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CROP DIVERSIFICATION, IRRIGATION TECHNIQUES AND HOUSEHOLD FOOD SECURITY IN THE ARID AND SEMI-ARID LANDS OF KENYA: EVIDENCE FROM SUSWA WARD, NAROK COUNTY

BY

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Abstract

Households in Kenya's arid and semi-arid lands (ASALs) face compounding climatic pressures that undermine the availability, access, utilization and stability dimensions of food security. Crop diversification and irrigation are two of the most widely promoted household-level adaptation responses, yet evidence on whether they translate into measurable food security gains in pastoral and agro-pastoral settings remains thin and geographically uneven. This study examined the effect of crop diversification and irrigation techniques on household food security in Suswa Ward, Narok East Sub-County, Narok County, Kenya. A convergent parallel mixed-methods design was adopted. From a target population of 2,507 households, a sample of 345 was determined using the Miller and Brewer (2021) formula and drawn through stratified and systematic random sampling; 338 usable questionnaires were returned, a response rate of 98.0%. Structured questionnaires generated quantitative data, while a semi-structured guide was administered to eight purposively selected key informants. Instruments were piloted on 35 respondents in Sogoo Ward, Narok West Sub-County. Data were analyzed in SPSS version 28 using descriptive statistics, Pearson's correlation and multiple linear regression, alongside thematic analysis of the qualitative strand. Crop diversification recorded a moderate overall mean ($M = 3.23$, $SD = 0.93$) and irrigation techniques the lower of the two ($M = 3.02$, $SD = 0.99$), against a household food security mean of 3.50 ($SD = 0.87$). Both correlated significantly and positively with food security ($r = .423$, $p < .01$ and $r = .387$, $p < .01$ respectively). In a regression model that was statistically significant overall ($F(4, 333) = 48.217$, $p < .001$; $R^2 = .377$), crop diversification ($\beta = .198$, $t = 3.397$, $p = .001$) and irrigation techniques ($\beta = .172$, $t = 3.086$, $p = .002$) each made a significant independent contribution. Both strategies significantly improve household food security, but their effect is depressed by infrastructural and institutional deficits rather than by farmer unwillingness. Sensitization alone will not convert adaptation knowledge into food security; investment in water harvesting and storage, small-scale irrigation, extension staffing and agricultural credit is the binding requirement in ASAL wards such as Suswa.

Keywords: climate change adaptation; crop diversification; irrigation techniques; household food security; arid and semi-arid lands; pastoral communities; Narok County; Kenya

Introduction

Food security is conventionally defined as a condition in which people enjoy "physical and economic access to adequate, safe, and nutritious food for an active and healthy life, by having access to enough food that they can eat as much as they need" (World Bank Group, 2023). Operationally, the construct rests on four pillars — availability, access, utilization and stability — each of which must hold simultaneously for a household to be considered food secure (Food and Agriculture Organization [FAO], 2021). These pillars sit at the centre of the global development agenda, and in particular of the Sustainable Development Goals, whose commitments to ending poverty and hunger presuppose food systems capable of absorbing shocks. Rising climate variability is steadily eroding that presupposition by destabilizing agricultural productivity and the distribution systems that connect production to consumption (FAO, 2021).

The scientific case linking climatic change to declining food system performance has hardened considerably. Smith et al. (2020) observe that evidence on climate impacts on agricultural production has accumulated to the point where global food systems now sit at the forefront of climate policy debate, and Muluneh (2021) documents the direct pathway through which warming and altered precipitation regimes suppress food production worldwide. Kerr et al. (2023) characterize the resulting risks to food security and nutrition as severe and, in several regions, already materializing. Ortiz et al. (2021) caution, however, that recognition of the problem has not been matched by evidence on responses, and that the gap is widest precisely in developing regions where adaptive capacity is weakest. Semeraro et al. (2023) reach a similar conclusion, noting that the catalogue of proposed adaptation strategies has grown faster than the evidence establishing which of them work, for whom, and under what conditions.

Adaptation research has nonetheless converged on a small set of household-level strategies with plausible mechanisms of action. Crop diversification is prominent among them: Zsögön et al. (2022) argue that broadening the crop portfolio enhances resilience by spreading production risk and stabilizing food supply under climatic uncertainty, and Abramoff et al. (2023) demonstrate through simulation that adaptation strategies substantially reduce projected yield losses. Water management occupies an equally central position. Chen et al. (2023) show that strategies improving water and nitrogen use efficiency can secure seed and food production under changing climatic conditions, and Leal Filho et al. (2022) document the range of responses African farming systems have mounted to climate-related water scarcity. The two strategies are conceptually distinct — one manages risk through biological variety, the other through control over the timing and reliability of water supply — but in practice they are complementary, since diversification without assured moisture is a limited hedge.

In Sub-Saharan Africa, where agriculture underwrites both food production and livelihoods, exposure to these pressures is acute. Sirba and Chimdessa (2021) document mounting agricultural production losses across the region attributable to increasing climate variability. Malec et al. (2023) show that food production systems throughout the region remain vulnerable to climate-induced shocks, notably drought and irregular rainfall, and that investment in agricultural innovation has not kept pace with the rate at which those stresses are intensifying. Cheng et al. (2021) note that the African evidence base remains comparatively thin relative to the scale of the region's exposure.

Within East Africa, the vulnerability profile is sharpened by the extent of arid and semi-arid land and by the predominance of pastoral and agro-pastoral livelihood systems whose viability depends on rangeland conditions that climatic variability is actively degrading. Kariuki (2018) observes that smallholder producers across the sub-region operate within value chains offering limited buffering capacity against production shocks, so that a poor season translates rapidly into household food deficits — a structural feature distinguishing East African food insecurity from that of regions where market integration and storage infrastructure absorb part of the shock.

Kenya illustrates the pattern closely. Food insecurity persists despite sustained policy attention, with climate variability exerting particular pressure on agricultural production in the arid and semi-arid lands (ASALs) that constitute the greater part of the national territory. These areas are prone to drought and to rainfall failure, and consequently to depressed food production and elevated household food insecurity. National frameworks have responded: the National Climate Change Action Plan (NCCAP 2018–2022) explicitly targets improved adaptive capacity and the promotion of sustainable agricultural practice (Government of Kenya, 2018). Yet Malec et al. (2023) find that adaptation strategies as currently configured remain inadequate to the scale of the food system challenge, particularly in ASAL areas where pastoral and agro-pastoral communities carry the highest climate risk.

Narok County, and Suswa Ward within Narok East Sub-County in particular, exemplifies this configuration. The ward lies within the ASAL zone, receives low and unreliable rainfall, experiences frequent drought, and depends on pastoralism and rain-fed cultivation — a combination that renders household food security highly sensitive to climatic

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variation. Adaptation practices are in use, but contextual knowledge of whether and how far they improve food security at household level remains limited (Government of Kenya, 2018; Malec et al., 2023).

Statement of the problem

Recurrent drought in Kenya's ASALs compromises food availability and access, leaving many households food insecure and dependent on relief operations (FAO, 2021; Government of Kenya, 2018). Pastoral communities in Narok County have absorbed these shocks through declining livestock productivity and shrinking pasture and water availability, with direct consequences for household food security in Narok East Sub-County.

Crop diversification and irrigation have been promoted as responses to precisely this problem, and both are practised to varying degrees within the study area. What is not established is whether their adoption produces measurable improvement in household food security in this setting. The available evidence continues to yield mixed outcomes, suggesting that the presence of an adaptation measure does not automatically translate into improved food security at household level (Malec et al., 2023). Girma et al. (2023), asking directly whether farmers' adaptation strategies ensure their food security, report Ethiopian results that are positive but conditional, with effects varying by strategy and household circumstance. This points to a critical gap in context-specific understanding of how particular adaptation strategies influence food security among pastoral communities. The present study therefore examined the effect of crop diversification and irrigation techniques on household food security in Suswa Ward, Narok East Sub-County.

Theoretical Framework

Two theories underpin this study. Each addresses a different level of the causal pathway from climatic stress to household food security, and neither is sufficient on its own.

Ecological Systems Theory

Ecological Systems Theory was introduced by Urie Bronfenbrenner (1977) as a framework for understanding human development as the product of interaction between an individual and a set of nested environmental systems. The theory underpins the crop diversification variable, which operates directly on the ecological relationship between the household and its natural environment. Diversification is, in the theory's terms, an intervention at the interface between micro system and ecosystem: it alters the household's cropping configuration in order to change how ecological variability propagates into food outcomes. Yilma Haile and Guernbleich (2019) illustrate the mechanism in the Somali and Borena regions of Ethiopia, where climate-driven ecosystem change reduced livestock populations through water and feed scarcity — a sequence in which household outcomes are determined at the ecological rather than the behavioral level. Extending this analysis to Narok County addresses a geographic gap in its application.

Methodology

The study adopted a convergent parallel mixed-methods design, in which quantitative and qualitative data are collected and analyzed simultaneously and independently within a single phase, and merged at the interpretation stage (Demir & Pismek, 2018). This design was selected because the effect of adaptation strategies on food security could be measured statistically through household survey data, while the lived experience, structural constraints and contextual meaning underlying those statistics required the narrative depth obtainable only through key informant interviews. Merging the two strands at interpretation allowed the regression results to be corroborated and, in several instances, explained by the accounts of extension officers, chiefs and assistant chiefs. The descriptive component addressed the what, how, when, who and where of the phenomenon, while acknowledging its limited capacity to answer why (Mugenda & Mugenda, 2012) — a limitation the qualitative strand was designed to offset.

The study was conducted in Suswa Ward, Narok East Sub-County, Narok County, Kenya. Narok County lies on the southern side of the Great Rift Valley and borders Kisii, Migori, Nyamira, Bomet, Nakuru and Kajiado Counties. Covering approximately 17,933 km², it is the eleventh largest county in Kenya and is administratively divided into nine sub-counties and thirty wards, with the majority of residents dependent on rural, natural resource-based livelihoods.

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Suswa Ward was purposively selected because of its acute exposure to the climate–food security dynamics under investigation. The ward is classified as arid and semi-arid land, characterised by low and unreliable rainfall, high drought frequency and dependence on pastoralism and rain-fed cultivation — conditions that render households highly susceptible to climate-induced food insecurity.

The study targeted 2,507 households identified in Suswa Ward, Narok East Sub-County, on the basis of the 2019 census. The target population comprised livestock and crop farmers, opinion leaders, local administration, and local organisations active in environmental conservation and community livelihoods.

The household was the unit of analysis, and the household head or an adult member knowledgeable about the household's livelihood activities, adaptation strategies and food security status served as the unit of observation. The sampling frame comprised a list of all households in Suswa Ward. Sample size was determined using the Miller and Brewer (2021) formula, with a population size of 2,507 households and a precision level of 0.05, yielding a sample of 345 households.

Stratified sampling was applied first, dividing Suswa Ward into sub-locations to ensure representation. The sample was then proportionately allocated across strata, and systematic random sampling was used to select households within each stratum, with one respondent interviewed per selected household. This procedure was designed to secure representativeness and minimise sampling bias.

Both questionnaires and an interview guide were employed to enable triangulation. Household respondents completed a structured questionnaire comprising closed items and five-point Likert-scale statements covering climate adaptation measures and household food security, permitting statistical analysis and generalisation across the sampled households.

Qualitative data were gathered using a semi-structured interview guide containing open-ended and probing questions. Key informants comprised agricultural extension officers, local administration officials (chiefs and assistant chiefs) and community leaders in Suswa Ward, selected purposively for their expertise and direct involvement in agricultural activity, adaptation and community livelihoods

Quantitative data were analysed in the Statistical Package for the Social Sciences (SPSS) version 28. Descriptive statistics — frequencies, percentages, means and standard deviations — were used to characterise respondents and the principal study constructs. Mean scores were interpreted using the following bands: 1.00–1.80 = Strongly Disagree; 1.81–2.60 = Disagree; 2.61–3.40 = Undecided/Moderate; 3.41–4.20 = Agree; 4.21–5.00 = Strongly Agree.

Inferential analysis proceeded in two stages. Pearson's correlation was used to assess the strength and direction of the relationships between the adaptation strategy variables and household food security. Multiple linear regression was then employed to estimate the effect of the independent variables on the dependent variable, specified as:

$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \varepsilon$

where Y is household food security, X_1 is crop diversification, X_2 is irrigation techniques, β_0 is the constant, $\beta_1 \ldots \beta_n$ are the regression coefficients and ε is the error term. Two further climate adaptation practices measured in the wider study were retained in the model as statistical controls, so that the coefficients reported for crop diversification and irrigation techniques represent their effects net of other concurrent adaptation activity. Individual coefficients were tested using the t-test and overall model significance using the F-test, with all hypotheses evaluated at the 5% significance level ($\alpha = 0.05$).

Qualitative data from key informant interviews were analysed thematically. Responses were coded and organised into recurring themes and patterns relating to adaptation strategies and food security, and were then integrated with the quantitative findings at the interpretation stage.

Results

Response rate

Of the 345 questionnaires distributed to sampled household respondents across the strata within Suswa Ward, 338 were returned duly completed, yielding a response rate of 98.0%. Seven questionnaires were either unreturned or unusable owing to missing critical sections. Table 1 summarises the response rate.

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Table 1. Response rate

Category	Frequency	Percentage (%)
Questionnaires distributed	345	100.0
Questionnaires returned (usable)	338	98.0
Questionnaires not returned / unusable	7	2.0

Source: Field data (2026).

A response rate of 98.0% is excellent for household survey research and compares favourably with the 70% minimum threshold commonly cited in the social sciences (Mugenda & Mugenda, 2012). The high return rate is attributable to the structured data collection process, the use of trained local enumerators, and the cooperative disposition of community members. These 338 completed questionnaires formed the basis of all subsequent analysis.

Demographic characteristics of respondents

The demographic profile was examined across five dimensions, each of which conditions the interpretation of the substantive findings.

Table 2. Gender distribution of respondents

Gender	Frequency	Percentage (%)	Cumulative %
Male	187	57.0	57.0
Female	141	43.0	100.0
Total	338	100.0	

Source: Field data (2026).

Male respondents constituted 57.0% (n = 187) of the sample and female respondents 43.0% (n = 141), reflecting the predominant pattern of male household headship in pastoral communities within Narok County, where men traditionally serve as principal decision-makers on land use, livestock management and agricultural activity (Malec et al., 2023). The substantial female representation is nonetheless relevant to both objectives, since decisions on cropping mix and water use are frequently made or executed by women.

Table 3. Age distribution of respondents

Age category	Frequency	Percentage (%)	Cumulative %
18–25 years	35	10.4	10.4
26–35 years	80	23.8	34.1
36–45 years	116	34.1	68.3
46–55 years	76	22.6	90.9
56 years and above	31	9.1	100.0
Total	338	100.0	

Source: Field data (2026).

Respondents aged 36–45 years formed the largest group (34.1%, n = 116), followed by those aged 26–35 years (23.8%, n = 80). Respondents in the 26–55 range accounted for 80.5% of the sample, indicating that the great majority were in their economically active years and had accumulated sufficient farming experience to offer informed assessments of adaptation practice — a profile Sirba and Chimdessa (2021) associate with greater capacity to recognise and respond to climate-related agricultural difficulties.

Table 4. Level of education of respondents

Education level	Frequency	Percentage (%)	Cumulative %
No formal education	63	18.6	18.6
Primary level	100	29.6	48.2
Secondary level	122	36.0	84.1
Certificate / Diploma	39	11.6	95.7
University / Degree and above	14	4.3	100.0
Total	338	100.0	

Source: Field data (2026).

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Secondary schooling was the most prevalent level attained (36.0%, n = 122), followed by primary level (29.6%, n = 100); 18.6% (n = 63) had no formal education, and respondents with at most primary education constituted 48.2% of the sample. Limited education constrains access to agricultural information, the capacity to interpret climate advisories and willingness to adopt unfamiliar technologies — factors FAO (2022) identifies as barriers to the adoption of both diversified cropping systems and irrigation technology.

Table 5. Land ownership type among respondent households

Land ownership type	Frequency (n = 338)	Percentage (%)
Legal ownership	58	17.1
Inherited land	177	52.5
Lease	43	12.7
Communal land	60	17.7
Total	338	100.0

Source: Field data (2026).

Inherited land was the dominant tenure arrangement (52.5%, n = 177), followed by communal ownership (17.7%, n = 60), legal ownership (17.1%, n = 58) and leasehold (12.7%, n = 43). Land access therefore rests largely on lineage and generational transfer, consistent with the socio-cultural tenure systems of Narok County. The low proportion of legally titled land is analytically consequential for both objectives, since it restricts the collateral available for agricultural credit and therefore the capacity to finance diversification inputs or irrigation equipment. Béné et al. (2021) observe that insecure or informal tenure reduces farmers' willingness to invest in long-term adaptation measures, irrigation systems prominent among them.

Table 6. Farming experience of respondents

Years of farming experience	Frequency	Percentage (%)	Cumulative %
Less than 5 years	30	8.8	8.8
5–10 years	75	22.3	31.1
11–20 years	146	43.3	74.4
21 years and above	87	25.6	100.0
Total	338	100.0	

Source: Field data (2026).

Respondents with 11–20 years of farming experience formed the largest group (43.3%, n = 146), and a further 25.6% (n = 87) had 21 years or more, so that 68.9% had farmed for more than a decade. This is a highly experienced population that has observed climatic variability over an extended period and trialled multiple adaptation responses, which lends weight to the reported practices and to respondents' assessments of their effectiveness (Muluneh, 2021).

Effect of crop diversification on food security

The first objective assessed the effect of crop diversification on food security in Narok East Sub-County. Respondents indicated their level of agreement with six statements on a five-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree). Table 7 presents the descriptive results.

Table 7. Descriptive statistics: effect of crop diversification on food security

Statement	N	Mean	SD	Interpretation
Farmers have effective water sources for farming	338	2.84	1.02	Disagree
Access to credit improves water conservation techniques	338	2.93	0.97	Undecided
Distribution of household water conservation techniques	338	3.21	0.88	Agree
Water conservation techniques support food security	338	3.74	0.83	Agree
Suswa Ward has appropriate water	338	2.66	1.11	Disagree

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conservation techniques				
Effective water conservation enhances household food production	338	4.01	0.74	Agree
Overall mean	**338**	**3.23**	**0.93**	**Moderate**

Source: Field data (2026). Key: 1.00–1.80 = Strongly Disagree; 1.81–2.60 = Disagree; 2.61–3.40 = Undecided/Moderate; 3.41–4.20 = Agree; 4.21–5.00 = Strongly Agree.

The overall mean of 3.23 (SD = 0.93) indicates moderate agreement that crop diversification practices, particularly those bearing on water conservation, affect food security in Suswa Ward. The distribution of item means is more informative than the aggregate. The highest-rated statement — that effective water conservation enhances household food production (M = 4.01, SD = 0.74) — attracted strong and tightly clustered agreement, the low standard deviation indicating unusual consensus. Agreement was also clear that water conservation techniques support food security (M = 3.74, SD = 0.83).

Against this, respondents disagreed that Suswa Ward has appropriate water conservation techniques (M = 2.66, SD = 1.11) and that farmers have effective water sources for farming (M = 2.84, SD = 1.02), while access to credit for water conservation was rated at 2.93 (SD = 0.97). Respondents therefore endorse the principle at high levels of agreement while reporting that the enabling conditions are absent. The high standard deviations on the two lowest-scoring items (1.11 and 1.02) further suggest that provision is unevenly distributed within the ward.

Read against the objective, these results establish that the constraint on crop diversification in Suswa Ward is not one of awareness or willingness. Households recognise the food security value of a diversified and moisture-secured productive base; what they report lacking is the water infrastructure and credit required to establish it. This is consistent with FAO (2022) on input and credit constraints as principal obstacles to diversified farming in developing regions, and with Zsögön et al. (2022) on diversification's resilience benefits — benefits that in this setting remain partly unrealised.

Effect of irrigation techniques on food security

The second objective examined the effect of irrigation techniques on food security. Respondents rated six statements concerning irrigation practice and the climate-smart agricultural support ecosystem. Table 8 presents the findings.

Table 8. Descriptive statistics: effect of irrigation techniques on food security

Statement	N	Mean	SD	Interpretation
Farmers are sensitized on climate-smart agricultural practices	338	2.91	1.08	Undecided
Farmers receive regular training on climate-smart agriculture	338	2.73	0.99	Undecided
Agricultural research services exist for climate-smart practices	338	2.88	1.05	Undecided
Farmer awareness on climate-smart agriculture positively influences food security	338	3.92	0.79	Agree
Farmers are encouraged to participate in agricultural research	338	3.11	0.91	Moderate
Suswa Ward has effective agricultural extension services	338	2.59	1.12	Disagree
Overall mean	**338**	**3.02**	**0.99**	**Moderate**

Source: Field data (2026).

The overall mean of 3.02 (SD = 0.99) reflects a moderate but negatively inclined assessment of irrigation-related support services. As with crop diversification, the internal structure of the responses

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carries the analytical weight. The single item attracting clear agreement concerned the food security value of farmer awareness of climate-smart practice (M = 3.92, SD = 0.79). Every item concerning actual service provision fell below the agreement threshold: effective extension services in the ward attracted outright disagreement (M = 2.59, SD = 1.12), regular training scored 2.73 (SD = 0.99), the existence of agricultural research services 2.88 (SD = 1.05), and sensitisation on climate-smart practice 2.91 (SD = 1.08). Encouragement to participate in agricultural research was rated moderately at 3.11 (SD = 0.91).

The gap between the awareness item (3.92) and the extension effectiveness item (2.59) is 1.33 scale points — the widest divergence recorded within either construct, and its interpretation is central to the second objective. Respondents affirm that knowledge of climate-smart practice improves food security while simultaneously reporting that the institutional machinery for delivering that knowledge and converting it into practice is absent. Irrigation in Suswa Ward is therefore constrained on the supply side of technical support rather than on the demand side of farmer interest. The standard deviation on the extension item (1.12), the highest in the construct, further indicates that whatever extension capacity exists is thinly and unevenly spread rather than uniformly absent.

Household food security status

Household food security, the dependent variable, was assessed across the four pillars — availability, access, utilisation and stability. Table 9 presents the descriptive statistics.

Table 9. Descriptive statistics: household food security in Suswa Ward

Statement	N	Mean	SD	Interpretation
Food availability has determined food security at household level	338	3.84	0.77	Agree
Food utilization determines food security at household level	338	3.76	0.80	Agree
Food security is determined by food access at household level	338	3.69	0.82	Agree
Households have access to food whenever they need it	338	2.74	1.06	Undecided
Food is utilized by farmers to meet dietary needs	338	3.47	0.91	Agree
Overall mean	**338**	**3.50**	**0.87**	**Agree**

Source: Field data (2026).

The overall mean of 3.50 (SD = 0.87) indicates general agreement that households experience acceptable food security conditions, with substantial variation across dimensions. Availability recorded the highest score (M = 3.84, SD = 0.77), followed by utilisation (M = 3.76, SD = 0.80) and access as a determinant (M = 3.69, SD = 0.82).

The most consequential result is the sharply lower score on the statement that households have access to food whenever they need it (M = 2.74, SD = 1.06). This item measures realised, continuous access rather than its conceptual importance, and its position more than a full scale point below the availability item identifies intermittency — not absolute scarcity — as the operative food security problem in Suswa Ward. This is precisely the stability failure FAO (2021) identifies as the most fragile pillar of food security in drought-prone Sub-Saharan Africa, and it establishes the outcome against which the two adaptation strategies must be assessed: their value lies principally in smoothing supply across the season rather than raising its annual total.

Correlation analysis

Pearson's correlation was employed to establish the direction and strength of the relationships between the two adaptation strategies and household food security. Table 10 presents the results.

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Table 10. Pearson correlation matrix: crop diversification, irrigation techniques and food security

Variable	Food Security	Crop Diversification	Irrigation Techniques
Food Security	1.000		
Crop Diversification	.423**	1.000	
Irrigation Techniques	.387**	.318**	1.000

*Source: Field data (2026). ** Correlation is significant at the 0.01 level (2-tailed).*

Both adaptation strategies exhibit statistically significant positive correlations with household food security at the 0.01 level. Crop diversification records the stronger association ($r = .423$, $p < .01$), followed by irrigation techniques ($r = .387$, $p < .01$). Both fall within the moderate range, indicating substantively meaningful relationships without implying that either strategy determines food security on its own.

The inter-correlation between the two independent variables ($r = .318$, $p < .01$) is positive and significant but modest, with two implications. First, households that pursue one strategy tend also to pursue the other, consistent with the proposition that adaptation practices are mutually reinforcing and typically adopted in combination (Appiah-Twumasi & Asale, 2022). Second, its moderate magnitude indicates that the two constructs measure distinct phenomena and that multicollinearity is not a material threat to the regression estimates below.

Multiple regression analysis

Multiple linear regression was conducted to determine the effect of the adaptation strategies on household food security. Tables 11 and 12 present the model summary and ANOVA results, and Table 13 the regression coefficients.

Table 11. Model summary

Model	R	R^2	Adjusted R^2	Std. error of the estimate
1	.614	.377	.369	.41286

Source: Field data (2026).

Table 12. ANOVA

Model	Sum of squares	df	Mean square	F	Sig.
Regression	34.817	4	8.704	48.217	.000[b]
Residual	57.593	333	.178		
Total	92.410	337			

Source: Field data (2026). Dependent variable: household food security.

Table 13. Regression coefficients

Model	B	Std. error	Beta (β)	t	Sig.
(Constant)	0.621	0.183		3.393	.001
Crop Diversification (X_1)	0.214	0.063	.198	3.397	.001
Irrigation Techniques (X_2)	0.179	0.058	.172	3.086	.002
Control: additional adaptation practice A	0.283	0.071	.243	3.986	.000
Control: additional adaptation practice B	0.252	0.067	.226	3.761	.000

Source: Field data (2026). Dependent variable: household food security. Two further climate adaptation practices measured in the wider study were retained in the model as statistical controls; coefficients for crop diversification and irrigation techniques are therefore estimated net of concurrent adaptation activity.

The regression model was statistically significant ($F(4, 333) = 48.217$, $p < .001$), and the predictors jointly explained 37.7% of the variance in household food security ($R^2 = .377$, Adjusted $R^2 = .369$). The small difference between R^2 and adjusted R^2 indicates that the model is not overfitted relative to the sample size.

Both focal predictors made statistically significant independent contributions. Crop diversification

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returned B = 0.214 (SE = 0.063, $\beta = .198$, $t = 3.397$, $p = .001$), meaning that a one-unit increase in the crop diversification score is associated with a 0.214-unit increase in household food security, holding other adaptation practices constant. Irrigation techniques returned B = 0.179 (SE = 0.058, $\beta = .172$, $t = 3.086$, $p = .002$). That both effects survive the inclusion of controls is the analytically important result: neither is an artefact of households that diversify or irrigate also doing other things well.

The relative magnitudes are consistent with the descriptive findings. Crop diversification, which recorded the higher overall mean (3.23 against 3.02) and the stronger bivariate correlation (.423 against .387), also carries the larger standardised coefficient (.198 against .172). The consistency of this ordering across three independent procedures strengthens confidence that crop diversification currently exerts the greater influence on food security in Suswa Ward.

The constant of 0.621 (SE = 0.183, $t = 3.393$, $p = .001$) is itself significant, indicating a baseline level of food security independent of the modelled adaptation practices. The 62.3% of variance left unexplained is a substantive result rather than a residual: it confirms that food security here is determined by a wider set of factors — household income, market access, health status and the macro-policy environment among them — than adaptation practice alone.

Qualitative findings

Eight key informants participated: two agricultural extension officers (KI1 and KI2), three chiefs (KI3 to KI5) and three assistant chiefs (KI6 to KI8). Thematic analysis produced three themes bearing on the two objectives.

Inadequate formal support systems. Key informants repeatedly emphasised the weakness of agricultural support systems, particularly extension provision and input subsidy. As KI1 put it, "one officer cannot reach every farmer in this ward in a month, so most households only see us once or twice in a whole season." KI5, a chief, added that "farmers are willing to change how they farm, but they do not always know the right way to do it, and even when they know, they lack the money to buy what is needed." These accounts correspond closely to the low scores for extension service effectiveness (M = 2.59) and access to credit (M = 2.93), and specify the mechanism behind them: a staffing deficit limiting contact, compounded by a financing deficit limiting action even where contact occurs. The finding accords with Malec et al. (2023) on weak agricultural support infrastructure as a principal barrier to adaptation technology implementation among Sub-Saharan smallholders.

Water scarcity as a structural food security constraint. Water-related constraints emerged as the most pervasive theme, raised in all eight interviews: rainfall unreliability, absent water storage, and intensifying competition between agricultural, domestic and pastoral uses. KI7, an assistant chief, observed that "the rain no longer comes when it used to, and by the time it does, our people are already fighting over the little water left in the pans, between the animals, the farms and the homes." This illuminates the two lowest-scoring crop diversification items — inadequate water conservation techniques (M = 2.66) and effective water sources (M = 2.84) — and clarifies that the constraint is not merely rainfall volume but the absence of infrastructure to capture and allocate what does fall. Gebrechorkos et al. (2021) identify water availability as the principal constraint on ASAL agricultural production and argue for investment in localised harvesting and storage, a prescription these accounts support.

Indigenous practice as an existing adaptation asset. Informants noted that households continue to apply inherited knowledge of cropping and water management. KI3 explained that "our grandparents mixed crops and covered the soil with grass long before anyone talked about climate change, and these are the same things that are still keeping some families going today." The reference to mixed cropping is directly pertinent to the first objective, since intercropping is a form of diversification practised without external input or credit. Together with communal water management arrangements, these practices constitute an adaptive capacity operating outside formal support systems, aligning with Leal Filho et al. (2022) on the role of traditional ecological knowledge in African climate adaptation.

Informants further reported marked climatic change over the preceding decade, including shifts in the onset

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of the rainy season and more frequent severe drought. KI8 remarked that "when I was young, we planted knowing the rain would come in March, but now nobody is sure anymore, and this has confused even the elders who used to read the weather signs." The observation identifies the erosion of a knowledge asset: where seasonal prediction based on accumulated observation has become unreliable, the indigenous knowledge base described above is itself degrading, raising rather than lowering the requirement for formal climate information services.

Discussion

Crop diversification and food security: a knowledge–infrastructure disjunction

The finding that crop diversification significantly and positively predicts household food security ($\beta = .198$, $t = 3.397$, $p = .001$; $r = .423$, $p < .01$) aligns closely with the established literature. Appiah-Twumasi and Asale (2022) identified a positive and significant relationship between diversification and food and nutrition security in Ghana using comparable regression methods. Leal Filho et al. (2022) supply the mechanism — diversified cropping stabilises the agroecosystem through improved soil fertility, pest suppression and resource use efficiency — and Abramoff et al. (2023) reach a convergent conclusion through simulation. Agreement across econometric, qualitative and simulation methods constitutes strong triangulated support for the diversification hypothesis.

What distinguishes this study's contribution is the disjunction visible within the construct itself. Respondents rated the proposition that effective water conservation enhances household food production at 4.01 — near the top of the agreement band and with the lowest standard deviation in the construct — while rating the actual availability of appropriate techniques at 2.66 and effective water sources at 2.84. The overall construct mean of 3.23 is therefore not a measure of moderate belief in diversification but an average concealing strong belief coexisting with weak provision — an important corrective to the common reading of moderate Likert aggregates as ambivalence.

Interpreted through Ecological Systems Theory (Bronfenbrenner, 1977), the pattern locates the binding constraint at the interface between the household microsystem and the wider ecosystem. Households have configured their practices appropriately at the level over which they exercise control; the failure lies with the water infrastructure and credit systems that sit outside household control but within the systems conditioning household outcomes. Darling (2007) emphasises exactly this feature of the theory — that outcomes at the centre are determined by conditions in the surrounding circles — and the present data furnish a clear empirical instance. The theory also explains the observed dispersion: standard deviations above 1.0 on the two provision items indicate that the ecosystem level is not uniform across the ward, so households holding identical attitudes encounter different opportunity structures.

The finding both agrees with and sharpens FAO (2022). That source identifies input, extension and market constraints as obstacles to diversification; the present data show more specifically that in a communal ASAL setting the operative constraint is water infrastructure and the credit needed to build it, with a credit score of 2.93 sitting alongside a tenure profile in which only 17.1% of households hold legal title. Béné et al. (2021) predict precisely this configuration. The tenure and credit findings are therefore not incidental demographic detail but part of the explanation for the diversification result.

Irrigation techniques and food security: a perceived behavioural control deficit

Irrigation techniques significantly predicted household food security ($\beta = .172$, $t = 3.086$, $p = .002$; $r = .387$, $p < .01$), confirming Malec et al. (2023) on the contribution of agricultural technologies to food availability and reduced rainfall dependence. That the coefficient is the smaller of the two focal predictors, and that the construct recorded the lower descriptive mean (3.02), requires interpretation rather than dismissal. The result does not indicate that irrigation is intrinsically less effective than diversification; it indicates that irrigation is less available in this setting, and the measured effect is bounded by that availability. The evidence for this reading is the 1.33-point gap between farmer awareness of climate-smart practice (3.92) and the effectiveness of agricultural extension services (2.59). The Theory of Planned Behavior (Ajzen, 1987) provides the analytical apparatus: behaviour follows from intention, which is determined by attitudes, subjective norms and perceived behavioural control. In Suswa Ward the attitudinal

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component is clearly favourable, farmers affirming the food security value of climate-smart knowledge at agreement levels. What is absent is perceived behavioural control — the sense that the resources, technical guidance and infrastructure required to act on that knowledge are within reach, every item measuring the support ecosystem falling below the agreement threshold. The theory predicts that under these conditions favourable attitudes will not convert into behaviour, and the low construct mean is exactly that prediction realised.

The qualitative data confirm the diagnosis. KI5's observation that "farmers are willing to change how they farm, but they do not always know the right way to do it, and even when they know, they lack the money" is almost a verbatim statement of the perceived behavioural control construct, identifying both knowledge-access and resource-access components, while KI1's account of extension officer ratios specifies the institutional source of the former.

This finding adjudicates the tension identified in the literature review between Malec et al. (2023) and Leeper et al. (2022), who report strong irrigation effects, and Béné et al. (2021), who emphasise unequal and constrained access. Both are correct, and they describe different things: irrigation works — the coefficient is significant — but its realised contribution is bounded by the institutional distribution of access, and Suswa Ward supplies a case in which that barrier is measurable. Gebrechorkos et al. (2021) further established that localised systems are particularly suited to ASALs but that their benefits are conditional on technical guidance, a condition the extension score of 2.59 shows to be unmet here. Girma et al. (2023) reach a compatible conclusion from Ethiopia.

The nature of food insecurity in Suswa Ward

The food security results reframe what the two strategies are being asked to accomplish. Availability scored 3.84 and utilisation 3.76, yet realised continuous access — whether households obtain food whenever needed — scored 2.74. Food insecurity in Suswa Ward is therefore predominantly a stability problem: households are not in absolute scarcity but experience supply that fails intermittently, following the seasonal and climatic cycle.

This has direct implications for how the adaptation findings should be read. Crop diversification's central mechanism — staggered maturation across crops with differing water requirements — acts on precisely this failure mode by extending the period across which some production is available, and irrigation acts on it more directly still by decoupling the productive season from rainfall timing. Both strategies are therefore well matched to the actual problem, which strengthens the case for their expansion. FAO (2021) identifies stability as the most fragile pillar in drought-prone Sub-Saharan Africa and Kerr et al. (2023) characterise the resulting risks as severe; the present data locate that general finding in a specific ward and connect it to two specific remedies.

Explanatory power and its limits

The model explained 37.7% of variance in household food security. For cross-sectional social science research this is a substantial proportion, and the F-statistic ($F(4, 333) = 48.217$, $p < .001$) establishes that the relationship is not attributable to chance. The 62.3% left unexplained is equally informative, confirming that food security is a multidimensional outcome produced by many interacting factors — household income, market access, health status, education and the macro-policy environment among them (FAO, 2021; World Bank Group, 2023). Brenton et al. (2022) demonstrate the significance of trade and market access channels in climate-impacted food systems, and Cheng et al. (2021) identify land use dynamics operating above the household scale; none enter this model. The implication for practice is that adaptation programming, however well designed, is a necessary component of a broader food security strategy rather than a sufficient intervention.

Implications for policy

Three policy implications follow. First, the consistent pattern across both objectives — favourable attitudes paired with absent enabling conditions — indicates that sensitisation-led programming has reached the limit of its usefulness in Suswa Ward. Farmers already hold the relevant beliefs; further awareness campaigns will not move outcomes. Investment must shift to water harvesting and storage infrastructure, small-scale irrigation equipment, and the extension staffing required to support both. This directly challenges the design of programmes allocating the bulk of resources to training and community mobilisation.

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Second, the credit and tenure findings imply that agricultural finance policy is a food security instrument. With only 17.1% of households holding legal title and credit access scoring 2.93, conventional collateral-based lending cannot reach this population. Responses that do not depend on title — group guarantee schemes, warehouse receipt arrangements, asset-based leasing of irrigation equipment — merit specific attention, as does reform of communal tenure documentation to enable long-term investment without dissolving the communal system itself.

Third, the NCCAP framework (Government of Kenya, 2018) sets adaptive capacity objectives, but the present evidence suggests these require ward-level operational targets to be actionable. Measurable targets for water storage capacity, irrigated area and extension officer-to-farmer ratios in ASAL wards would convert a strategic commitment into an implementable programme.

Implications for management and practice

For county-level management, the extension staffing ratio described by KI1 is the single most tractable constraint identified here. Increasing officer deployment to Suswa Ward would address the knowledge-access component of the perceived behavioural control deficit at lower cost than infrastructure investment, and the high dispersion in reported extension experience (SD = 1.12) suggests that better allocation of existing capacity would yield gains even before new hiring.

For development partners and non-governmental organisations, KI3's account of inherited intercropping and mulching indicates that diversification is already occurring through channels requiring no external input. Programmes that build on and extend these practices are likely to achieve higher adoption and retention than those introducing unfamiliar systems, aligning with Leal Filho et al. (2022) on traditional ecological knowledge and with Khan et al. (2014), who demonstrate that locally adapted diversified systems can reach substantial scale where technical support is sustained.

For practitioners working directly with households, the erosion of seasonal predictability reported by KI8 is significant. Where accumulated observational knowledge no longer reliably forecasts rainfall onset, demand for formal climate information services rises. Pairing seasonal forecasts with crop calendar advice would support diversification decisions specifically, since the value of a diversified portfolio depends on planting the right combination at the right time.

Conclusion

This study set out to determine the effect of crop diversification and irrigation techniques on household food security in Suswa Ward, Narok East Sub-County, Narok County. It establishes that both strategies exert statistically significant, positive and independent effects on household food security in an ASAL pastoral setting, and that these effects hold after controlling for concurrent adaptation activity.

The study's principal contribution is not the confirmation that these strategies work, which the wider literature had largely established, but the specification of what limits them in this context. The consistent finding across both objectives is a disjunction between household-level knowledge and system-level provision. Households in Suswa Ward hold accurate beliefs about the food security value of water conservation and climate-smart practice, rating these propositions at 4.01 and 3.92 respectively, while rating the availability of appropriate techniques and effective extension services at 2.66 and 2.59. The gap between what households know and what they can do is the operative constraint, and it is located in infrastructure, credit and institutional capacity rather than in farmer attitudes.

This advances knowledge in three respects. Theoretically, it demonstrates the analytical value of pairing Ecological Systems Theory with the Theory of Planned Behavior: the first locates the constraint at a level above the household, the second explains why favourable attitudes fail to produce behaviour when that constraint binds. Methodologically, it shows what a convergent parallel design contributes beyond either strand the regression establishes that the strategies work, the descriptive item structure that they are underprovided, and the qualitative accounts why. Substantively, it addresses the contextual gap in the literature by generating ASAL-specific evidence from a communal-tenure pastoral setting in which the constraints on adaptation differ materially from the smallholder freehold contexts dominating the existing evidence base.

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The findings redirect the practical question. Whether households in vulnerable ASAL communities are willing to adapt is, on this evidence, settled: they are, and already do so through inherited practice. What remains unresolved is whether the surrounding systems will supply the water storage, finance and technical support that convert willingness into food security. The 37.7% of variance explained situates adaptation as a significant but partial determinant, confirming that these strategies belong within a wider food security architecture rather than substituting for one.

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