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ADOPTION AND IMPACT OF CLIMATE-SMART AGRICULTURE PRACTICES AMONG VEGETABLE FARMERS IN MASERU DISTRICT, LESOTHO

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This study evaluated the adoption and impact of climate-smart agriculture (CSA) mitigation practices among vegetable farmers in Maseru District, Lesotho. The research aimed to assess the extent of CSA practice implementation, identify barriers hindering their uptake, and examine their influence on farmers' income. A cross-sectional survey design was employed, collecting quantitative data from 180 vegetable farmers selected through multistage and snowball sampling methods. A set of structured questionnaires were used to gather information on socio-economic characteristics, CSA practices, and adoption barriers. Data was analyzed using descriptive statistics and regression analysis. The results revealed that small-scale irrigation (89.82%) and organic manure application (89.22%) were the most commonly adopted practices, while adoption of greenhouses (4.79%) and keyhole gardens (28.14%) remained low. Lack of knowledge and financial constraints were identified as major barriers to CSA adoption. Regression analysis indicated that small-scale irrigation had a significant positive effect on farmers' monthly income ($\beta = 1.40$; $p < 0.05$), while organic manure application had a significant negative impact ($\beta = -1.02$; $p < 0.05$). The findings highlight the need for targeted policy interventions to address knowledge gaps, improve access to financial resources, and enhance technical capacity among vegetable farmers in the region.

Keywords: climate-smart agriculture, vegetable farming, adoption barriers, irrigation, Lesotho

Introduction

Agriculture remains a cornerstone of livelihoods and food security in many developing countries, particularly in sub-Saharan Africa. Despite its importance, the sector is highly vulnerable to the adverse effects of climate change, which are manifested through increased climate variability, prolonged droughts, soil degradation, and water scarcity. These challenges undermine agricultural productivity and threaten the sustainability of farming systems (Dick-Sagoe et al., 2023). In response to these growing risks, climate-smart agriculture (CSA) has emerged as a comprehensive strategy aimed at enhancing agricultural resilience, increasing productivity, and contributing to climate change mitigation (Mensah et al., 2021; Shiferaw, 2021). CSA integrates a set of practices, such as conservation tillage, agroforestry, organic soil management, crop rotation, and efficient irrigation systems, which are designed to improve farm productivity while reducing greenhouse gas emissions and enhancing adaptive capacity (Rehman et al., 2022).

The adoption of CSA practices has gained increasing attention in regions particularly susceptible to climate-related shocks. In sub-Saharan Africa, however, the extent of CSA implementation varies significantly, often being constrained by socio-economic factors, limited technical knowledge, and insufficient institutional support (Jellason et al., 2021; Lee & Gambiza, 2022). Smallholder farmers, who constitute the majority of agricultural producers in the region, face substantial barriers in adopting CSA technologies, including inadequate access to resources, financial constraints, and limited exposure to extension services (Autio et al., 2021; Zerssa et al., 2021). These challenges are especially pronounced in Lesotho, where agriculture is predominantly rain-fed and vulnerable to erratic weather patterns. Studies by Oladele and Nthama (2024) and Slayi et al. (2023) highlight that while some farmers in Lesotho have adopted elements of CSA, the widespread uptake of these practices remains limited due to infrastructural deficiencies and socio-economic barriers.

In the Maseru District of Lesotho, vegetable farming is an essential livelihood activity but is increasingly affected by climate change-related stressors. Soil degradation, water scarcity and unpredictable rainfall patterns are among the key challenges undermining vegetable production in the region (Dick-Sagoe et al., 2023). While CSA practices hold promise for addressing these issues by improving soil fertility, enhancing water-use efficiency and boosting crop yields (Rehman et al., 2022; Zerssa et al., 2021), there is a notable lack of empirical studies assessing their adoption and impact among vegetable farmers in Lesotho. The existing literature provides limited insights into the factors influencing the uptake of CSA in this specific context, as well as the actual impacts of these practices on farm productivity and sustainability.

This study seeks to fill this critical research gap by evaluating the extent to which vegetable farmers in the Maseru District have adopted CSA mitigation practices and by examining the impact of these practices in addressing the effects of climate change. Through this analysis, the study aims to generate evidence that can inform policymakers and stakeholders in designing targeted interventions to support sustainable agricultural development and climate resilience. By contributing to the broader discourse on CSA implementation and adaptation strategies in sub-Saharan Africa, this research underscores the importance of addressing the socio-economic and institutional challenges that hinder the widespread adoption of climate-smart agricultural practices.

Material and Methods

Study Area

This study was conducted in the Maseru District of Lesotho, located in the western part of the country. Maseru District was purposefully selected as the study area due to its agricultural significance, characterized by relatively fertile soils and favorable conditions for vegetable farming. The district plays a central role in Lesotho's agricultural economy, particularly in horticulture, despite facing challenges associated with climate variability and water scarcity.

Research Design

The study adopted a quantitative research design, employing a cross-sectional survey approach to collect primary data from local vegetable farmers. The quantitative design was chosen to ensure the systematic collection of numerical data that could be analyzed to draw inferences regarding the adoption and impact of CSA practices in the district.

Sampling Procedure

A multistage sampling approach was used in the selection of respondents. Firstly, Maseru District was purposefully chosen based on its prominence in vegetable farming and its suitability for agricultural activities. Secondly, five communities within the district were purposefully selected due to their active involvement in vegetable production. These communities included St. Michaels, Tloutle, Maphotong, Khobeng and Ha Shale.

Within each of these communities, a snowball sampling technique was employed to identify and select participants. Snowball sampling was deemed appropriate because it facilitated the identification of vegetable farmers actively engaged in agricultural production, particularly in communities where formal records of farmers were limited (Yapp et al., 2025). In total, 36 vegetable farmers were selected from each of the five communities, yielding a total sample size of 180 respondents.

Data Collection Instruments and Procedures

Primary data were collected using a structured questionnaire designed to capture information on respondents' socio-economic characteristics, climate-smart agricultural mitigation practices, and the barriers to climate-smart agriculture practices. The questionnaire included both closed- and open-ended questions to allow for detailed responses.

Prior to the main data collection, the questionnaire was pre-tested on a small sample of farmers from a non-selected community within Maseru District to ensure clarity, validity and reliability of the instrument. Necessary adjustments were made based on the feedback received from the pre-test.

Face-to-face interviews were conducted by trained enumerators who were fluent in Sesotho and English. This approach was chosen to minimize literacy-related challenges and ensure respondents clearly understood the questions.

Data Analysis

The collected data were coded and entered into the Statistical Package for the Social Sciences (SPSS) version 25.0 for analysis. Descriptive statistics, including frequencies, percentages, means and standard deviations, were used to summarize the socio-economic characteristics of respondents, climate-smart agricultural mitigation practices and the barriers to climate-smart agriculture practices. Inferential statistical tools, such as regression analysis, were employed to examine the influence of climate-smart agriculture practices on monthly income of vegetable farmers. Thus, the significance of the variables was determined at the 5% probability level.

Ethical Considerations

The study was conducted following ethical research standards. Informed consent was obtained from all participants after the purpose and objectives of the study were explained. Participation was voluntary and respondents were assured of the confidentiality and anonymity of their responses. Ethical clearance was obtained from the relevant local authorities in Maseru District prior to data collection.

Results and Discussion

Socio-economic Profile of Vegetable Farmers

The socio-economic profile of vegetable farmers in Maseru District is presented in Table 1. The results show that the majority of respondents (48.80%) are middle-aged, between 31–50 years, with an average age of 46.40 years. Most farmers are female (67.07%) and married (62.28%). In terms of education, a significant proportion (55.09%) has attained only primary education. The mean work experience in vegetable farming is 17.01 years, while the average farm size is 2.07 acres. Notably, 88.02% of the respondents reported not belonging to any agricultural association. The monthly income derived from vegetable farming remains largely undisclosed by 68.26% of respondents, while 37.13% did not report their income from other sources.

These findings are consistent with the reports by Othman et al. (2021), who observed that smallholder farming in sub-Saharan Africa is often dominated by women and individuals with limited formal education. The low level of association membership could impede farmers' access to training, resources and collective bargaining power, which are crucial for the successful adoption of innovative agricultural practices.

Table 1 Socio-economic Profile of Vegetable Farmers in Maseru District, Lesotho

Variable	Mean	Majority
Age (Years)	46.40	31–50 (48.80%)
Sex	–	female (67.07%)
Marital Status	–	married (62.28%)
Education	–	primary (55.09%)
Monthly income from vegetables (M)	352.44	unknown (68.26%)
Monthly income from other sources (M)	646.45	unknown (37.13%)
Work Experience (Years)	17.01	11–20 years (31.14%)
Farm Size (Acres)	2.07	unknown (80.84%)
Association Membership	–	no (88.02%)

Source: field survey

Table 2 Distribution of Climate-Smart Agricultural Mitigation Practices assessment among Vegetable Farmers

CSA Mitigation Practices	Majority
Conservation Agriculture	no (55.09%)
Agroforestry	yes (50.30%)
Improved Crop Varieties	yes (70.06%)
Greenhouses (Tunnels)	no (95.21%)
Organic Manure Application	yes (89.22%)
Small-Scale Irrigation	yes (89.82%)
Keyhole Gardens	no (71.86%)
Afforestation	no (64.67%)

Source: Field Survey

Table 3 Barriers to Climate-Smart Agriculture Practices among Vegetable Farmers in Maseru District, Lesotho

CSA Mitigation Practices	Majority
Conservation Agriculture	no knowledge (64.1%)
Agroforestry	no knowledge (52.10%)
Improved Crop Varieties	inadequate finances (46.71%)
Greenhouses (Tunnels)	inadequate finances (91.02%)
Organic Manure Application	not interested (64.07%)
Small-Scale Irrigation	not interested (80.84%)
Keyhole Gardens	no knowledge (52.10%)
Afforestation	not interested (37.72%)

Source: Field Survey

Table 4 Influence of Climate-Smart Agriculture Practices on Monthly Income of Vegetable Farmers

CSA Mitigation practices	Effect (β)	Significance (*p*-value)	Result interpretation
Conservation agriculture	-0.37	0.20	not significant
Agroforestry	0.13	0.62	not significant
Improved crop varieties	0.45	0.11	not significant
Greenhouses (tunnels)	-0.06	0.93	not significant
Organic manure application	-1.02	0.02	significant (negative)
Small-scale irrigation	1.40	0.02	significant (positive)
Keyhole gardens	-0.04	0.89	not significant
Afforestation	-0.16	0.50	not significant

Source: Field Survey

Dependent variable: monthly income of vegetable farmers
Model summary: *R* value: 0.61; *R* square: 0.37; adjusted *R* square: 0.14; standard error: 0.59; *F* value: 1.61

Adoption of Climate-Smart Agricultural Mitigation Practices

The adoption of various climate-smart agricultural (CSA) mitigation practices is presented in Table 2. The most commonly implemented practices were small-scale irrigation (89.82%) and organic manure application (89.22%). Improved crop varieties were adopted by 70.06% of farmers, while agroforestry practices were employed by 50.30%. In contrast, greenhouse (tunnel) usage (4.79%), keyhole gardens (28.14%), afforestation (35.33%) and conservation agriculture (44.91%) had lower levels of adoption.

The high uptake of small-scale irrigation is likely due to its role in addressing water scarcity, which remains a significant constraint in Maseru District (Umer et al., 2024). Conversely, the low adoption of greenhouses and keyhole gardens may reflect the high initial investment costs and technical knowledge required, as suggested by Jellason et al. (2021).

Barriers to Adoption of Climate-Smart Agriculture Practices

The barriers limiting the uptake of CSA practices are shown in Table 3. The predominant challenge was lack of knowledge, cited by 64.1% of non-adopters of conservation agriculture and 52.10% of those not practicing agroforestry and keyhole gardening. Financial constraints were most pronounced in the adoption of improved crop varieties (46.71%) and greenhouse tunnels (91.02%). A lack of interest was the main reason cited for non-adoption of organic manure application (64.07%), small-scale irrigation (80.84%) and afforestation (37.72%).

These findings are consistent with prior studies, which indicate that the two most significant barriers to CSA adoption in developing countries are knowledge gaps and inadequate financial resources (Jellason et al., 2021; Lee & Gambiza, 2022).

Influence of CSA Practices on Farmers' Monthly Income

The influence of CSA practices on the monthly income of vegetable farmers was analyzed through regression analysis (Table 4). The results show that small-scale irrigation had a statistically significant positive effect on farmers' monthly income ($\beta = 1.40$; $p < 0.05$). In contrast, organic manure application had a significant negative effect ($\beta = -1.02$; $p < 0.05$). Other CSA practices, including agroforestry, improved crop varieties and conservation agriculture, did not show statistically significant effects on income.

The positive influence of small-scale irrigation highlights its potential to stabilize and enhance vegetable production in water-scarce regions, directly increasing household income (Umer et al., 2024). The negative effect of organic manure application may reflect inefficiencies in its use or the absence of complementary inputs, such as improved crop varieties and pest management, to maximize its potential benefits.

The model summary indicates a moderate level of explanatory power ($R^2 = 0.37$), suggesting that while CSA practices influence income, other external factors also play a significant role in determining farmers' earnings.

Discussion

The findings of this study reveal critical insights into the adoption and impact of CSA practices among vegetable farmers in Maseru District, Lesotho. The predominance of female farmers with primary education highlights gender dynamics in the agricultural sector and points to potential areas for targeted support, such as women-focused extension services and training programs (Othman et al., 2021).

Adoption rates for CSA practices such as small-scale irrigation and organic manure application suggest that farmers are inclined toward practices that offer immediate, tangible benefits. However, low adoption rates for more resource-intensive practices like greenhouses and keyhole gardens reinforce the need for financial support mechanisms and capacity-building initiatives (Jellason et al., 2021).

The significant positive influence of small-scale irrigation on farmers' income aligns with findings by Umer et al. (2024), which demonstrate the impact of irrigation technologies in improving agricultural productivity in water-scarce environments. Conversely, the negative impact of organic manure application highlights a need for complementary interventions to ensure that such practices are economically viable and agronomically effective.

Overall, the study call attention to the potential of CSA practices in improving agricultural resilience and livelihoods. However, it also highlights persistent barriers that require multi-faceted policy interventions, including increased access to knowledge, credit facilities and infrastructural development (Lee & Gambiza, 2022; Zerssa et al., 2021).

Conclusion

This study assessed the adoption and impact of climate-smart agricultural (CSA) mitigation practices among vegetable farmers in Maseru District, Lesotho. The empirical findings provide valuable insights into the socio-economic characteristics of the farmers, the extent to which CSA practices have been implemented, the barriers hindering their adoption, and their influence on farmers' income.

The socio-economic profile of the respondents revealed that vegetable farming in Maseru District is predominantly carried out by middle-aged women with primary-level education. Despite their significant experience in farming, most farmers were not members of agricultural associations, potentially limiting their access to collective resources, training, and institutional support. This socio-economic context has important implications for the design and delivery of extension services aimed at promoting CSA practices.

The study found a relatively high adoption of small-scale irrigation and organic manure application, while the uptake of other CSA practices such as greenhouses, keyhole gardens and conservation agriculture remained low. The widespread use of small-scale irrigation reflects its impact in addressing water scarcity, which is a critical challenge in the district. On the other hand, the limited adoption of resource-intensive practices like greenhouses points to financial and technical constraints, which were consistently identified as major barriers to CSA adoption.

Knowledge gaps and financial limitations emerged as the most significant obstacles impeding the widespread uptake of CSA practices. These findings are consistent with previous research in sub-Saharan Africa and highlight the need for integrated strategies to enhance farmers' technical capacity and access to affordable financing mechanisms.

Regression analysis demonstrated that small-scale irrigation had a statistically significant positive impact on farmers' monthly income, underscoring its potential to enhance productivity and household earnings in water-scarce areas. Conversely, organic manure application had a significant negative effect on income, suggesting potential inefficiencies in its use or the absence of complementary inputs needed to maximize its benefits.

Overall, the study highlights both the potential and the challenges associated with CSA adoption in Lesotho's vegetable farming sector. While certain practices show promise in improving agricultural resilience and income, widespread adoption is hindered by systemic barriers that must be addressed through coordinated policy and institutional interventions.

Future Research Directions

Future research should focus on longitudinal studies to assess the long-term impacts of CSA practices on agricultural productivity, soil health and farmers' livelihoods. There is also a need for qualitative studies that explore farmers' perceptions, attitudes and motivations regarding CSA adoption to complement quantitative findings. Additionally, research could investigate the role of agricultural cooperatives, extension services and microfinance in facilitating CSA uptake. Finally, experimental studies that evaluate the impact of bundled CSA technologies combining organic manure with improved crop varieties or pest management strategies could provide more nuanced insights into the optimal practices for enhancing both sustainability and profitability in vegetable farming in Lesotho and similar agro-ecological regions.

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