scale irrigation, is a reasonable action that smallholders can take. (Murken et al., 2019)**.** Using simple installation techniques and making a small investment in irrigation

can benefit the farmers in the northern parts of Ghana (Guodaar et al., 2021). Proper storage of the collected water, such as covering the water, will prevent the breeding of mosquitoes.

Financial and Risk Management

Crop insurance minimizes risks from climate change and can benefit farmers in Northern Ghana. Weather-based Index Insurance and Area-yield index insurance are types of insurance that have been implemented in Ghana since 2011(Murken et al., 2019). Weather index insurance schemes use the weather index to determine payout, while area yield index insurances use the average yield of the area to determine the payout. The Ghana Agricultural Insurance Pool reported that area-yield index insurance has the most considerable potential for smallholder farmers resulting in insurance for 3000-4000 smallholder farmers of cereal crops and over 18,000 acres of land. Many smallholders' farmers cannot afford crop insurance and rely on government subsidies, but crop insurance can benefit farmers depending on the insurance scheme design (Amankwah, 2013). Farmers in Northern Ghana obtain crop insurance because they benefit from maintaining their consumption when they meet crop failures due to climate change-related shocks (Ankrah et al., 2021). However, crop insurance requires much investment, and smallholder farmers' reliance on government subsidies can cause the program to neglect the trade-off between farmer participation and insurance industry profit.

Table 3: Evaluation of Adaptation Strategies to Land Degradation in Northern Ghana

Adaptation Strategy	*Results*	*Evaluation*
Sustainable Agricultural Intensification Practices	Reduced rate of declining soil fertility Improve soil structure Prevent soil erosion Allow sustained soil fertility	The practices are complicated, and knowledge-intensive making adoption in the further reaches low. Improved AKIS would assist with this challenge.
Composting	Replenish degraded soil	Already adopted at the local level, but some farmers are limited to small household gardens and not large croplands.
Stone bonding	Reduce the speed of water Trap eroded soil Retain water in the soil	It is adopted in some communities and is a great practice. It needs to be upscaled through policy.
Crop Rotation	Replenish soil nutrients between crops Improve Nitrogen (via beans and legumes)	Is also adopted at the community level. It can be upgraded to Diversified Crop Rotation where possible with inputs such as improved seeds.
Mulching	Prevent evaporation Maintain soil moisture	A use practice that is adopted at the local level. Finds challenges in crop and livestock agriculture
Diversified Crop Rotation	Replenish soil nutrients between crops Improve Nitrogen (beans and legumes)	It is a practice that can be upscaled with improved agricultural inputs and extension services.
Integrated Soil Fertility Management	Improve soil fertility Break the cycle of land degradation	The practices are complicated and knowledge-intensive, making adoption in the further reaches low. Improved AKIS would assist with this challenge.
Soil and Water Conservation Measures	Runoff control Soil moisture improvement Land rehabilitation Mitigate land degradation Nutrient management Improve food security Improve biodiversity Improve economic security	Requires proper environmental and stakeholder analysis to determine which measures are most appropriate for the environmental context.
Agroforestry	Create a sustainable land-use system	Low levels of research on this practice in Ghana

Policy Interventions for Scaling Up Adaptation

Several policy recommendations have emerged from the literature to enhance agricultural adaptation and long-term sustainability. Expanding agricultural insurance schemes has been suggested as a key intervention to protect smallholder farmers from climate-induced risks (Ankrah et al., 2021; Yahaya et al., 2018). Similarly, studies highlight the importance of investing in climate-smart agricultural technologies and knowledge-sharing systems, particularly to improve farmers' ability to adopt innovative climate adaptation techniques (Adolwa et al., 2017; Kumasi et al., 2019; Nti & Barkley, 2012). Strengthening conservation agriculture policies and providing financial incentives for sustainable land management practices have also been widely recommended (Ahiale et al., 2020; Akudugu et al., 2012; Benefoh, 2020). Additionally, studies call for better integration of

climate adaptation policies at the national level, including enhanced monitoring and evaluation frameworks to ensure the successful implementation of rural resilience programs (Brown et al., 2008; Yiran & Stringer, 2017).

Table 4: Policy Interventions

Study	*Policy Interventions Recommended*	*Study Design*
Ankrah et al. (2021)	Expansion of agricultural insurance schemes to protect smallholder farmers	Survey-based study on insurance access
Adolwa et al. (2017)	Strengthening agricultural knowledge and innovation systems to improve technology adoption	Comparative analysis of knowledge systems
Akudugu et al. (2012)	Need for climate-smart agriculture policies and farmer education	Policy analysis and case study
Ahiale et al. (2020)	Incentives for conservation agriculture and sustainable land management	Survey and economic modelling
Benefoh (2020)	Implementation of Ghana's climate change policies through renewable energy and conservation programs	National climate policy review
Brown et al. (2008)	Urgent need for water resource management policies to mitigate climate-induced conflicts	Environmental security assessment
Kumasi et al. (2019)	Strengthening rural finance mechanisms and access to extension services	Case study on rural financing policies
Nti & Barkley (2012)	Increasing funding for rural agricultural resilience programs	Mixed-methods policy evaluation
Yahaya et al. (2018)	Enhancing agricultural training programs for sustainable intensification	Agricultural training program assessment
Yiran & Stringer (2017)	Strengthening local adaptation policies to address climate hazards	Local governance and adaptation policy study

Climate change continues to undermine agricultural productivity in Northern Ghana, especially for smallholder and subsistence farmers who are highly vulnerable to environmental shocks. In response, various studies have emphasized the importance of policy-level actions to support and scale up adaptation strategies. These policy interventions aim to address systemic challenges such as inadequate access to agricultural insurance, limited extension services, poor infrastructure, and the need for climate-resilient technologies. This section synthesizes the policy recommendations identified across the reviewed literature and highlights strategic

areas for government action, institutional reform, and investment to foster sustainable agricultural development and enhance farmers' resilience to climate change.

According to international agreements, national policies have been implemented, while communities have created their own adaptation strategies and plans (Yiran & Stringer, 2017). Policies such as the National Climate Change Policy (NCCP), the Food and Agricultural Sector Development Policy (FASDEP), the Medium-Term Agricultural Sector Investment Plan (MOFA 2009), the Health Sector Policy, the Housing Policy, and the Water Sector Policy all addressed different aspects of climate change. They were examined to see which adaptation strategies were incorporated (Table 1) (Yahaya et al., 2018). Some of the policies focused on targeted adaptation strategies while others preparedness. For this study researchers focused on NCCP, FASDEP, and the Water Sector Policy.

Ghana's response to climate change is grounded in a range of national policies that collectively aim to build resilience across key sectors, including agriculture, water, housing, and health. These policies are particularly relevant in Northern Ghana, where the impacts of climate variability are most acute due to the region's dependence on rain-fed agriculture, limited infrastructure, and high vulnerability to environmental shocks. At the forefront is the National Climate Change Policy (NCCP), which provides a strategic framework for addressing climate-related challenges. The NCCP's core objectives include increasing resilience in climate-sensitive sectors such as agriculture and water, promoting sustainable land use practices, and supporting the development and adoption of climate-smart technologies. The policy prioritizes vulnerable populations—such as smallholder farmers—by promoting adaptive farming techniques, early warning systems, and community-based natural resource management.

Complementing the NCCP is the Food and Agriculture Sector Development Policy (FASDEP II) implemented through the Ministry of Food and Agriculture (MOFA). FASDEP II aims to improve food security and incomes by enhancing agricultural productivity in a sustainable manner. It supports climate adaptation by promoting diversification of crops and livelihoods, strengthening agricultural extension services, and facilitating access to climate-resilient seeds and inputs. MOFA plays a crucial operational role by delivering extension programs, leading agricultural research initiatives, and coordinating with development partners to mainstream climate considerations into national agricultural planning.

The National Water Policy addresses the water-related dimensions of climate adaptation. It advocates for Integrated Water Resources Management (IWRM) to ensure equitable and sustainable access to water for agriculture, households, and ecosystems. This is particularly critical in Northern Ghana, where irregular rainfall and increasing temperatures exacerbate water scarcity. The policy emphasizes infrastructure development for small-scale irrigation, water harvesting, and conservation technologies that directly benefit farmers.

The National Housing Policy also contributes to climate resilience by promoting sustainable and climate-responsive housing designs, especially in rural and peri-urban areas. The policy encourages the use of locally available and climate-friendly building materials, disaster-resilient construction techniques, and

improved spatial planning to reduce the vulnerability of communities to climate-related hazards such as floods and extreme heat.

Lastly, the National Health Policy recognizes the intersection of climate change and public health, particularly the rise in climate-sensitive diseases such as malaria, cholera, and respiratory illnesses. The policy emphasizes strengthening the healthcare system to respond to climate-induced health risks through improved disease surveillance, climate-resilient health infrastructure, and health education programs targeted at rural populations. Collectively, these policies represent a multi-sectoral commitment to climate adaptation. While agriculture remains central, effective adaptation in Northern Ghana requires coordinated action across water, housing, and health sectors to protect livelihoods, enhance resilience, and support long-term sustainable development.

The National Climate Change Policy (NCCP) offered a broader cross-sectoral perspective that targeted a range of climatic hazards with strategies aimed at ensuring safe and reliable water supply during extreme weather events. The policy emphasized the importance of disseminating indigenous early warning systems and promoting the use of ICT to improve access to timely climate-related information. While this policy was comprehensive in addressing safety and preparedness for climate hazards, it was critiqued for lacking a targeted and sector-specific adaptation strategy, which could limit its effectiveness in delivering localized climate resilience. Overall, while each policy demonstrated some level of commitment to climate adaptation, the depth and specificity of adaptation measures varied across sectors. The agriculture and water sectors showed stronger alignment with adaptation goals, whereas broader frameworks such as the NCCP were more focused on general preparedness than on targeted, actionable strategies (Yiran & Stringer, 2017). Some policies implemented by the Government of Ghana were not created with adaptation to climate change in mind, while some of the policy actions reinforced local practices, which is good. Overall, these policies failed to take advantage of the good practices being implemented by farmers as demonstrated by the top-down approach used in policy development.

It is recommended that barriers to implementation be addressed through varying decision-making approaches, including explicitly addressing adaptation and using a participatory model to reduce the barriers to adopting new technologies and farming practices. (Yiran & Stringer, 2017). Gender mainstreaming, community advocacy, and education should be addressed in policy and program plans. Gender analysis and gendered approaches that address inequalities and promote inclusive climate change adaptation will be necessary (File & Derbile, 2020). To ensure a sustainable water supply, women must be considered because of their tasks concerning water. Women's participation is crucial in water and resource management (Akolgo & Ayentimi, 2020). Ghanaian women make up about 52% of the agricultural labor force and contribute 70% of total crop output (Kumasi et al., 2019). Despite the prominent role, they lack land, access, and decision-making power in the agriculture sector (Kumasi et al., 2019). Vulnerability is worsened by gender disparity (Alhassan et al., 2019).

Improved crop insurance design, which uses the most accurate technology to determine if payouts are necessary, will benefit farmers and the insurance industry while also preparing for climate change shocks that cannot be mitigated (Murken et al., 2019). Post-harvest management is a low-cost and cost-effective strategy

that needs to be upscaled through policy (Murken et al., 2019). Research on crop varieties and drought-resistant varieties of staple crops need to be funded to address decreased yields (Murken et al., 2019).

A content analysis of key policy documents in Ghana reveals varying levels of climate change adaptation integration across sectors. The reviewed policies align closely with the principles of sustainable development by linking agricultural growth with environmental stewardship and social inclusion. They advance the targets of SDG2 and SDG13. In the FASDEP, the overarching objective was to enhance food security and ensure emergency preparedness in the face of climatic hazards such as dry spells, droughts, and floods. To address these threats, the policies advocated for the use of improved crop varieties, increased access to fertilizer, and the introduction of climate-resilient livestock breeds. Notably, the integration of crop and livestock auction systems within policy activities contributed to boosting food security, which reflected a practical alignment between policy objectives and implementation strategies. In the Water Sector Policy, the policies emphasized integrated water resource management (IWRM) to counter challenges such as floods, droughts, and prolonged dry spells. Adaptation strategies included the construction of flood protection infrastructure at vulnerable sites and the incorporation of rainwater harvesting systems into building codes. These measures demonstrated a clear climate adaptation orientation, particularly focusing on reducing the impacts of flooding and water scarcity.

CONCLUSION

This review has synthesized a body of research that clearly demonstrates the escalating threat of climate change to agricultural productivity and food security in Northern Ghana. The findings underscore that rising temperatures, increasingly erratic rainfall patterns, and the growing frequency of extreme weather events are key drivers of land degradation, declining crop yields, and heightened vulnerability for smallholder farmers. The analysis reveals that these climatic shifts not only undermine agricultural output but also exacerbate poverty and malnutrition, creating a cycle of vulnerability that is difficult to break. Projections indicate that these adverse trends are likely to intensify, posing a significant challenge to the sustainability of agricultural livelihoods in the region.

In response to these challenges, a range of adaptation strategies have been implemented in Northern Ghana, including sustainable agricultural intensification practices, soil and water conservation techniques, and the adoption of improved crop varieties. These efforts have shown some success in mitigating the negative impacts of climate change, such as improving soil fertility, enhancing water security, and diversifying income sources. However, the widespread adoption and long-term effectiveness of these strategies are constrained by several factors, including limited access to financial resources, inadequate extension services, and socio-economic inequalities, particularly gender disparities.

The review highlights the urgent need for robust policy interventions to create an enabling environment for effective climate change adaptation in the agricultural sector. Scaling up successful adaptation practices requires integrated policy approaches that address systemic barriers and promote climate-resilient development. Key policy recommendations include expanding agricultural insurance schemes to protect farmers from climate-related losses, investing in climate-smart agricultural technologies and knowledge-sharing systems, and strengthening conservation agriculture policies with financial incentives for sustainable land management.

Furthermore, enhancing coordination and implementation of climate adaptation policies at the national and local levels is crucial for ensuring that resources are effectively targeted and that adaptation efforts are aligned with broader development goals.

In conclusion, addressing the complex nexus of climate change, agriculture, and food security in Northern Ghana demands a multifaceted approach that integrates scientific knowledge, local expertise, and policy innovation. While adaptation strategies offer pathways to build resilience, their success hinges on overcoming persistent socio-economic constraints and implementing well-designed, effectively coordinated policies. There must be a concerted effort to empower vulnerable communities, enhance their adaptive capacity, and foster sustainable agricultural practices. Only through such comprehensive and sustained action can the region safeguard its agricultural future and ensure the well-being of its people in the face of an increasingly uncertain climate. The long-term prosperity of Northern Ghana depends on embedding the principles of sustainability and sustainable development at the core of all adaptation and policy efforts, ensuring progress towards food security and climate resilience endures for future generations.

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