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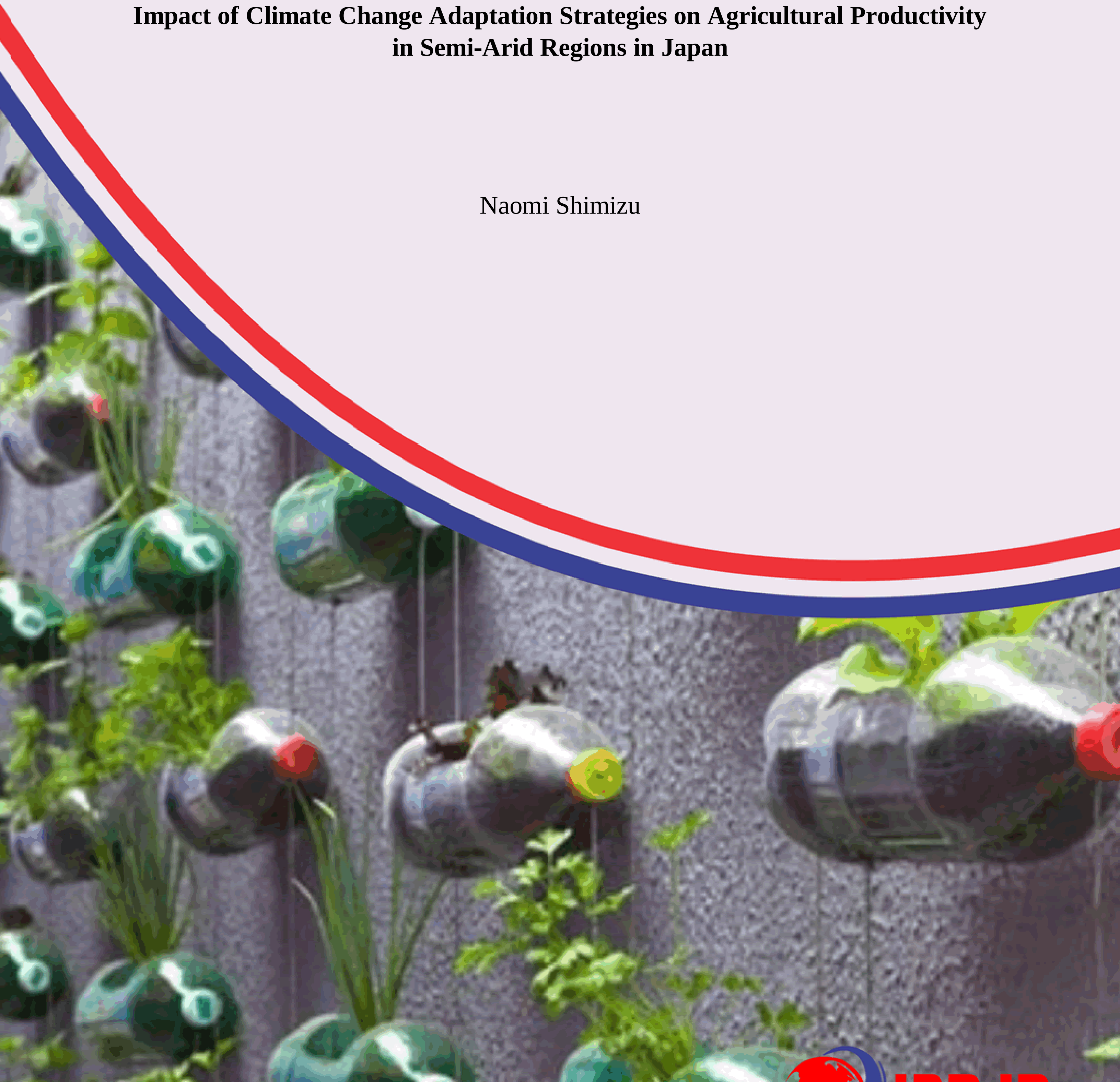

Impact of Climate Change Adaptation Strategies on Agricultural Productivity in Semi-Arid Regions in Japan

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Abstract

Purpose: To aim of the study was to analyze impact of climate change adaptation strategies on agricultural productivity in semi-arid regions in Japan.

Methodology: This study adopted a desk methodology. A desk study research design is commonly known as secondary data collection. This is basically collecting data from existing resources preferably because of its low cost advantage as compared to a field research. Our current study looked into already published studies and reports as the data was easily accessed through online journals and libraries.

Findings: Climate change adaptation strategies in semi-arid regions of Japan, such as drought-resistant crops, efficient irrigation systems, and improved soil management, have helped maintain and improve agricultural productivity under changing climate conditions. These measures reduce the negative effects of water scarcity, extreme temperatures, and unpredictable rainfall on farming activities. However, continued investment in technology, farmer training, and sustainable resource management is necessary to ensure long-term agricultural resilience and food security.

Unique Contribution to Theory, Practice and Policy: Diffusion of innovation theory, sustainable livelihoods theory & resilience theory may be used to anchor future studies on the impact of climate change adaptation strategies on agricultural productivity in semi-arid regions in Japan. This study contributes to practice by giving farmers, extension officers, agricultural trainers, cooperatives, and development partners practical guidance on improving productivity in semi-arid regions. This study contributes to policy by providing evidence that climate change adaptation should be treated as a key agricultural productivity strategy in semi-arid regions.

Keywords: *Climate Change Adaptation Strategies, Agricultural Productivity*

INTRODUCTION

Agricultural productivity refers to the efficiency with which agricultural inputs such as land, labour, capital, seeds, fertilizer, water, and technology are converted into agricultural outputs including crops and livestock. High agricultural productivity means that farmers are able to produce more output using the same or fewer resources, which improves food security, farmer income, and economic growth. In the United States of America (USA), agricultural productivity has increased significantly because of mechanization, biotechnology, irrigation, precision farming, and agricultural research. Studies show that total factor productivity in United States agriculture grew by approximately 170% between 1948 and 2021, meaning that agricultural output expanded much faster than input use. However, recent evidence suggests that climate change is slowing productivity growth, leading researchers to estimate that public agricultural research and development investment would need to increase by 5.2% to 7.8% annually between 2021 and 2050 to offset climate-related productivity losses (Ortiz-Bobea, 2024).

Japan provides another example of a developed economy where agricultural productivity is strongly linked to technological innovation and efficient land use. Despite limited arable land and an ageing farming population, Japan has maintained relatively high productivity through mechanization, greenhouse farming, robotics, and precision agriculture. In the United Kingdom (UK), agricultural productivity has also improved through scientific farming methods, improved crop varieties, digital agriculture, and sustainable land management practices. Recent evidence from developed economies shows that productivity growth increasingly depends on innovation, climate adaptation, and efficient resource use rather than simply expanding farmland or labour. This supports the argument that developed economies maintain agricultural productivity by combining technology, policy support, and long-term agricultural research investment (Ortiz-Bobea, 2024).

In developing economies, agricultural productivity is important because agriculture supports food supply, employment, exports, and rural livelihoods. However, productivity growth is often limited by poor infrastructure, climate variability, limited mechanization, weak market access, inadequate irrigation, and low use of modern farming technology. India is a strong example because agriculture remains a major economic activity, yet productivity varies greatly across regions due to differences in irrigation, technology adoption, and climate conditions. Studies show that India has experienced increased crop productivity over recent decades because of improved seed varieties, fertilizer use, irrigation expansion, and government support programs, although challenges such as soil degradation and climate stress continue to affect yields. Recent agricultural productivity studies in India also show uneven productivity trends across cities and regions due to environmental and climatic pressures affecting farming systems (Gil-Alana & Carmona-González, 2025).

Brazil provides another important developing-economy example because it has become one of the world's largest agricultural producers through mechanized farming, agribusiness expansion, improved seed technology, and export-oriented agriculture. Brazil's soybean production increased from approximately 39 million metric tons in 2000 to over 150 million metric tons in 2023, showing a major rise in agricultural productivity. However, this growth has also raised concerns about deforestation, biodiversity loss, and environmental sustainability in the Amazon region.

Developing economies therefore face the challenge of increasing agricultural productivity while also protecting land, forests, and water resources. This demonstrates that productivity growth in developing countries depends not only on increased production but also on balancing food security, environmental conservation, and sustainable agricultural practices (Correia Filho , 2024).

In Sub-Saharan economies, agricultural productivity is a major concern because agriculture remains the primary source of income and employment for a large share of the population. Agricultural productivity in the region is generally lower than in developed economies because of limited mechanization, low fertilizer use, weak irrigation systems, poor infrastructure, limited access to finance, and climate variability. A peer-reviewed study by Djoumessi (2022) examining 23 Sub-Saharan African countries from 1991 to 2015 found that agricultural productivity growth has improved in some countries, although progress remains uneven across the region. The study showed that productivity growth is important for poverty reduction, food security, and rural economic transformation in Sub-Saharan Africa. It also emphasized that improving total factor productivity is necessary for long-term agricultural and economic development in the region (Djoumessi, 2022).

Kenya provides a good Sub-Saharan example because agriculture contributes significantly to employment, exports, and food supply, with tea, coffee, maize, horticulture, and dairy farming being major agricultural activities. Agriculture contributes about 24% of Kenya's Gross Domestic Product (GDP) directly and supports a large share of rural livelihoods. Nigeria also demonstrates the importance of agricultural productivity because agriculture remains a key economic sector despite increasing urbanization and industrialization. Recent studies show that productivity in Sub-Saharan Africa can improve through better technology adoption, irrigation, farmer training, improved seeds, digital agriculture, and stronger agricultural institutions. Therefore, agricultural productivity in Sub-Saharan economies is closely linked to food security, poverty reduction, climate resilience, and sustainable economic development (Sithole, 2024).

Climate change adaptation strategies refer to the practical measures that farmers, communities, and governments use to reduce the negative effects of climate change on farming systems. These strategies are important because climate change affects agricultural productivity through droughts, floods, unreliable rainfall, rising temperatures, pest outbreaks, and soil degradation. The first likely strategy is climate-smart crop selection, where farmers use drought-tolerant, heat-tolerant, early-maturing, or disease-resistant crop varieties to maintain yields under changing climate conditions. The second strategy is improved water management, which includes irrigation, rainwater harvesting, water storage, and efficient watering methods such as drip irrigation to reduce crop losses during dry seasons. These strategies improve agricultural productivity by helping crops survive climate stress and by reducing dependence on unreliable rainfall (Sithole, 2024).

The third likely strategy is soil and land conservation, which includes mulching, terracing, minimum tillage, agroforestry, cover cropping, and use of organic manure to protect soil fertility and reduce erosion. Healthy soils improve agricultural productivity because they retain moisture, support plant growth, and reduce the risk of crop failure during drought or heavy rainfall. The fourth strategy is climate information and early warning systems, where farmers use weather forecasts, seasonal climate predictions, pest alerts, and extension advice to make better decisions on planting, harvesting, input use, and crop protection. This improves productivity because farmers

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can adjust their farming practices before climate shocks become severe. Therefore, climate-smart crop selection, improved water management, soil and land conservation, and climate information systems support agricultural productivity by reducing climate risks, improving resource efficiency, and strengthening farmers' resilience (Djoumessi, 2022; Bedeke, 2019).

Problem Statement

Semi-arid regions are increasingly experiencing serious agricultural productivity challenges due to climate change effects such as prolonged droughts, erratic rainfall, rising temperatures, land degradation, water scarcity, and increased pest and disease pressure. These regions depend heavily on rain-fed agriculture, yet rainfall is becoming more unpredictable and insufficient to support stable crop and livestock production. The Food and Agriculture Organization (FAO) notes that arid and semi-arid areas receiving less than 400 millimetres of annual precipitation dominate many dryland farming systems, making them highly vulnerable to climate stress. As climate risks intensify, farmers in semi-arid regions face declining yields, crop failure, reduced household income, food insecurity, and weakened rural livelihoods. Recent evidence also shows that climate change adaptation practices are increasingly important because they help smallholder farmers reduce climate-related losses and improve productivity under difficult farming conditions (Zagre, 2024).

Despite the growing use of adaptation strategies such as drought-tolerant crop varieties, irrigation, rainwater harvesting, conservation agriculture, agroforestry, crop diversification, climate information services, and early warning systems, agricultural productivity in many semi-arid regions remains low. This suggests that adaptation strategies may not be equally accessible, affordable, effective, or properly implemented among farmers. In Kenya, empirical evidence shows that farmers' use of multiple climate change adaptation strategies improves food security, with adoption of two strategies increasing food security by about 11% to 14%, three strategies by about 12% to 15%, and four strategies by about 14% to 18%, compared with farmers who adopt none (Gebre, 2023). However, many farmers still face barriers such as limited capital, weak extension services, poor access to climate information, inadequate irrigation infrastructure, low technology adoption, and limited market support. These barriers reduce the ability of adaptation strategies to translate into higher agricultural productivity.

The problem is that while climate change adaptation strategies are widely promoted as solutions to agricultural vulnerability, their actual impact on agricultural productivity in semi-arid regions is still not fully understood in many local contexts. Some farmers adopt improved seeds but lack water, while others receive climate information but lack inputs or credit to act on it. This means that adaptation may only improve productivity when strategies are well matched to local rainfall patterns, soil conditions, farmer capacity, and institutional support. Madamombe (2024) found that farmers' awareness of extreme weather events and adaptation choices are important in explaining maize yield outcomes, showing that adaptation is directly connected to productivity performance. Therefore, this study seeks to examine the impact of climate change adaptation strategies on agricultural productivity in semi-arid regions in order to generate evidence that can guide farmers, extension officers, policymakers, and development partners in improving climate-resilient agricultural production.

Theoretical Review

Diffusion of Innovation Theory

Originated by Everett Rogers, explains how new ideas, practices, and technologies spread within a community over time. Its relevance to the topic is that farmers in semi-arid regions may adopt adaptation strategies such as drought-tolerant seeds, irrigation, conservation agriculture, agroforestry, and climate information services at different rates depending on awareness, affordability, perceived usefulness, and social influence. The theory helps explain why some farmers adopt climate-smart practices earlier than others and how adoption affects agricultural productivity (Bedeke, 2019).

Sustainable Livelihoods Theory

Commonly associated with Robert Chambers and Gordon Conway, argues that households depend on livelihood assets such as natural, financial, human, social, and physical capital to survive shocks and improve wellbeing. Its relevance is that farmers in semi-arid regions face drought, rainfall failure, soil degradation, and food insecurity, so adaptation strategies help protect livelihood assets and sustain farm productivity. The theory supports the study by showing how access to land, water, credit, skills, extension services, and social networks influences farmers' ability to adapt to climate change and improve yields (Quandt, 2018).

Resilience Theory

Associated with C. S. Holling, focuses on the ability of systems to absorb shocks, adjust, and continue functioning. It is relevant because semi-arid farming systems are exposed to climate shocks such as droughts, heat stress, pest outbreaks, and erratic rainfall. Climate change adaptation strategies strengthen resilience by helping farmers recover from climate stress and maintain agricultural productivity over time (Meuwissen, 2019).

Empirical Review

Gebre, Amekawa, Fikadu, and Rahut (2023) examined farmers' use of climate change adaptation strategies and their effects on food security among rain-fed farming households. The purpose of the study was to determine the factors influencing farmers' choice of adaptation strategies and how these strategies affected food security, which is closely linked to agricultural productivity. The methodology used data collected from 540 farmers across six counties, and the researchers applied multivariate probit, censored least absolute deviation, and propensity score matching models. The findings showed that the main adaptation strategies were drought-tolerant crop varieties at 55%, crop diversification at 34%, early-maturing crops at 22%, and income diversification at 18%. The study further found that farmers who adopted one adaptation strategy had 7% to 11% higher food security, while those adopting four strategies had 14% to 18% higher food security than non-adopters. The study recommended improving access to extension services, farmer training, climate information, and support for multiple adaptation practices to increase productivity and food security in climate-vulnerable regions.

Zagre (2024) examined climate change adaptation strategies among smallholder farmers in Senegal's semi-arid zone. The purpose of the study was to assess how socio-economic factors and institutional support influence farmers' responses to climate change across three semi-arid regions with different rainfall gradients. The methodology used a two-stage stratified sampling method, household surveys from 145 households, descriptive statistics, and logit models. The findings showed that climate-smart technology options are important for improving productivity and incomes in dryland agricultural systems. The study also found that access to credit, extension services, farming experience, government subsidies, and interaction with extension workers significantly influenced farmers' adoption of climate-smart technologies. The study recommended stronger institutional support, improved access to credit, regular extension contact, and context-specific climate-smart agriculture interventions to increase productivity and resilience in semi-arid farming systems.

Madamombe (2024) assessed farmers' awareness of extreme weather events, identify adaptation strategies, and evaluate maize yield under different soil fertility and water management practices. The methodology involved a household survey of 245 smallholder farmers in Marange, Zimbabwe. The findings showed that farmers were aware of and had experienced extreme weather events, and they used adaptation strategies such as soil water harvesting, improved varieties, mulching, and tree planting. However, maize yields remained low, averaging only 0.62 tonnes per hectare among farmers using some soil fertility and water management practices. The study recommended further research and improved support on fertilizer use, water and nutrient management, improved varieties, and socio-economic factors to strengthen adaptation and raise maize productivity in semi-arid areas.

Magesa (2023) investigated the interaction between farmers' climate change adaptation strategies and Sustainable Development Goals in the semi-arid Mwanga and Same Districts of Tanzania. The purpose was to identify potential adaptation measures and assess their contribution to poverty reduction and zero hunger. The methodology used 200 household surveys, 36 key informant interviews, and a multi-stakeholder participatory approach. The findings showed that adaptation strategies such as early-maturing crops, drought-resistant crops, changing planting dates, improved varieties, and mixing short- and long-duration varieties were used by many farmers and could reduce climate impacts on productivity. However, the study also found that these strategies could have both positive and negative effects, especially where supporting services such as irrigation, credit, and extension were weak. The study recommended that adaptation planning should combine crop-based strategies with irrigation schemes, credit access, extension services, and improved infrastructure to achieve better yields and stronger food security outcomes.

Odelola, Matthew, and Aniramu (2025) assessed the impact of climate variability and farmers' adaptation strategies on food crop productivity in egbedore local government area of osun state, southwestern Nigeria. The purpose was to examine climate variability, identify adaptation strategies used by indigenous farmers, and assess constraints affecting their effectiveness. The methodology used a mixed-methods approach involving social surveys, interviews, and climate data analysis. The findings showed that annual rainfall increased by 2.2 millimetres per year and temperature increased by 0.02°C per year between 1975 and 2014, while 88.1% of respondents were aware of climate change impacts. The study also found that 84.6% of respondents linked declining agricultural produce to climate change, while 85.8% had adopted changes in planting dates as an adaptation strategy. The study recommended improved access to weather forecast services, improved crop varieties, affordable farm inputs, and credit facilities to enhance sustainable food production under climate change.

Kamuzora (2023) studied the effects of climate change adaptation strategies on maize productivity among smallholder farmers in Dodoma, Tanzania. The purpose of the study was to determine whether adaptation strategies improve maize productivity among smallholder farmers in a semi-arid area. The methodology used a cross-sectional research design, structured questionnaires, data from 274 randomly selected respondents, propensity score matching, and multiple linear regression. The findings showed that farmers who adopted climate change adaptation strategies achieved higher maize yields than non-adopters. The study further found that drought-resistant maize varieties, intercropping, minimal tillage, adjusted planting dates, fertilizers, irrigation, and short-duration maize varieties were associated with higher maize yields, while crop rotation had no significant effect. The study recommended government investment in modern irrigation schemes, promotion of drought-resilient seeds, and wider support for climate adaptation strategies to reduce losses and improve farmers' wellbeing.

Dawid (2025) examined farmers' adaptation strategies to climate change and their influence on agricultural production in Arsi Zone, Oromia, Ethiopia. The purpose was to explore farmers' perceptions of climate change, identify adaptation strategies, assess constraints, and determine factors influencing farmers' adaptation choices. The methodology used data from 303 households selected through multistage sampling, structured questionnaires, descriptive statistics, Mann-Kendall trend analysis, weighted average index, and a multivariate probit model. The findings showed that farmers used multiple adaptation strategies, including improved crop varieties, improved livestock breeds, mixed farming, soil and water conservation, and adjustment of planting dates. The study also found that cooperative membership, access to extension services, access to climate information, perception of climate change, and farm income significantly influenced adoption decisions. The study recommended stronger climate awareness through mass media, improved extension services, cooperative support, and better access to climate information to help farmers adapt and maintain agricultural productivity.

METHODOLOGY

This study adopted a desk methodology. A desk study research design is commonly known as secondary data collection. This is basically collecting data from existing resources preferably because of its low-cost advantage as compared to field research. Our current study looked into already published studies and reports as the data was easily accessed through online journals and libraries.

FINDINGS

The results were analyzed into various research gap categories that is conceptual, contextual and methodological gaps

Conceptual Gap

The reviewed studies discuss several climate change adaptation strategies, but many focus on either adoption decisions, food security, farmer awareness, or specific crop outcomes rather than giving a direct and integrated explanation of how adaptation strategies affect agricultural productivity. For example, Gebre, Amekawa, Fikadu, and Rahut (2023) focused on food security among rain-fed households, while Dawid (2025) examined farmers' perceptions, constraints, and adaptation choices. Other studies focused on maize yields, climate-smart technology adoption, sustainable development goals, or climate variability. This creates a conceptual gap because agricultural productivity is broader than food security or adoption of strategies alone; it involves crop yield, livestock output, farm efficiency, income from production, and stability of production under climate stress. Therefore, the current study can fill this gap by examining how selected adaptation strategies such as drought-resistant crops, irrigation, crop diversification, conservation agriculture, and climate information services jointly influence agricultural productivity in semi-arid regions.

Contextual Gap

The reviewed studies were mainly conducted among smallholder farmers, rain-fed households, maize farmers, and dryland farming communities. While these contexts are useful, they may not fully capture the broader farming conditions in semi-arid regions where farmers may engage in mixed farming, livestock keeping, irrigation farming, subsistence farming, and market-oriented agriculture at the same time. For instance, Madamombe (2024) focused on maize yield under soil fertility and water management practices, while Kamuzora (2023) examined maize productivity among smallholder farmers in Dodoma, Tanzania. This leaves a contextual gap because focusing mainly on one crop or one farmer category may not fully explain the wider relationship between climate change adaptation strategies and overall agricultural productivity. The current study can address this gap by considering semi-arid farming systems more broadly, including different crops, livestock activities, water access, farm inputs, extension support, and household-level adaptation capacity.

Geographical Gap

The reviewed empirical studies were conducted in selected countries and locations such as Kenya, Senegal, Zimbabwe, Tanzania, Nigeria, and Ethiopia. Although these studies provide important evidence, their findings may not be fully generalizable to all semi-arid regions because climatic conditions, rainfall patterns, soil types, institutional support, irrigation access, market systems, extension services, and farmer resources differ from one area to another. For example, adaptation strategies that improve maize productivity in Dodoma, Tanzania may not produce the same outcomes in Senegal's semi-arid zone, Marange in Zimbabwe, Arsi Zone in Ethiopia, or semi-arid counties in Kenya. This creates a geographical gap because there is still a need for location-specific evidence on how climate change adaptation strategies affect agricultural productivity in the selected semi-arid region of the proposed study. Therefore, the current study is justified because it will generate localized findings that can guide farmers, extension officers, policymakers, and development partners in designing adaptation strategies that fit the specific environmental and agricultural conditions of the study area.

CONCLUSION AND RECOMMENDATIONS

Conclusions

In conclusion, climate change adaptation strategies play a vital role in improving agricultural productivity in semi-arid regions. Semi-arid areas are highly exposed to drought, unreliable rainfall, high temperatures, soil degradation, water scarcity, crop failure, and pest outbreaks, all of which reduce farm output and threaten food security. Adaptation strategies such as drought-resistant crop varieties, early-maturing crops, crop diversification, irrigation, rainwater harvesting, conservation agriculture, agroforestry, soil and water conservation, and climate information services help farmers reduce climate-related losses and maintain production under difficult conditions. These strategies improve productivity by strengthening crop survival, improving water use, protecting soil fertility, reducing production risks, and helping farmers make better farming decisions.

The study therefore concludes that agricultural productivity in semi-arid regions cannot be improved sustainably without strengthening farmers' capacity to adapt to climate change. Farmers need access to affordable farm inputs, reliable climate information, extension services, credit facilities, irrigation infrastructure, improved seeds, and training on climate-smart agriculture. Government agencies, development partners, research institutions, and local communities should work together to promote adaptation strategies that fit local rainfall patterns, soil conditions, farming systems, and household resources. Overall, climate change adaptation should not be treated as an emergency response only, but as a long-term agricultural productivity strategy for improving food security, farmer income, resilience, and sustainable rural development in semi-arid regions.

Recommendations

Theory

This study contributes to theory by strengthening the understanding of how climate change adaptation strategies influence agricultural productivity in semi-arid regions. It extends Diffusion of Innovation Theory by showing how farmers adopt adaptation practices such as drought-resistant seeds, irrigation, conservation agriculture, and climate information services at different rates depending on awareness, affordability, access to extension support, and perceived usefulness. It also contributes to Sustainable Livelihoods Theory by showing that adaptation strategies protect farmers' livelihood assets, including land, water, labour, income, knowledge, and social networks. In addition, the study contributes to Resilience Theory by explaining how farming systems in semi-arid regions can absorb climate shocks, recover from droughts, and continue producing food. Therefore, the study links innovation adoption, livelihood protection, and farming resilience into one useful framework for understanding agricultural productivity under climate change.

Practice

This study contributes to practice by giving farmers, extension officers, agricultural trainers, cooperatives, and development partners practical guidance on improving productivity in semi-arid regions. It shows that productivity can be improved when farmers do not rely on one adaptation strategy alone, but combine several strategies such as improved seeds, irrigation, crop diversification, soil conservation, agroforestry, and climate information. The findings can help extension officers design farmer training programs that are simple, practical, and suited to local farming conditions. Farmers can use the findings to make better decisions on what to plant, when to plant, how to conserve water, and how to protect soil fertility. In practice, the study encourages a shift from traditional rain-fed farming toward more climate-smart, risk-reducing, and productivity-oriented farming systems.

Policy

This study contributes to policy by providing evidence that climate change adaptation should be treated as a key agricultural productivity strategy in semi-arid regions. Policymakers can use the study to design policies that promote drought-resistant seeds, irrigation infrastructure, farmer training, climate information systems, agricultural insurance, and affordable credit. County and national governments should allocate more funds to climate-smart agriculture programs in semi-arid regions because these areas are highly vulnerable to drought, food insecurity, and low farm output. The study also supports the need for stronger collaboration between government agencies, research institutions, meteorological departments, extension services, non-governmental organizations, and farmer cooperatives. Therefore, the study provides a policy foundation for building climate-resilient agriculture, improving food security, increasing farmer income, and supporting sustainable rural development in semi-arid regions.

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