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EFFECTIVENESS OF ADAPTATION STRATEGIES ADOPTED BY GREEN GRAM FARMERS IN IMPROVING YIELDS IN MAKUENI SUB-COUNTY, KENYA

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ABSTRACT

Purpose of the Study: This study examined the effectiveness of adaptation strategies adopted by green gram (Vigna radiata) farmers in improving yields in Makueni Sub-County, Kenya.

Statement of the Problem: Although global and regional studies have documented a range of adaptive practices, scanty empirical evidence exists on the specific adaptation strategies adopted by green gram farmers in Makueni.

Methodology: Anchored on the Sustainable Livelihood Theory (SLT) and adopting an explanatory sequential mixed-methods design, the study used primary data from 387 respondents sampled from 50,280 households through structured questionnaires, complemented by four key informant interviews. Data were analyzed using descriptive statistics and a simple linear regression of an aggregated Adaptation Strategy Composite Index on a Likert-scaled yield outcome at the 5% significance level, with qualitative data analyzed thematically.

Findings: Drought-resistant varieties (36.6%), early maturing varieties (29.6%) and changed planting dates (21.1%) were the most adopted crop management strategies, while conservation tillage (91.2%), water conservation structures (88.1%) and terracing (87.6%) dominated soil and water conservation. Adaptation was predominantly short-term, with 90.7% of strategies implemented within two years. Cost (100%), ease of implementation (96.6%), traditional knowledge (93.0%) and peer experience (86.6%) were the principal factors influencing strategy selection. Regression revealed a weak, statistically non-significant relationship between the adaptation strategies index and yields ($\beta = -0.097$, $p = 0.055$; $R^2 = 0.009$), indicating that the strategies primarily mitigate risk rather than drive productivity.

Conclusion: Current adaptation practices stabilize yields against climatic shocks but do not translate into measurable productivity gains, functioning largely as short-term coping rather than sustained adaptive capacity.

Recommendation: Sustained and disaggregated adoption of crop management and soil-water strategies, supported by financially accessible, context-specific interventions and stronger institutional support, is needed to convert short-term risk mitigation into long-term yield improvement and food security in Makueni Sub-County.

Keywords: *Adaptation strategies; Climate variability; Green grams; Makueni Sub-County; Sustainable Livelihood Theory; Kenya*

INTRODUCTION

Climate change and variability have emerged as defining global challenges to food security and smallholder agriculture. The Intergovernmental Panel on Climate Change reports that warming of the climate system is unequivocal, with global mean temperature already 1.1 °C above pre-industrial levels and rainfall regimes becoming increasingly variable across the tropics (IPCC, 2021). Globally, rain-fed cropping systems which account for approximately 80% of cultivated land and produce close to 60% of the world's food are the most exposed to these shifts (FAO, 2020). Recent multi-region analyses confirm that climate variability is reducing the suitability of agricultural land and depressing yields across Asia, Africa and Latin America (Abd-Elmabod et al., 2020; Kaushik et al., 2023; Pathak et al., 2022).Sub-Saharan Africa is among the regions most vulnerable to climate variability, with East Africa expected to warm by 1 °C by 2030 and 2 °C by 2050, accompanied by an increased frequency of dry and wet extremes (Mubenga-Tshitaka et al., 2023). Within East Africa, Kenya's arid and semi-arid lands (ASALs), which cover roughly 80% of the national territory, are disproportionately exposed (Kalele et al., 2021). Rainfall variation has emerged as a major challenge in these regions, disrupting farming and exposing smallholder households to growing food insecurity (Ireri & Wambugu, 2019).

Green grams (Vigna radiata) are widely cultivated in Kenya's ASALs and serve as a critical source of food, income and soil-nitrogen fixation for smallholder households (Muchomba et al., 2023). The crop's productivity, however, is highly sensitive to seasonal rainfall variability. As outlined by Mueni et al. (2024), green gram production in Eastern Kenya is constrained by changing climatic conditions, while adaptation levels remain low and more adaptive options are needed to strengthen the productive capacity of farmers. Adapting to climate change is therefore crucial in ensuring that the impacts do not engulf communities, society and the ecosystem (Schipper, 2020); yet despite farmers' awareness of adaptation strategies, the adoption level remains low, which warrants an imperative examination of locally relevant interventions (Kalele et al., 2021).

Evidence from Makueni Sub-County illustrates a striking disconnect between climatic exposure, the area under cultivation and actual productivity. As summarised in Table 1, over the decade 2015–2024 annual rainfall was highly variable yet showed no statistically significant trend (Mann-Kendall $\tau = -0.111$, $p = 0.655$), and green gram production similarly showed no significant growth trend ($\tau = 0.135$, $p = 0.590$). By contrast, the area under green gram cultivation expanded substantially, recording a strong, positive and statistically significant trend ($\tau = 0.796$, $p = 0.002$).This defines the empirical problem motivating the study: a statistically significant expansion in cultivated land produced with no significant rise in output, implying that per-hectare productivity has stagnated or declined and that production is sustained through extensification (cultivating more land) rather than intensification (raising yield per hectare). Despite documented awareness and adoption of adaptation strategies, those strategies have not delivered measurable productivity gains. Because land expansion is finite and ecologically constrained, this leaves household food security fragile and exposed to rainfall shocks. Yet scanty empirical evidence exists on which adaptation strategies green gram farmers in Makueni Sub-County adopt, how effective they are in improving yields, and whether their predominantly short-term implementation explains the adoption–productivity disconnect, making Makueni Sub-County a specific and urgent empirical problem.

Table 1. Trend Analysis of Rainfall, Green Gram Production and Field Size in Makueni Sub-County, 2015–2024

Variable	Mean	SD	Mann-Kendall (τ)	p-value	Trend
Annual rainfall (mm)	877.58	179.34	−0.111	0.655	Not significant
Green gram production (tonnes)	44,777.50	4,608.51	0.135	0.590	Not significant
Field size (ha)	64,660.30	13,935.51	0.796	0.002	Significant (increase)

Source: County Government of Makueni (2015–2024)

This study therefore examined the effectiveness of adaptation strategies adopted by green gram farmers to improve yields in Makueni Sub-County to profile the crop management and soil and water conservation strategies in use, including their duration, the factors influencing their choice and the criteria used to evaluate their success; test the statistical relationship between an aggregated adaptation strategies index and yield outcomes. The study is anchored on the Sustainable Livelihood Theory (SLT), developed by Chambers and Conway (1992) and later operationalized through the DFID Sustainable Livelihood Framework (Natarajan et al., 2022), which conceptualizes livelihood outcomes as a function of the interaction between five assets , that is, human, natural, financial, physical and social capital and the structures and processes within which farmers operate.

METHODS

Description of the Study Area

The study was conducted in Makueni Sub-County, one of the six sub-counties of Makueni County in lower Eastern Kenya, located approximately between latitudes 1°35′ and 2°59′ South and longitudes 37°10′ and 38°30′ East, approximately 175 km south-east of Nairobi (See Figure 1). The sub-county falls within agro-ecological zones IV (semi-humid to semi-arid) and V (semi-arid), with altitudes ranging from 600 to 1,900 metres above sea level. Mean annual rainfall ranges from 500 to 1,200 mm distributed in a bimodal pattern: the long rains from March to May and the short rains from October to December, with mean annual temperatures of 20.2–24.6 °C and high rates of evapotranspiration (Maluvu et al., 2023). According to the most recent Kenya Population and Housing Census, Makueni Sub-County has approximately 50,280 farming households relying predominantly on rain-fed agriculture, with green grams cultivated as one of the principal cash and food crops (KNBS, 2019; Makueni County Government, 2023). The area was purposively selected because of its representativeness of Kenya's ASAL green gram production zones and its empirical data on local adaptation responses remains limited despite documented climatic stress.

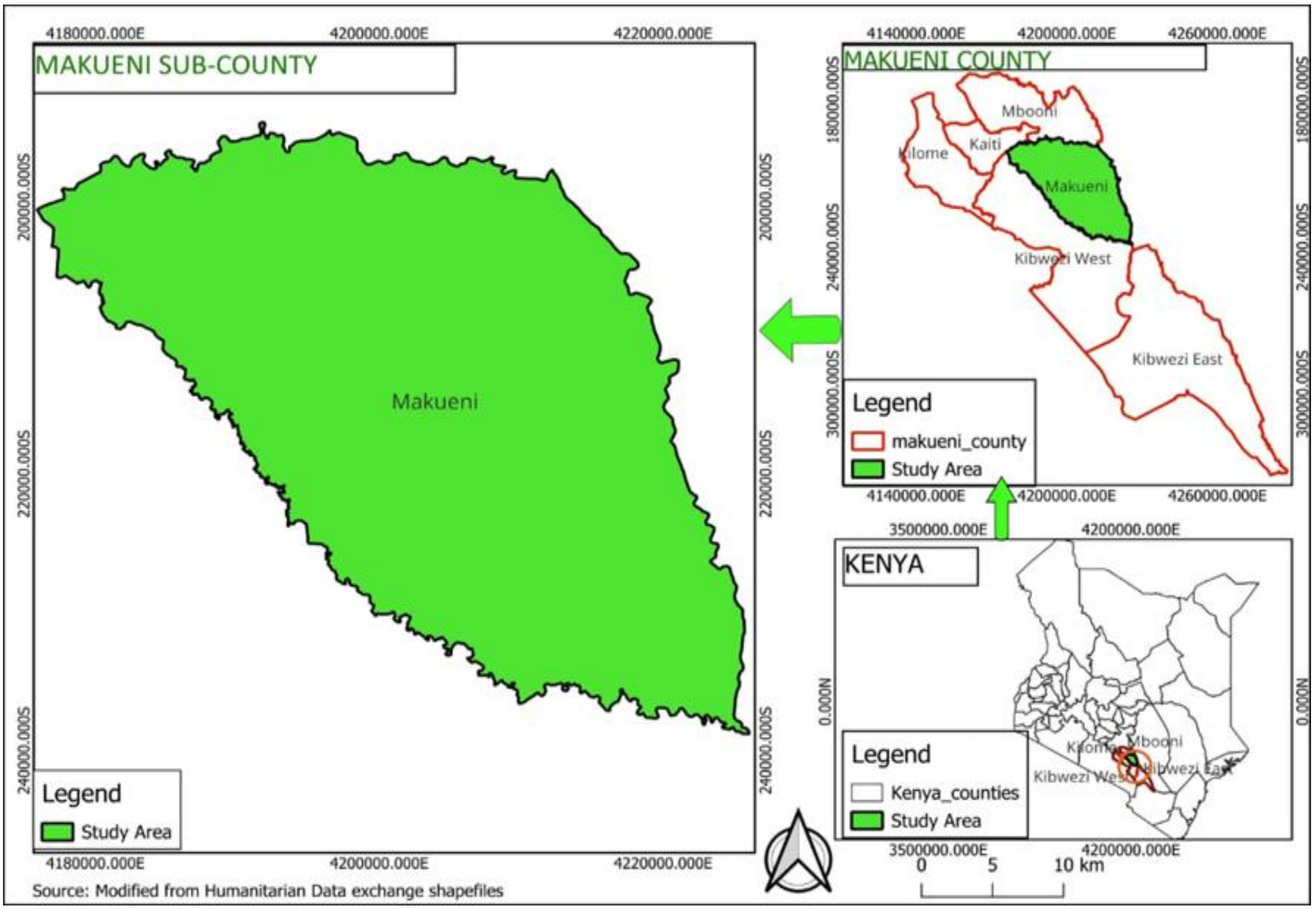

Figure 1: Study Area Location

Research Design

The study adopted an explanatory sequential mixed-methods design. The quantitative analysis was conducted first to identify general patterns and statistical relationships in the adoption and effectiveness of adaptation strategies followed by the qualitative to deepen and contextualize the quantitative findings through narrative evidence from key informants.

Sampling and Sample Size

The study targeted 50,280 farming households in Makueni Sub-County. Using Slovin's formula at a 95% confidence level, a sample of 396 households was drawn, of which 387 returned fully completed questionnaires, which represented 96.5% response rate. A multi-stage random sampling was used to select green gram farming households across the sub-county wards. Additionally, four structured key informant interviews were conducted with purposively selected county agricultural extension officers and meteorologists.

Pilot Study, Validity and Reliability

A pilot study was conducted in Tharaka South Sub-County, incorporating 10%(N=41) of the sample size. The location was chosen because it shares comparable Agro-ecological characteristics with Makueni. Content and face validity of the instruments were established by subject-matter experts in the Department of Social Sciences, Tharaka University while reliability was assessed using Cronbach's Alpha, yielding a coefficient of 0.78, which was above the acceptable threshold of 0.7 as required by Tavakol and Dennick (2011). Ethical clearance was obtained from the National Commission for Science, Technology and Innovation (NACOSTI), and informed consent was obtained from all participants.

Data Collection and Analysis

Quantitative data were collected using structured questionnaires administered by trained enumerators, while qualitative data was collected through eight structured key informant interviews using an interview guide. Quantitative data were analysed using the Statistical Package for the Social Sciences (SPSS v. 30), employing both descriptive (frequencies of multiple responses, percentages, means and standard deviations) and inferential statistics. Specifically, a simple linear regression was fitted with green gram yield outcome (on a 5-point Likert scale) as the dependent variable and the aggregated Adaptation Strategy Composite Index as the single predictor. A simple regression model was preferred because the predictor was the overall intensity of adaptation, captured as one composite construct, in line with the SLT framing of livelihood-strategy aggregation. The model was tested at the 5% significance level while qualitative interview data were analysed using thematic analysis.

RESULTS AND DISCUSSION

Crop Management Adaptation Strategies

The findings, summarized in Table 2, showed that the use of drought-resistant varieties (36.6%, N=26), early maturing varieties (29.6%, N=21) and changed planting dates (21.1%, N=15) were the most adopted crop management strategies, while intercropping (19.7%, N=14) and crop rotation (8.5%, N=6) were the least used in crop management.

Table 2: Crop Management Adaptation strategies in Makueni Sub-County.

Strategy	Frequency (N)[1]	Percent of Cases (%)[2]
Drought-resistant varieties	26	36.6
Early maturing varieties	21	29.6
Changed planting dates	15	21.1
Intercropping	14	19.7
Crop rotation	6	8.5

The dominance of drought-resistant and early maturing varieties as adaptive responses observed, aligns with regional evidence. Gebre et al. (2023) reported that 54% of Kenyan farmers across six counties used drought-tolerant varieties, while Mueni et al. (2024) confirmed variety switching and early planting as the principal adaptive responses among green gram farmers in Eastern Kenya. The pattern is also consistent with Bedeke et al. (2019) in Ethiopia, who demonstrated that combining drought-resistant varieties with conservation tillage and mixed cropping increased both productivity and resilience among maize-dependent smallholders. The comparatively low uptake of intercropping (19.7%) and crop rotation (8.5%) in Makueni, despite their well-documented soil-health and yield-stabilisation benefits signals persistent structural barriers to diversified cropping, most plausibly the cost and knowledge constraints.

Soil and Water Conservation Strategies

The frequency of soil and water management practices is presented in Table 3.

Table 3: Soil and Water Conservation Strategies

Strategy	Frequency (N)[1]	Percent of Cases (%)[2]
Conservation tillage	353	91.2
Water harvesting structures	341	88.1
Terracing	339	87.6
Mulching	40	10.3

[1] *Multiple responses were permitted for respondents allowing selection of more than one strategy during survey*
[2] *Evaluated as a total number of responses as a fraction of the sampled farmers(N=387)*

The data showed that green gram farmers in Makueni Sub-County are conversant with soil and water conservation measures, since all practices explored by the research exceeded 80% adoption, except mulching. Conservation tillage (91.2%, N = 353) and water harvesting structures (88.1%, N = 341) were the most adopted, while mulching (10.3%) was the least adopted.

The high rate of adoption of conservation tillage and water harvesting structures closely mirrors findings from Kimonimarrietar et al. (2022) in neighbouring Masinga Sub-County and Agesa et al. (2019) in Yatta Sub-County, confirming that physical soil and water conservation has become the predominant adaptive anchor across Kenya's semi-arid counties. This adoption pattern reflects both decades of extension messaging and the practical accessibility of these measures, since conservation tillage requires no additional financial outlay and water conservation structures attract NGO and government co-investment.

Period of Implementation of Adaptation Strategies

The results in Table 4 indicate that adaptation strategies are largely short term than long term, with 90.7% of strategies implemented within the last two years. Only 2.6% of farmers had sustained their adaptation strategies for more than ten years.

Table 4: Duration of Adaptation Strategy Implementation

Duration	Frequency (N)	Percentage (%)
Less than 2 years	351	90.7
2–5 years	14	3.6
6–10 years	12	3.1
More than 10 years	10	2.6

The results indicate that adaptation strategies are largely short-term rather than long-term, with 90.7% of strategies implemented within the last two years. This suggested that adaptation was mainly driven by recent climate variability rather than long-term planning. The dominance of reactive, short-term adaptation is a critical systemic finding. Farmers in Makueni Sub-County are primarily responding to immediate shocks rather than building durable adaptive capacity a pattern documented by Mu et al. (2020) in semi-arid Northwest China, where farmers selected delayed remedy measures only after climatic agricultural disasters had occurred. This reactive posture limits the cumulative yield benefits that sustained, multi-season application of adaptation strategies would otherwise generate, as confirmed by the regression analysis. The absence of long-term planning reflects structural deficiencies in climate information access, extension service delivery, and financial instruments that would otherwise support forward-looking adaptive investment.

Factors Influencing Choice of Adaptation Strategies

The study listed seven factors that were percieved to have been influencing the choice of adoption strategies in Makueni Sub-County as shown in Table 5.

Table 5: Factors Influencing Adaptation Strategy Choice

Factor	Frequency (N)	Percent of Cases (%)
Cost of implementation	387	100.0
Ease of implementation	374	96.6
Traditional knowledge	360	93.0
Other farmers' experience	335	86.6
Available technical support	38	9.8
Effectiveness	32	8.3
Access to required inputs	18	4.7

It was found out that cost was the most dominant factor (100%, N=387), followed by ease of implementation (96.6%,N=374), traditional knowledge (93.0%, N=360) and the experience of other farmers (86.6%, N=335). In contrast, perceived effectiveness (8.3%, N=32) and access to required inputs (4.7%, N=18) were cited by very few respondents. This is a counter-intuitive finding warranting careful interpretation as salience of effectiveness does not mean that farmers consider their strategies ineffective; rather, it indicates that under binding financial and informational constraints since effectiveness is not the operative decision filter. Farmers first eliminate any strategy that is too expensive or impractical, leaving them to choose among the small subset that is affordable and familiar at which point comparative effectiveness rarely differentiates the remaining options.

The similarly low responses of input access (4.7%) means that where inputs are already known to be unavailable or unaffordable, farmers do not list input access as a 'selection factor' because it is treated as a precondition rather than a choice variable. This is corroborated by Singh (2020), who identified low livelihood status as the primary barrier to adaptation in dryland India, and by Lamichhane et al. (2022), who found irrigation-based strategies too expensive for smallholder farmers in Nepal. The high weight placed on ease of implementation (96.6%) further confirms that farmers rationally default to low-effort, familiar strategies. The prominence of traditional knowledge (93.0%) and peer experience (86.6%) underscores the role of informal learning networks an insight consistent with Batungwanayo et al. (2023) in Burundi, where peer networks and agricultural education were significant adaptive decision-making drivers. Formal extension services thus have a critical, though currently underutilized, role in formalising and scaling locally validated knowledge.

Evaluation Criteria for Adaptation Success

Table 6 presents the criteria farmers use to evaluate adaptation success.

Table 6: Evaluation Criteria Used by Farmers to Assess Adaptation Success

Evaluation Criterion	Frequency (N)	Percent of Cases (%)
Comparison with other farmers	387	100.0
Cost-benefit analysis	377	97.4
Soil moisture levels	371	95.9
Plant health monitoring	355	91.7
Yield measurements	354	91.5

Farmers primarily evaluate adaptation success through comparative and experiential methods rather than purely quantitative measures. Peer comparison (100%, N = 387) outranked cost–benefit analysis (97.4%) and yield measurements (91.5%). This reliance on peer-based evaluation reinforces the role of informal learning networks and is consistent with Batungwanayo et al. (2023), who found that peer comparison serves as the de facto benchmark of strategy success in smallholder systems where formal yield-monitoring infrastructure is unavailable. The implication is that extension services is most likely to gain traction when channelled through peer-validated demonstration rather than top-down technical prescription.

Descriptive Statistics of Adaptation Strategy Indices

Composite indices for the three strategy categories and an overall Adaptive Strategy Composite Index were computed by averaging Likert-scale ratings for the constructs in each category. The results are summarised in Table 7.

Table 7. Descriptive Statistics for Adaptation Strategy Indices

Index strategy	Mean	Std. Deviation
Crop Management Index	3.749	0.397
Soil & Water Conservation Index	3.169	0.380
Storage Improvement Index	3.354	0.156
Adaptive Strategy Composite Index	3.424	0.195

All indices exceeded the neutral midpoint of 3, indicating that adaptation strategies are generally perceived as moderately to highly effective. The Crop Management Index (M = 3.749) approached the 'very effective' threshold, while the Soil & Water Conservation Index (M = 3.169) remained just above 'moderately effective' despite very high adoption levels. This divergence suggests that farmers perceive crop-based strategies as producing more immediate and visible yield outcomes than soil and water conservation, consistent with Mugo et al. (2021), who note that soil and water conservation measures enhance resilience and moisture retention rather than producing immediate yield gains. High adoption of soil conservation strategies therefore reflects necessity in a moisture-limited environment rather than perceived productivity, while the higher-rated crop management strategies are valued for their faster pay-off horizon.

Adaptation Strategy Index as a Predictor of Green Grams Yields

A simple linear regression was used to evaluate the effectiveness of current adaptation strategies on green gram yields. From Table 8, it was found that the adaption strategy index (β = -0.097, p = 0.055) is statistically insignificant at the 5% confidence level indicating a weak negative relationship.

Table 8: Regression Results of Adaption Strategy Index and Green Grams Yields

Variable	B	Std. Error	Beta	T	Sig.
Constant	3.507	1.014		3.460	.001
Adaption strategy index	-0.568	0.296	-0.097	-1.921	.055

Model Summary: $R^2 = 0.009$, $F = 3.690$, $p = 0.055$

The model explains only 0.9% of the variation in green gram output ($R^2 = 0.009$) from adaption index, which indicates that adaptation strategies contribute minimally to explaining changes in green gram yields. The analysis confirmed that, while individual strategies particularly drought-resistant varieties and conservation tillage demonstrated positive associations with yield outcomes, the overall predictive strength was moderated by the short-term, reactive nature of their implementation. This finding contrasts with Esayas et al. (2019), who reported a positive and significant relationship between adaptation strategies and agricultural productivity, but is consistent with Mugo et al. (2023), who argued that under highly variable climatic conditions, the effectiveness of adaptation strategies is minimal or inconsistent. The reliance on a single-predictor specification is acknowledged as a limitation; disaggregating the composite index and applying multiple-regression or robust estimation in future work would permit a more precise attribution of yield effects to specific strategy categories.

Three contextual factors plausibly explain the weak measured relationship. First, 90.7% of farmers have implemented their strategies for less than two years, meaning that the strategies may not yet have produced cumulative yield effects. Second, the aggregation of qualitatively distinct strategies (crop management, soil and water, storage) into a single composite index may mask the differentiated effects of individual strategies, particularly soil and water conservation, which Mugo et al. (2021) note enhances resilience and moisture retention rather than producing immediate yield gains. Third, as Panda et al. (2019) emphasize, adaptation in rain-fed systems typically stabilises yields against shocks rather than significantly increasing them, so the appropriate yield benchmark may be 'loss avoided' rather than 'yield gained'. This stabilization interpretation is supported by the descriptive evidence that 85.8% of respondents reported some yield improvement from their adaptation efforts, even where the regression coefficient is statistically indistinguishable from zero. The weak measured effect should therefore be read as evidence that current strategies function as risk-mitigation mechanisms rather than as productivity drivers, a conclusion consistent with Mushore et al. (2021) in Zimbabwe and Lamichhane et al. (2022) in Nepal.

Qualitative Findings on Adaptation Strategies

Thematic analysis from the eight structured key informant interviews corroborated the survey evidence on the repertoire of strategies in use and on the conditions that shape their effectiveness. Key informants consistently identified drought as the dominant climatic stressor, with a meteorologist observing that *'Drought is the main climatic condition that significantly affects green gram farming, leading to small or zero harvest'*. Specific drought-tolerant varieties used by farmers were identified as *Karembo, Biashara, N26, KS20 and Ndengu Tosha*, alongside terracing, early maturing crops, conservation agriculture and *'conventional farming (kilimo ya kawaida)'*. Capacity-building was reported to occur through *'series of capacity training through collaboration between the Makueni Sub-County agricultural department, KALRO, the Cereal Growers Association (CGA) and the International Centre for Research Institutes for Semi-Arid Tropics (ICRISAT)'*, supporting the high perceived effectiveness (mean composite index > 3) observed in the quantitative analysis. However, the informants consistently emphasised that the effectiveness of these strategies is conditional on rainfall reliability, a contextual qualification that helps to explain the weak regression coefficient.

Integrating the survey and interview evidence reveals a coherent but cautionary picture. The same strategies that farmers describe as effective in qualitative narratives, namely drought-tolerant varieties, terracing, conservation tillage and water conservation structures, returned only a weak and statistically non-significant signal in the aggregated regression model (β =

−0.097, $p = 0.055$; $R^2 = 0.009$). Two features of the data caution against any claim that these strategies enhance productivity. First, with 90.7% of strategies implemented within the previous two years, the findings predominantly capture short-term reactive coping rather than sustained adaptive capacity capable of producing measurable yield gains. Second, the use of a single composite adaptation index may mask the separate effects of crop management, soil-water conservation and storage-related strategies, reduce analytical precision and potentially diluting any positive contribution from individual practices. The strategies are therefore best interpreted as risk-mitigation mechanisms that stabilizes yields against climatic shocks and avert crop loss, rather than as drivers of productivity growth. This reading is consistent with the SLT proposition that adaptive outcomes are shaped by the interaction between household assets and external structures and processes such as rainfall variability, which informants described as 'irregular in onset, distribution and cessation', rather than by any single intervention in isolation.

CONCLUSION

This study concludes that green gram farmers in Makueni Sub-County have adopted a meaningful repertoire of adaptation strategies most prominently drought-resistant and early maturing varieties (Karembo, Biashara, N26, KS20 and Ndengu Tosha), conservation tillage, water conservation structures and terracing and that these strategies are subjectively perceived as moderately to highly effective, with composite index means above the neutral midpoint of 3.

However, the statistical evidence does not support a significant positive relationship between the aggregated Adaptation Strategy Composite Index and yield outcomes ($\beta = -0.097$, $p = 0.055$; $R^2 = 0.009$). This result is best explained by three structural features of current adaptation in the sub-county: the short implementation horizon (90.7% of strategies within two years), the masking effect of index aggregation, and the dependence of strategy effectiveness on rainfall reliability. Read together with the descriptive evidence that 85.8% of respondents nevertheless reported yield improvements, the most defensible reading is that current strategies serve as risk-mitigation rather than productivity-enhancement mechanisms. Adaptation in Makueni Sub-County is thus locally rational preserving yields against climatic shocks but has not yet been sustained, disaggregated or sequenced in a way that converts short-term risk mitigation into long-term yield gains. Through the lens of the Sustainable Livelihood Theory, the findings highlight the need to reinforce the human capital (technical knowledge, peer-validated learning) and physical-asset (improved seed, water infrastructure) dimensions of the livelihood pentagon if adoption is to translate into measurable productivity outcomes.

Accordingly, the principal outcome of current adaptation in Makueni Sub-County is best characterized as yield stabilization and avoided crop loss rather than yield improvement, and future analysis should disaggregate the composite index and employ more robust regression specifications before any productivity-enhancing effect can be confidently claimed

RECOMMENDATIONS

Policy and Practice Recommendations

The Makueni County Government, in partnership with the National Treasury and agricultural finance institutions, should prioritise subsidised access to drought-resistant and early maturing green gram varieties to relax the cost barrier identified by 100% of respondents as the dominant determinant of strategy choice. (Targeted investment in water harvesting infrastructure water pans, sand dams and check dams would institutionalise the already high uptake of water conservation structures (88.1%) and extend their cumulative impact across multiple seasons, allowing the soil-water conservation index to move closer to the 'very effective' threshold. Extension services should be revitalised through facilitated farmer field schools that explicitly leverage peer learning and traditional knowledge, both of which were dominant influences on strategy choice (93.0% and 86.6% respectively) and on evaluation of strategy success (100% reliance on peer comparison).

Recommendations for Further Research

Future studies should employ longitudinal panel designs to track yield effects of adaptation strategies across multiple seasons, since the short implementation horizon (90.7% within two years) plausibly attenuated the regression signal in this study. Comparative work across Makueni, Kitui and Tharaka South sub-counties would illuminate the extent to which agro-ecological and socioeconomic conditions shape adaptive outcomes. Finally, disaggregating the Adaptation Strategy Composite Index into its component sub-indices in a multiple regression framework rather than testing it as a single composite would allow researchers to separate the productivity effects of crop management strategies from the resilience effects of soil and water conservation, and so resolving barriers to effective implementation.

CONFLICT OF INTEREST DECLARATION

The author declares that there is no conflict of interest, financial or otherwise, that could be perceived as influencing the design, execution, analysis or reporting of this research.

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DATA AVAILABILITY

The datasets generated and analysed during the current study are available from the corresponding author on reasonable request.

REFERENCES

Abd-Elmabod, S. K., Muñoz-Rojas, M., Jordán, A., Anaya-Romero, M., Phillips, J. D., Laurence, J., & De la Rosa, D. (2020). Climate change impacts on agricultural suitability and yield reduction in a Mediterranean region. *Geoderma*, *374*, 114453.

Agesa, B., Hubbard, C., & Agesa, J. (2019). Adapting to the impacts of climate change and variability: Responses of farmers in Kenya's semi-arid regions. *Climatic Change*, *152*, 95–108.

Batungwanayo, T., Ochola, W. O., & Mugisha, J. (2023). Confronting climate change and livelihood: Smallholder farmers' perceptions and adaptation strategies in Northeastern Burundi. *Climate Risk Management*, *39*, 100474.

Bedeke, S., Vanhove, W., Gezahegn, M., Natarajan, K., & Van Damme, P. (2019). Adoption of climate change adaptation strategies by maize-dependent smallholders in Ethiopia. *NJAS: Wageningen Journal of Life Sciences*, *88*, 96–104.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101.

Chambers, R., & Conway, G. (1992). *Sustainable rural livelihoods: Practical concepts for the 21st century* (IDS Discussion Paper No. 296). Institute of Development Studies.

Creswell, J. W., & Plano Clark, V. L. (2018). *Designing and conducting mixed methods research* (3rd ed.). SAGE Publications.

Esayas, B., Simane, B., Teferi, E., Ongoma, V., & Tefera, N. (2019). Climate variability and farmers' perception in Southern Ethiopia. *Advances in Meteorology*, *2019*, 1–14.

Food and Agriculture Organization of the United Nations. (2020). *The state of food and agriculture 2020: Overcoming water challenges in agriculture*. FAO.

Gebre, G. G., Isoda, H., Amekawa, Y., Nomura, H., & Watanabe, T. (2023). Farmer use of climate change adaptation strategies and their impacts on food security in Kenya. *Climatic Change*, *176*(2), 14.

Intergovernmental Panel on Climate Change. (2021). *Climate change 2021: The physical science basis: Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press.

Ireri, L. M., & Wambugu, S. W. (2019). Impact of climate variability on socio-economic activities of mixed farmers in Embu East Sub-County. *International Journal of Scientific Research and Management*, *7*(12), 1465–1476.

Kabubo-Mariara, J., & Mulwa, R. (2019). Adaptation to climate change and climate variability and its implications for household food security in Kenya. *Food Policy*, *87*, 101743.

Kalele, D. N., Wasonga, O. V., & Doyo, J. (2021). Effects of climate change and variability on pastoralists and agro-pastoralists in the arid and semi-arid lands of Kenya. *Climate Risk Management*, *32*, 100271.

Kaushik, P., Tomar, R., & Kapil, R. (2023). Quantifying crop yield impacts of climate change across South Asia. *Current Research in Environmental Sustainability*, *5*, 100195.

Kimonimarrietar, S., Mureithi, S. M., & Wasonga, O. V. (2022). Climate change adaptation strategies among smallholder farmers in Masinga Sub-County, Kenya. *African Journal of Agricultural Research*, *18*(2), 80–89.

Kenya National Bureau of Statistics. (2019). *2019 Kenya population and housing census: Volume II: Distribution of population by administrative units*. Kenya National Bureau of Statistics.

Lamichhane, P., Drake, M., & Devkota, R. P. (2022). Climate change adaptation in smallholder agriculture: Adoption barriers, determinants and policy implications in Western Province, Nepal. *International Journal of Climate Change Strategies and Management*, *14*(4), 364–381.

Makueni County Government. (2023). *Makueni County integrated development plan (CIDP) 2023–2027*. Makueni County Government.

Maluvu, K., Mutua, J., & Nziku, J. K. (2023). Analysis of rainfall and temperature trends and their implication on green gram production in Kibwezi East, Kenya. *African Crop Science Journal, 31*(1), 65–78.

Mu, L., Ma, J., Wang, S., & Zhang, Y. (2020). Identifying barriers and enablers for climate change adaptation of farmers in semi-arid Northwest China. *Land, 9*(11), 445.

Mubenga-Tshitaka, J., Muteba-Leso, B., & Kabongo, B. E. (2023). Panel threshold effect of climate variability on agricultural output in East African countries. *Environmental Science and Pollution Research, 30*, 34678–34694.

Muchomba, A. W., Kamau, N. J., & Mutua, B. M. (2023). Overview of green gram crop, its economic importance, ecological requirements and production constraints in Kenya. *African Journal of Agricultural Research, 19*(6), 300–312.

Mueni, M., Nziku, J. K., & Gachene, C. K. K. (2024). Adaptation strategies and interventions to increase yield in green gram production under changing climate in Eastern Kenya. *Agriculture, Ecosystems & Environment, 345*, 108316.

Mugo, J. W., Omondi, C. K., & Karanja, R. (2021). Seasonal rainfall totals and temperature and their impacts on green gram yields in Kitui County, Kenya. *Journal of Agricultural Science, 13*(8), 112–120.

Mugo, J. W., Omondi, C. K., Karanja, R., & Kimani, P. (2023). Simulated effects of climate change on green grams production in Kitui County, Kenya. *Environmental Challenges, 12*, 100651.

Mushore, T. D., Mudavanhu, C., Musasa, B., & Shoko, C. (2021). Climate change adaptation and mitigation strategies for smallholder farmers: A case study of Nyanga District, Zimbabwe. *Jàmbá: Journal of Disaster Risk Studies, 13*(1), Article a985.

Natarajan, N., Brickell, K., & Parsons, L. (2022). The sustainable livelihoods approach twenty years on. *World Development, 157*, 105910.

Panda, A., Sharma, U., Ninan, K. N., & Patt, A. (2019). Impacts of climate change variability on crop yield in Kalahandi, Balangir and Koraput Districts of Odisha, India. *Regional Environmental Change*, *19*(3), 711–723.

Pathak, T. B., Maskey, M. L., Dahlberg, J. A., Kearns, F., Bali, K. M., & Zaccaria, D. (2022). Climate change trends and impacts on California agriculture. *Agronomy, 12*(6), 1319.

Schipper, E. L. F. (2020). Maladaptation: When adaptation to climate change goes very wrong. *One Earth*, *3*(4), 409–414.

Singh, C. (2020). Farmer perception of climate change and adaptation decision: Micro-level evidence from Bundelkhand region, India. *Mitigation and Adaptation Strategies for Global Change, 25*, 1121–1143.

Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's alpha. *International Journal of Medical Education, 2*, 53–55.