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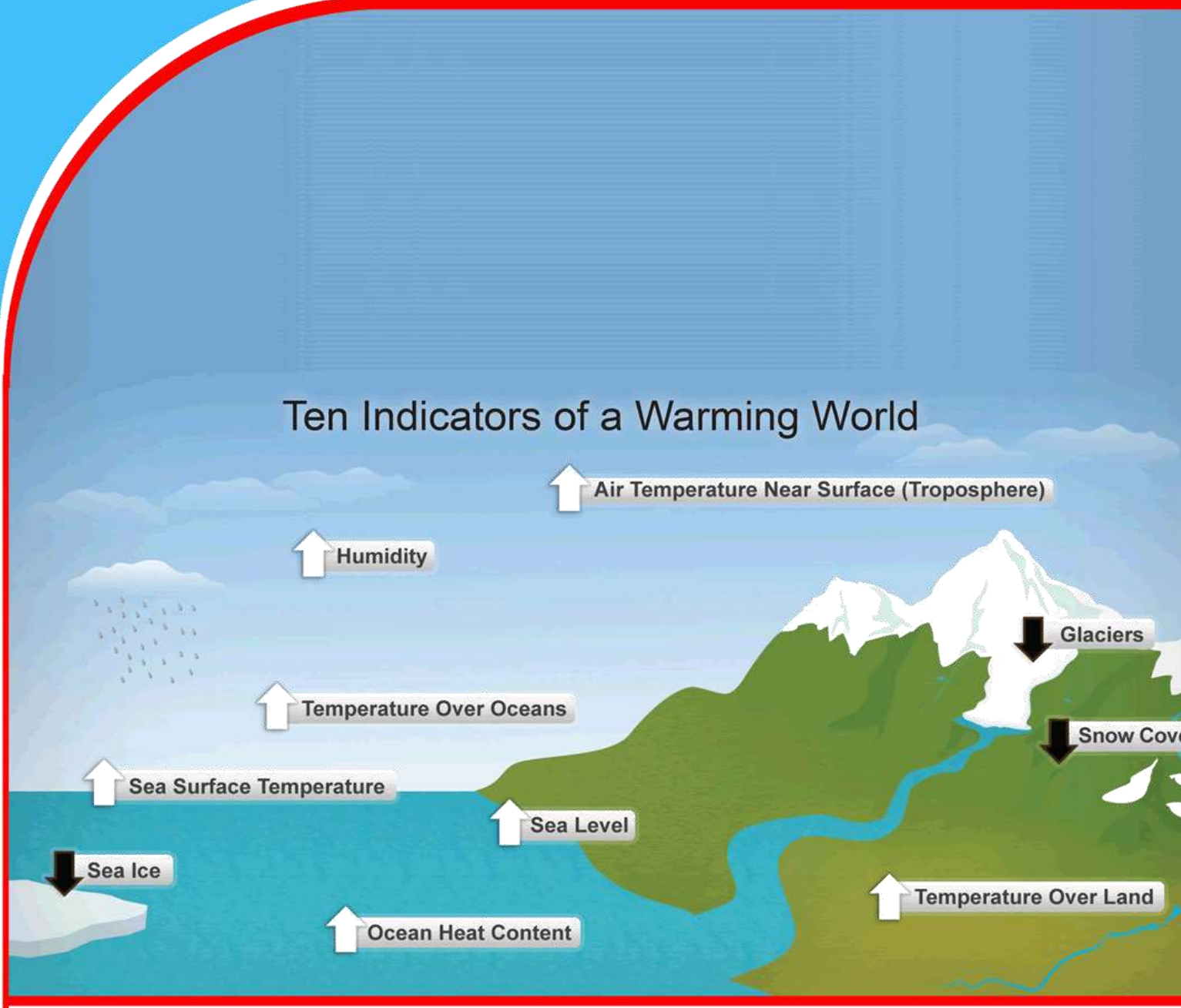

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The Effects of Change in Climatic Conditions on Agriculture in Ghana: A Review

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Abstract

Purpose: The aim of this review is to examine the effect of change in climatic conditions on Ghana's agriculture, focusing on how changing climatic conditions affect agricultural productivity, the economic implications for the sector, and the effectiveness of governmental policies designed to mitigate these impacts.

Materials and Methods: The review synthesizes up-to-date work done on changes in climatic conditions in the contextual setting of Ghana. It explores various data sources, including peer-reviewed journals, government reports, and climate assessments, to analyze the situation at hand. The study also evaluates the pennyworth of agriculture to the economy of Ghana and examines policy responses.

Findings: The review identifies that climate change has brought about significant variability so far as weather patterns are concerned, resulting in decreased agricultural productivity, decreased food security, and economic instability in the sector being discussed. The analysis highlights that while Ghana's economy hinges on the agricultural sector, its defenselessness of changes in climatic conditions poses a significant challenge to economic sustainability.

Unique Contribution to Theory, Practice and Policy: The findings will add deep insight to the effect of changes in climatic conditions in tropical agricultural contexts, emphasizing the need for adaptive strategies that are context-specific. It also adds to the discourse on sustainable agricultural practices within the framework of climate resilience. For practitioners, this study underscores the urgency of embracing climate-smart agricultural norms, improving water management, and diversifying crops to enhance resilience. The findings also suggest the need for capacity building among farmers to be receptive to climate-related challenges. The review advocates for a robust inculcation of climate change adaptation strategies into national agricultural policies. It calls for increased governmental support for research and development, improved availability of climate data for farmers, as well as the creation of policies that promote sustainable land use and resource management.

Keywords: *Climatic Conditions, Agriculture, Drought, Economy, Economic Development*

JEL Code: Q54

INTRODUCTION

Changes in climatic conditions have become a significant worldwide topic in recent times, impacting different areas such as agriculture. Agriculture in Ghana is not just the mainstay of the economy, but also a crucial money-making venture for a significant segment of the people. Agriculture currently contributes approximately 21.2% to Ghana's GDP and employs about 33% of the workforce according to recent national accounts (Ghana Statistical Service, 2023; FAO, 2023). Nevertheless, the growing unpredictability in weather patterns, increasing temperatures, and extreme climatic events are presenting major challenges to agricultural productivity and sustainability. Before the industrial period, an increase of approximately 1.1 °C of the average temperature of the earth was recorded, and this rise is projected to persist unless there are substantial cutbacks in greenhouse gas emissions (IPCC, 2021). Recent projections indicate that Ghana's mean annual temperature is expected to increase by 1.5-2.5 °C by 2050 under medium-emission scenarios (UNFCCC, 2022; Ghana EPA, 2022). Additionally, throughout the past 40 years, rainfall has decreased in every ecological zone in Ghana (Ministry of Environment, Science, Technology and Innovation [MESTI], 2013). Sea level rise along Ghana's coastline is estimated at 3–6 mm annually, with projections indicating a rise of 20–30 cm by 2050 (UNFCCC, 2022; EPA, 2022). Rainfall variability, however, has seen considerable variation across Ghana's agro-ecological zones. The Coastal Savannah and Sudan Savannah have experienced reductions of 20-30%, while the Forest and Transition zones have shown increasingly erratic rainfall distribution rather than total declines (Ghana EPA, 2020). Key crops such as maize, cassava, and groundnut have been particularly affected, with notable yield declines observed in the Northern, Upper East, and Upper West regions due to prolonged dry spells and late onset of rains (MoFA, 2022). Case studies from the Upper East Region reveal that delayed rainfall onset has shifted planting dates by 2-4 weeks, contributing to recurrent crop failures among smallholders (Adimassu et al., 2024). Due to this impact on temperature, precipitation, and harsh conditions like drought and flood, the agriculture industry is clearly highly susceptible to changes in climatic conditions (Wood et al., 2021). This significantly influences agriculture in Ghana, impacting crop yields, livestock production, and overall food security. Another effect is the change in rainfall patterns, causing either droughts or heavy rainfall. These alterations cause disruptions to the timing of planting and harvesting, impacting the number of crops produced and the availability of food (Asante et al., 2017).

The majority of agricultural producers are low-income farmers who are susceptible to the negative impact of changes in climatic conditions. They are especially at risk because they have restricted availability of resources and adaptive technologies. Recent studies further highlight the acute vulnerability of Ghanaian smallholders. Antwi-Agyei et al. (2020) reported that limited livelihood assets, declining soil fertility, and inadequate climate information services substantially reduce farmers' adaptive capacity, particularly in the Northern and Transition zones. Similarly, Diao et al. (2021) found that climate-induced yield variability significantly threatens household income stability, with poor farmers disproportionately affected due to their reliance on rain-fed agriculture and low levels of mechanization." These farmers frequently do not have enough money to invest in irrigation systems, better seed types, and other adaptive techniques, making them more at risk of climate-related crop losses (World Bank, 2018). Moreover, climate change worsens current problems like soil depletion, restricted financial resources, and insufficient infrastructure. As a result, there is a risk to food security, causing higher poverty and malnutrition rates, especially in rural regions where their source of income is based on agriculture. Agriculture remains one of the top contributors to Ghana's greenhouse gas emissions, accounting for approximately 34% of national emissions, mainly from enteric fermentation, manure management, and rice cultivation (Ghana EPA, 2022). It increases NO_2

and CH_4 emissions in Sub-Saharan Africa, with a projected steady rise as reported by Acheampong in 2011.

Problem Statement

Ghana's agricultural sector is susceptible to change in climatic conditions as a result of its position in a warmer climate zone, geographically. It puts food security at risk, aggravates unemployment in rural areas by displacing workers from the agricultural sector, and eventually has a restraint on economic expansion. The agricultural sector, being predominantly rain-fed, quickly detect changes in climatic variables like temperature, rainfall, and harsh weather conditions. Despite the recognition of this issue, there is a huge void in comprehending the specific effects of changes in climatic conditions on different agricultural systems and regions within Ghana. The current literature lacks specificity regarding regions and crops. Most existing publications focus primarily on traditional mitigation strategies such as crop diversification, improved irrigation techniques, and soil conservation practices. However, there remains limited exploration of innovative and emerging approaches that could enhance agricultural resilience, which will be discussed in later sections. Moreover, the effectiveness of existing governmental policies and adaptation strategies in mitigating these impacts remains uncertain. On the other hand, researchers lack the necessary data to help in policy formulation with regards to biotechnology approaches in solving the problems identified. The significant decrease in agriculture's contribution to Ghana's GDP necessitates a deep examination of the effects of climatic variability on the sector. Recent national accounts show that agriculture's share of GDP declined from 31.8% in 2009 to about 21.2% in 2022 (Ghana Statistical Service, 2023). This decline coincides with increasing climate-induced yield variability, particularly in staples such as maize, sorghum, and groundnut, which are highly sensitive to prolonged dry spells and rainfall unpredictability (MoFA, 2022).

THEORETICAL FRAMEWORK

Application of Adaptation Theory

Adaptation theory in terms of changes in climatic conditions and agriculture involves the strategies and measures that farmers and communities adopt to lessen the adverse effects of changes in climatic conditions. In Ghana, where agriculture is a critical sector, adaptation strategies are crucial for maintaining agricultural productivity and ensuring food security. Adaptation can take various forms, including technological innovations, changes in agricultural practices, and shifts in crop selection. For instance, Adger et al. (2007) alluded that Ghanaian farmer may adopt drought-resistant crop varieties or diversify their crops to reduce the vulnerability in connection with climate change.

The theory emphasizes the dynamic nature of adaptation, recognizing that it is not a one-time action but a continuous process that evolves as climate conditions and socio-economic factors change (Smit & Wandel, 2006). In Ghana, the success of adaptation efforts relies on various factors such as access to information, financial and institutional support. This theory is particularly relevant as it highlights the importance of local knowledge and community-driven approaches in developing effective adaptation strategies. Applying adaptation theory is crucial as policymakers and researchers can better understand the specific needs of Ghanaian farmers and design targeted interventions that enhance their resilience to climate change.

In the context of this study, Adaptation Theory informs the selection of variables related to farmers' adjustment strategies such as crop diversification, adoption of drought-tolerant varieties, irrigation practices, and soil- and water-management techniques. By grounding the study in this theory, these variables are interpreted not as isolated practices but as components

of an evolving adaptive process shaped by changing climatic conditions, resource access, and institutional support within Ghana's agricultural systems.

Insights from Vulnerability Theory

Vulnerability theory examines the susceptibility of a system, population, or individual to harm from environmental changes, such as those brought about by climate change. In the context of Ghanaian agriculture, vulnerability theory identifies which communities, crops, or regions are most defenseless to the effects of changes in climatic conditions. Studies show that factors contributing to vulnerability include socio-economic status, geographic location, and access to resources (Adger, 2006). For example, smallholder farmers in Ghana's northern regions, who rely heavily on rain-fed agriculture, are particularly susceptible to the variability of rainfall patterns and prolonged droughts.

Vulnerability theory also explores the interplay between exposure, sensitivity, and adaptive capacity (Turner et al., 2003). In Ghana, where exposure to climate risks such as floods and droughts are high, the sensitivity of agricultural systems can vary depending on factors like soil quality, crop type, and farming practices. Poverty, lack of education, and inadequate infrastructure often limit the adaptive capacity of farmers to adjust to changing conditions. Stakeholders can prioritize areas and groups that require urgent attention and support, thereby enhancing the overall resilience of Ghana's agricultural sector.

For this study, Vulnerability Theory directly shapes how exposure (rainfall variability, temperature anomalies), sensitivity (crop type, soil fertility), and adaptive capacity (education, access to extension, farm assets) are operationalized as analytical variables. These components guide data interpretation by highlighting the uneven distribution of climate impacts across Ghana's agro-ecological zones and farmer groups, particularly smallholder farmers in northern Ghana who face the greatest exposure and least adaptive capacity.

Socio-Ecological Systems (SES) Theory and Agricultural Adaptation

Socio-ecological systems (SES) theory provides a holistic framework for understanding how human communities and ecological systems interact to shape agricultural outcomes (Berkes et al., 2003). In Ghana, where farming is closely tied to rainfall patterns, soil fertility, and ecosystem health, SES theory is particularly relevant for analyzing how climate change disrupts both ecological processes (e.g., soil moisture dynamics, water availability, biodiversity) and social structures (e.g., labor availability, local institutions, cultural practices).

SES theory is also useful in explaining how feedback loops, such as reduced yields leading to soil nutrient mining, or drought prompting land-use changes, amplify climate impacts over time. It highlights the importance of adaptive management, continuous learning, and institutional coordination in strengthening resilience. In Ghana, extension services, farmer-based organizations, and district-level institutions play essential roles in mediating these feedback loops by enabling knowledge sharing, resource access, and collective decision-making.

In this study, SES theory informs the conceptual model by linking environmental variables (rainfall, temperature, soil conditions) with socio-economic and institutional variables (farm income, extension access, policy support). This enables an integrated interpretation of findings that considers both ecological responses to climate variability and the social systems that influence farmers' adaptive choices.

How the Selected Theories Inform the Conceptual Model

The three selected theories collectively provide the foundation for the study's conceptual model. Adaptation Theory identifies the behavioral and technological adjustment strategies that farmers employ, which guide the selection of variables such as crop diversification, irrigation practices, and adoption of improved varieties. Vulnerability Theory shapes how the study interprets exposure (rainfall and temperature trends), sensitivity (crop characteristics, soil conditions), and adaptive capacity (education, access to extension, livelihood assets), helping determine which groups or regions may be more affected by climate variability. Socio-Ecological Systems Theory integrates these components by illustrating how ecological processes and social structures interact. This informs the inclusion of variables related to institutional support, environmental conditions, socioeconomic status, and feedback loops within farming systems. These theories ensure that the study captures the multidimensional nature of climate impacts on Ghanaian agriculture and provides a coherent basis for analyzing farmer responses, disparities in climate vulnerability, and the overall resilience of agricultural systems.

Empirical Review

In regions like the Jaman South Municipality, farmers have observed significant changes in rainfall, leading to shorter planting seasons and erratic weather events (Kwakye, 2023). These shifts have directly resulted in lower crop yields, creating a precarious situation for those who depend on agriculture for their sustenance and income. Broader evidence from global and regional assessments supports these local observations. The IPCC's Sixth Assessment Report (WGII) highlights that West Africa, including Ghana, faces increasing temperature and precipitation variability that is already affecting crop productivity and food systems (IPCC, 2022). FAO's regional and city-level briefs also document the combined effects of climate shocks and socio-economic vulnerability on food systems in northern Ghana, with climate variability, pests, and market shocks reducing household food and income security (FAO, 2023). National planning documents, such as the Climate-Smart Agriculture Investment Plan for Ghana, further confirm that climate impacts (especially reduced rainy-season reliability and increased dry spells) are key drivers of yield declines and livelihood risks for smallholders (World Bank & MoFA, 2021). Further, a study by Afele et al. (2024) highlighted that cocoa farmers who play a crucial role in Ghana's economy have reported declining yields. Mounting evidence from Ghana corroborates cocoa and staple crop yield sensitivity to climate variation: e.g., region-specific analyses show that legume and cereal yields in the Guinea-Savanna and Transition zones are particularly vulnerable to changing rainfall patterns and heat stress (Yeleliere et al., 2023). Studies on climate information and services also indicate that better access to timely forecasts can substantially increase farmers' adaptive capacity, yet uptake and reach remain uneven across agro-ecological zones (Baffour-Ata et al., 2022; Antwi-Agyei et al., 2021). Approximately 71.43% of these farmers attribute the decrease in productivity not only to climate change, but also to deforestation and other environmental factors. This situation underscores the interrelated challenges of agriculture and environmental degradation.

In response to these climatic challenges, farmers in Ghana are adopting various adaptation strategies to mitigate the negative impacts on their crops. According to Kwakye (2023), many are turning to practices such as crop diversification, the use of drought-resistant varieties and cover cropping, which allow them to create resilient agricultural systems. By adjusting their planting schedules and experimenting with different crop varieties, farmers are attempting to buffer their production against the uncertainties of weather. In urban areas like Wa in Ghana, Naazie et al. (2024) highlights that the emphasis on mixed farming and crop diversification

further illustrates how communities are responding to climatic stressors. These strategies are crucial as they not only aim to sustain production but also to enhance food security within vulnerable populations. Large-scale assessments and syntheses indicate that while crop diversification and drought-tolerant varieties are widely promoted, their effectiveness depends on access to inputs, extension services, financial instruments, and reliable climate information (IPCC, 2022; World Bank & MoFA, 2021). Country-level evidence highlights persistent constraints: low irrigation coverage, limited seed system support for stress-tolerant varieties, and weak credit/insurance markets, which together limit the scale and success of farmer adaptations (World Bank & MoFA, 2021; FAO, 2023).

A study by Awuni et al. (2023) reveals that, despite these adaptation efforts, there is a pressing need for improved climate education and policy interventions. They further indicate that many farmers face significant barriers due to inadequate funding and challenges in implementing effective adaptation measures. Multiple studies underline the policy and capacity gaps that constrain meaningful up-scaling of adaptation. National assessments and investment plans identify weaknesses in institutional coordination, inadequate extension coverage, gendered constraints on resource access, and limited monitoring of climate-agriculture outcomes (World Bank & MoFA, 2021; NCCAS, 2010). A recent study also points to persistent data gaps (long-term, location-specific yield and climate records) and limited ex-post evaluations of adaptation interventions, which together hinder robust, evidence-based policy making (IPCC, 2022; Antwi-Agyei et al., 2021). In rural regions, particularly, there is a noticeable lack of resources and support, which could exacerbate the difficulties brought on by climate change. Therefore, creating comprehensive policies that emphasize climate resilience in agriculture is critical. These policies should focus on providing financial support, education, and resources to enable farmers to adapt successfully to changing climatic conditions.

Although there is growing evidence that Ghanaian agriculture is affected by climate variability, several critical gaps remain. First, many studies are either national in scope or small, localized case studies; there is a scarcity of *comparative*, agro-ecology-specific analyses that link crop-level yield trends to observed local climate signals across multiple regions. Second, there is limited empirical evidence on the feasibility and socio-economic acceptability of biotechnology and stress-tolerant varieties alongside traditional adaptation measures (e.g., how adoption varies by gender, wealth, and institutional access). Third, policy assessments often describe planned actions but lack rigorous evaluation of which adaptation investments actually improve yields and livelihoods under variable climates. Lastly, uptake and equity of climate information services and financial instruments (credit, insurance) remain under-documented across agro-ecological zones. This study addresses these gaps by (1) conducting regionally stratified analyses of climate signals and crop performance, (2) evaluating farmer adoption and constraints for both conventional and biotechnology-enabled adaptations, and (3) assessing policy-relevant institutional and socio-economic barriers to scaling effective practices.

MATERIALS AND METHODS

The present study employs an extensive method of review of literature to examine the effects of changes in climatic conditions on Ghanaian agriculture. A systematic approach ensures the synthesis of diverse perspectives and findings from existing research, enabling a rigorous analysis of these specific agricultural impacts. This study relied solely on secondary data from publicly available sources, ensuring adherence to ethical standards in academic research.

FINDINGS

Conceptual Gaps

Farmers in Ghana have reported significant changes in rainfall patterns and temperature, adversely affecting crop production. They employ various adaptation strategies, such as crop diversification and adjusting planting times, but these strategies are often influenced by factors like education and access to extension services (Kwakye, 2023). Consequently, there is a notable gap in integrating indigenous knowledge with modern scientific techniques. While indigenous practices are crucial for resilience, they are often overlooked in favor of scientific methods, leading to ineffective adaptation strategies (Sedegah et al., 2023). These gaps highlight the need to develop strategies that enables the successful integration of scientific knowledge into traditional farming practices which is appropriate in Ghana.

Contextual Gaps

The existing classification of Ghana's agro-climatic zones is outdated. The continued use of these outdated classifications in the context of agriculture as much as is not scientifically healthy is also not good for its productivity (Yamba et al., 2023). Current studies primarily focus on broad regional impacts, neglecting localized variations in climate effects on specific crops (Bonsu et al., 2022). For instance, while temperature increases have been documented, the specific thresholds for various crops remain underexplored, limiting targeted interventions (Gyamerah et al., 2024).

Geographical Gaps

The current literature lacks specificity regarding regions and crops. South Africa's Debra Roberts of the Sustainable and Resilient city Initiatives Unit, Ethekwini municipality reports that works being done at the city and community levels are not documented and hence provides a gap in understanding the specificities regarding the indicators of climate change in various African countries, with Ghana being no exception (Roberts, 2015). A recent study by Yamba et al. (2023) suggests a need for a reclassification to reflect current climatic realities because the agro-climatic zoning has not been done properly.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Changes in climatic conditions continue to pose a complex, multi-layered challenge to Ghana's agricultural sector, with consequences for food security, rural livelihoods, and national economic stability. The findings of this research reaffirm that Ghana's predominantly rain-fed agriculture is highly sensitive to shifts in rainfall, temperature, and extreme weather events. These impacts were evident in declining crop yields, shortened growing seasons, and increasing livelihood vulnerabilities among smallholder farmers.

Situating these findings within the Social Ecological Model (SEM) shows clarity on how climate change interacts with multiple levels of influence. At the individual level, farmers' adaptive actions, such as adjusting planting dates or adopting drought-tolerant crop varieties, are often constrained by limited access to climate information, credit, or modern inputs. At the interpersonal and community levels, social networks, farmer-based organizations, and local knowledge systems provide both support and limitations in responding to climatic stress. At the organizational level, the study highlighted persistent weaknesses in extension services, input delivery systems, and agricultural institutions, which reduce farmers' capacity to adopt climate-resilient practices. Finally, at the policy and societal levels, inconsistencies between national climate policies and on-ground implementation deepen the vulnerability of the sector.

These multi-level insights underscore that climate impacts are not only environmental but also structural and systemic. The present study also emphasizes the need to strengthen higher-level system supports, such as research and development in crop improvement, improved water management, and sustainable land-use practices, which are critical for enabling resilience across all layers of the SEM. When these structural supports are weak, lower-level adaptive efforts become insufficient, further widening the gap between policy design and farmers' reality.

Despite the significant threats posed by climate change, the findings also revealed opportunities for innovation, particularly through climate-smart agriculture, improved farmer education, and technological advances that can enhance productivity under variable conditions. Ultimately, building a resilient agricultural future for Ghana requires coordinated action at all levels of the ecological system: individual farmers, communities, institutions, and the national policy environment. Strengthening these interconnected layers will be essential to creating a durable and adaptive agricultural system capable of withstanding ongoing climatic changes.

Recommendations

Before implementing theoretical, practical, and policy interventions, this study recommends the adoption of an integrated conceptual model that connects climate variables, socio-economic factors, and farmers' adaptive capacity. The model illustrates that changes in climatic conditions (e.g., rainfall variability, temperature increases, and extreme weather events) directly influence agricultural productivity. However, the extent of impact is mediated by socio-economic factors, including access to credit, education, extension services, farm size, and gender roles. These factors shape the adaptive capacity of farming households, determining whether farmers adopt innovations such as drought-tolerant varieties, improved irrigation, agroforestry, and climate-smart practices. Highlighting the interaction between environmental pressures and social constraints, the model underscores that effective climate adaptation in Ghana must target both biophysical challenges and structural socio-economic barriers. Future empirical studies should operationalize this model by testing these pathways statistically to guide targeted interventions.

Theory

In the future, research work should elaborate on refining theoretical models that explain the dynamics of the effect of changes in climatic conditions on agriculture, particularly in tropical regions like Ghana. These models should integrate interdisciplinary approaches, combining insights from climatology, agricultural science, economics, and the social sciences to create a holistic understanding of climate resilience in agriculture. Theoretical frameworks should also consider the socio-economic dimensions of climate change, including the role of gender, income levels, and social capital in shaping the adaptive capacities of farming communities. This would show how different communities react to and cope with changing climatic conditions.

Practice

In order to increase resilience to climate variability, it is imperative to accelerate the implementation of climate-smart agricultural techniques. This covers the application of agroforestry, effective irrigation methods, soil conservation strategies, and crop cultivars resistant to drought. Training programs and demonstrations should be expanded to reach more farmers, especially in vulnerable regions. Farmers should have improved ways to timely and accurate climate information to make informed decisions. This can be solved by using mobile technology, community-based weather stations, and partnerships with meteorological services.

Tailoring information to the specific needs of different farming communities is crucial for effective decision-making.

Policy

Ghana has a number of policies in place to mitigate the effects of climate change on agriculture, but their execution still needs to be improved. This includes ensuring that policies are well-funded, monitoring their impact, and making necessary adjustments based on feedback from stakeholders, including farmers. Climate adaptation strategies should be mainstreamed into all aspects of national development planning. This includes incorporating climate resilience into agricultural policies, infrastructural development, and rural development programs to ensure a coordinated approach.

The government should increase support for research and innovation in climate-smart agriculture. This includes funding for research on new crop varieties, pest and disease management, and sustainable land use practices. Public-private partnerships can help in driving innovation and scaling up successful practices.

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