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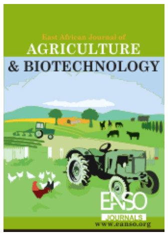

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Original Article

Adoption and Barriers to Climate Change Adaptation and Mitigation Strategies for Food Security in the Lower Nyando Basin, Kenya

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ABSTRACT

Climate change is a critical threat to food security, particularly in sub-Saharan Africa, where livelihoods are highly dependent on climate-sensitive sectors such as rain-fed agriculture and fisheries. In Kenya, the Lower Nyando Basin (LNB) exemplifies this vulnerability, with communities facing recurrent floods and prolonged droughts that disrupt food production and exacerbate poverty. Despite growing promotion of climate-smart practices, evidence on the extent of adoption, their effectiveness in improving food security, and the barriers constraining their impact at the community level remains limited. This study sought to assess household adoption of climate change adaptation and mitigation measures, examine their relationship with food security, and identify systemic constraints limiting their effectiveness in the LNB. A mixed-methods cross-sectional design was employed, combining a household survey of 378 respondents with 12 key informant interviews and 10 focus group discussions. Quantitative data were analysed using descriptive statistics, Chi-square tests, and regression models, while qualitative data were thematically analysed and triangulated with survey results to enrich contextual understanding. Findings revealed high levels of adaptation, with more than 90% of households adopting drought-resistant and early-maturing crop varieties, crop diversification, and indigenous seeds. Irrigation, water harvesting, and watershed management were also reported, though adoption was constrained by high costs and limited technical support. Adaptation was positively associated with improved food security outcomes, as households employing multiple strategies reported fewer incidences of hunger and more stable food access. However, food insecurity persisted, with many households experiencing shortages lasting up to four months annually, especially during extreme climatic events. Major barriers included financial constraints, high input and irrigation costs, inadequate extension services, technical knowledge gaps, and limited participation in adaptation planning. The study concludes that while communities in the LNB are proactive in adopting climate-smart practices, structural and institutional barriers undermine their transformative potential. Addressing these constraints through enhanced financial inclusion, participatory governance, improved extension services, and investment in climate-resilient infrastructure will be critical for achieving sustainable food security in climate-vulnerable landscapes.

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INTRODUCTION

Climate change represents one of the most pressing challenges of the twenty-first century, threatening global food systems, economic stability, and environmental sustainability. Its impacts are disproportionately severe in developing regions, particularly in sub-Saharan Africa, where livelihoods are heavily dependent on rain-fed agriculture and natural resource-based economies (Enete & Musa, 2010; Katunzi et al., 2016). The increasing frequency and intensity of climate-related shocks such as droughts, floods, and heatwaves have significantly compromised agricultural productivity, reduced water availability, and undermined household livelihoods, thereby exacerbating poverty and inequality (FAO, 2017; IPCC, 2018; WFP, 2021). These disruptions have direct consequences for food security, which is already precarious in regions where population growth, land degradation, and socio-economic constraints intersect to limit adaptive capacity (Wijerathna-Yapa & Pathirana, 2022; Ofori et al., 2021).

Kenya illustrates these vulnerabilities acutely. Over the past two decades, the country has experienced recurrent droughts, erratic rainfall patterns, and increasingly severe flooding events. These changes have not only undermined agricultural productivity but have also compromised water security, human health, and the sustainability of fisheries and livestock systems (GoK, 2018; Abuya, 2021; Raihan, 2023). Nationally, climate variability has emerged as one of the most significant threats to socio-economic development, with rural communities—who constitute the majority of the population—bearing the brunt of these impacts due to their reliance on climate-sensitive sectors. The government has responded by formulating strategic frameworks, including the National Climate Change Response Strategy (NCCRS, 2010) and the Climate Change Act (2016), but localised implementation and uptake of adaptation measures remain uneven.

The Lower Nyando Basin (LNB), situated within the Lake Victoria catchment, exemplifies the intersection of ecological fragility and socio-economic vulnerability. Historically, the area has

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been prone to recurrent floods and droughts, but climate change has intensified the frequency and magnitude of these events, disrupting traditional livelihood systems and ecosystems (Orindi & Eriksen, 2005; Okotto et al., 2017; Swarnokar et al., 2025). Households in the basin depend primarily on subsistence agriculture and artisanal fisheries, both of which are directly threatened by environmental shocks. Moreover, intensified land use changes—including wetland conversion, deforestation, and unsustainable cultivation practices—have further degraded the resilience of the basin (Swallow et al., 2009; Mulianga & Ng'onyere, 2022). The loss of critical ecosystems such as wetlands and floodplains has not only diminished natural buffers against floods and droughts but has also jeopardised local food production and fisheries, central to household food and nutrition security (Obiero et al., 2012; Kiwango & Wolanski, 2008; Dida et al., 2020).

Although climate adaptation and mitigation strategies are increasingly promoted at national and county levels, their adoption at the community level within the LNB remains constrained by a range of barriers. Socio-economic limitations such as poverty, lack of access to credit, and low levels of education intersect with institutional weaknesses, poor governance, and limited technical capacity to restrict the effective implementation of adaptation strategies (Musyimi, 2020; Mumo, 2021). Knowledge-related barriers—including limited awareness, inadequate extension services, and insufficient integration of indigenous knowledge—further compound vulnerability, especially among marginalised groups. In contexts such as the LNB, where households rely on fragile ecosystems and have limited adaptive capacity, these barriers are particularly acute (Masese et al., 2016).

Against this backdrop, this study investigates the adoption of climate change adaptation and mitigation measures in the Lower Nyando Basin, with a focus on the barriers that constrain their effectiveness in securing household food security. Specifically, it examines the socio-demographic factors shaping adaptive capacity, the strategies households employ to cope with floods and droughts, and the systemic constraints that limit their transformative potential. By doing so, the study contributes to a deeper understanding of the interplay between climate stress, local adaptation, and food security in ecologically fragile landscapes. The insights generated aim to inform evidence-based recommendations for strengthening community resilience, aligning local adaptation strategies with Kenya's national climate policies, and contributing to broader regional and global debates on sustainable responses to climate change.

METHODOLOGY

Study Area

The research was conducted in Kadibo, Nyando, and Lower Nyakach sub-counties located within the Lower Nyando Basin (LNB) of Kisumu County, Kenya (Figure 1). The basin lies within the Lake Victoria catchment and is characterised by fragile ecosystems that are highly sensitive to climate variability. The area experiences a bimodal rainfall pattern, with long rains occurring between March and May and short rains between October and December. Annual rainfall ranges between 1,200–1,800 mm, although spatial and temporal variability has increased considerably in recent decades. Seasonal flooding during the rainy seasons is a recurrent phenomenon, often displacing households and destroying crops, while extended dry spells contribute to drought-induced crop failures and livestock stress. The soils vary from fertile alluvial deposits in the floodplains to sandy and less productive soils in the uplands, influencing crop choices and agricultural productivity.

Livelihoods in the LNB are predominantly agrarian, with subsistence farming and small-scale fishing forming the mainstay of household economies. Farmers grow maize, beans, sorghum, rice, millet, and vegetables, supplemented by livestock rearing and artisanal fisheries from rivers and wetlands.

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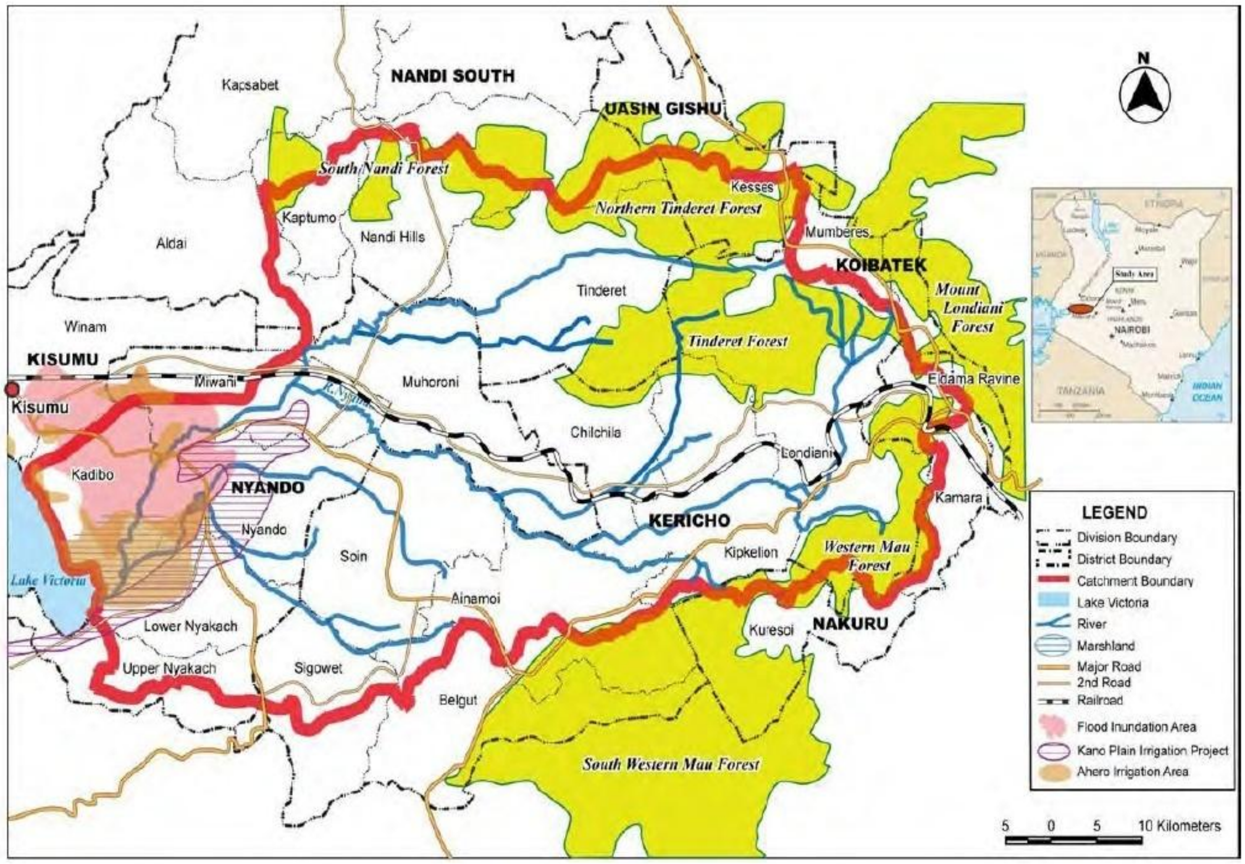
However, dependence on rain-fed agriculture and open-access fisheries makes households highly vulnerable to climate-related shocks. Rapid population growth, wetland degradation, and deforestation in the upper catchments further exacerbate exposure to floods and droughts, compounding livelihood insecurity. The selection of this area was deliberate, as it exemplifies regions in Sub-Saharan Africa where environmental fragility and socio-economic vulnerability converge to heighten the risks of food insecurity under climate change.

Figure 1: Map of the Drainage Basin of the Nyando River



Study Design

This study employed a mixed-methods cross-sectional survey design that combined quantitative and qualitative approaches to capture both statistical patterns and nuanced community perspectives. The quantitative household survey provided standardised data on socio-demographic characteristics, adaptation strategies, and food security outcomes, thereby enabling the measurement of adoption levels and the testing of associations between variables. Complementary qualitative methods—including Key Informant Interviews (KIIs) and Focus Group Discussions (FGDs)—were used to generate in-depth insights into community perceptions, institutional responses, and context-specific challenges that cannot be adequately captured through structured questionnaires alone. The integration of both approaches allowed for triangulation of findings, thereby enhancing the validity and reliability of the results while aligning with best practices in climate change and food security research (Creswell & Plano Clark, 2017).

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Target Population and Sampling

The target population consisted of households residing within the flood-prone areas of the LNB whose livelihoods are directly dependent on climate-sensitive sectors, particularly smallholder agriculture and fisheries. A sample size of 384 households was determined using Cochran's formula at a 95% confidence level and a 5% margin of error, which ensured representativeness of the population while allowing for statistical inference. After data cleaning, 378 complete household responses were retained for analysis. A multi-stage sampling approach was employed. In the first stage, sub-counties (Kadibo, Nyando, and Lower Nyakach) were purposively selected because of their high exposure to floods and droughts. In the second stage, villages within floodplain areas were identified, and households were selected using simple random sampling to minimise selection bias. To complement the household survey, purposive sampling was used to select 12 key informants—including agricultural extension officers, chiefs, community elders, and representatives of local non-governmental organisations—and 10 focus group discussions comprising 7–13 participants each. Stratification of FGDs by gender, age, and livelihood activities ensured representation of diverse voices, including women, youth, and the elderly, whose experiences of climate change and adaptation differ significantly.

Data Collection Methods

Primary data were collected through multiple instruments. Structured household questionnaires captured demographic profiles, livelihood activities, adaptation and mitigation measures, sources of food, and household-level food security. The questionnaire also included items on perceptions of floods and droughts, information access, and barriers to adopting climate-smart practices. Qualitative data were gathered through Key Informant Interviews (KIIs) with government officials, agricultural officers, local leaders, and NGO staff working in agriculture and climate adaptation. These interviews provided expert insights into institutional frameworks, policy implementation, and community-level challenges. Focus Group Discussions (FGDs) were conducted to capture collective experiences, indigenous knowledge, and community strategies in managing climate risks. Discussions followed semi-structured guides and were moderated to encourage participation while minimising dominance by a few individuals.

Secondary data were obtained from relevant government reports, scholarly publications, and institutional documents on climate change, agriculture, and food security in the Nyando Basin. These sources provided contextual background and enabled comparison of primary findings with existing literature.

Data Analysis

Data analysis followed a mixed-methods framework. Quantitative data from the household survey were coded and analysed using SPSS version 25 and STATA version 16. Descriptive statistics such as frequencies and percentages were generated to profile household characteristics and adaptation measures. Inferential statistics, including Chi-square tests and logistic regression models, were applied to examine associations between the adoption of adaptation practices and food security outcomes. Statistical significance was set at $p < 0.05$. Qualitative data from KIIs and FGDs were transcribed, coded, and analysed thematically. Emergent themes focused on perceptions of climate variability, community responses, barriers to adoption, and institutional roles. Triangulation of qualitative and quantitative results was conducted to enhance robustness, with qualitative findings providing contextual depth to statistical patterns and helping explain outliers or unexpected results. This methodological design—combining breadth from quantitative surveys with depth from qualitative insights—ensured a comprehensive understanding of how floods and droughts affect household food security in the LNB, the adaptation measures

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employed, and the systemic barriers limiting resilience.

Ethical Considerations

Ethical integrity was upheld throughout the research process. Prior to data collection, approval was obtained from relevant institutional and county authorities, including research clearance permits from the National Commission for Science, Technology, and Innovation (NACOSTI) in Kenya. Local administrative leaders were consulted to gain community entry and to ensure cultural sensitivity in the research process. Informed consent was obtained from all respondents after explaining the purpose, procedures, and potential benefits of the study. Participation was voluntary, and respondents were assured of the right to withdraw at any stage without consequence.

Confidentiality and anonymity were strictly maintained; household identifiers were removed from datasets, and only aggregate results are reported. FGDs and KIIs were conducted in safe, neutral settings to encourage open dialogue, with measures taken to minimise potential discomfort or dominance by certain individuals. Special attention was given to gender sensitivity, ensuring that women and vulnerable groups felt free to express their views. All data were stored securely and used exclusively for academic purposes. By adhering to these ethical protocols, the study ensured the protection of participants' rights, dignity, and privacy while strengthening the credibility and trustworthiness of the findings.

RESULTS

Socio-Demographic Characteristics of the Respondents

The majority of the households surveyed in the Lower Nyando Basin were male-headed (67.7%), followed by female-headed households (25.4%), those headed by children (6.3%), and a small proportion (0.5%) led by elderly caregivers supporting orphans. In most households, the husband (53.2%) played the primary role in household decision-making, while wives accounted for 44.7% and children only 2.1% (Table 1). Respondents were predominantly aged above 30 years (86.1%), and 51.4% were male, indicating balanced gender representation. Most participants (88.2%) had some level of formal education, with primary education being the most common (57.1%). In terms of residency, 68.5% had lived in the area for over 30 years, while 15.4% had resided for less than 20 years. Household sizes were generally moderate, with 70.9% of respondents living in households of 4 to 7 members, and 17.2% in households of three or fewer members. The main livelihood activity was farming (51.9%), followed by business (23.5%) and fishing (16.3%). These characteristics are detailed in Table 1.

Table 1: Socio-Demographic Characteristics of the Respondents

Demographic Characteristic	Attribute	Frequency	Percent
What is the type of household	Male headed	256	67.7
	Female headed	96	25.4
	Child headed	24	6.3
	Elderly supporting orphans	2	0.5
What is the role of the respondents in the household	Husband	199	53.2
	Wife	167	44.7
	Child	8	2.1
Age of the respondent	<18	4	1.1
	18-29	47	12.8
	30-50	176	48.1
	>50	139	38

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Demographic Characteristic	Attribute	Frequency	Percent
Gender of the respondents	Male	190	51.4
	Female	180	48.6
Marital status of the respondent	Married	303	81
	Single	7	1.9
	Widowed	64	17.1
Level of education of the respondents	None	42	11.9
	Primary	202	57.1
	Secondary	93	26.3
	College	17	4.8
How long have you lived in this sub-county	Up to 10 years	29	7.7
	11-20 years	29	7.7
	21-30 years	61	16.1
	Over 30 years	259	68.5
	Total	378	100
How many are you in this household	0-3	65	17.2
	4-7	268	70.9
	8-11	27	7.1
	12 and above	18	4.8
Primary occupation of the respondents	Farmer	230	51.9
	Fisherman	72	16.3
	Business	104	23.5
	Formal Employment	10	2.3
	Housewife	13	2.9
	Unemployed	10	2.3
	Student	4	0.9

Adaptation and Mitigation Measures Adopted

Findings from the household survey show that a high proportion of respondents in the Lower Nyando Basin (LNB) had been introduced to various climate change adaptation and mitigation strategies. These included planting of drought-resistant crops (90.6%), reintroduction of indigenous crop varieties (88.3%), fast-maturing crops (93.3%), crop diversification (85.0%), use of improved farm inputs, and capacity building through training (73.6%). These differences in adoption were statistically significant ($p < 0.0001$), as shown in Table 2.

Table 2: Climate Change Adaptation and Mitigation Measures Adopted by Residents of LNB

Adaptation and mitigation measures	Yes	No	Total	χ^2	*p*
Planting of drought-resistant crops	339 (90.6%)	35 (9.4%)	374 (100%)	67.24	0.0000
Re-introduction of indigenous crop varieties	323 (88.3%)	43 (11.7%)	366 (100%)	57.76	0.0000
Reintroduction of fast-maturing crops	349 (93.3%)	25 (6.7%)	374 (100%)	73.96	0.0000

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Adaptation and mitigation measures	Yes	No	Total	χ^2	*p*
Diversification of crops	311 (85%)	55 (15%)	366 (100%)	49.0	0.0000
Use of improved farm inputs and empowerment through education and training	273 (73.6%)	98 (26.4%)	371 (100%)	23.04	0.0000
Water management infrastructure (pans, dams, reservoirs)	271 (72.5%)	103 (27.5%)	374 (100%)	20.26	0.0000
Watershed management (tree planting, agro-forestry, stream bank rehabilitation, soil conservation, runoff and drainage management, etc.)	286 (77.1%)	85 (22.9%)	371 (100%)	29.16	0.0000
Irrigated agriculture	349 (95.4%)	17 (4.6%)	366 (100%)	81.0	0.0000
Rain-fed agriculture	310 (86.4%)	49 (13.6%)	359 (100%)	51.84	0.0000
Predict and manage responses to floods and drought	286 (78.8%)	77 (21.2%)	363 (100%)	33.64	0.0000

Qualitative data from key informant interviews (KIIs) and focus group discussions (FGDs) corroborated these findings. During flood periods, farmers adopted measures such as planting flood-tolerant varieties, raising planting beds, using canals and drainage systems, and applying farm inputs strategically. During drought periods, respondents employed early planting, drought-resistant varieties, irrigation, and trench digging for moisture conservation.

Adaptation Measures to Improve Food Security

When asked about specific adaptation strategies adopted to improve food security, most respondents confirmed their uptake of key practices, notably planting of drought-resistant crops (99.2%), fast-maturing crops (98.9%), indigenous varieties (96%), and irrigation (96.8%). All measures were significantly associated with improved food security ($p < 0.0001$), as presented in Table 3.

Table 3: Adaptation Strategies Adopted to Improve Food Security in LNB *(n ≈ 370)*

Activity	Yes	No	Total	χ^2	*p*
Planting of drought-resistant crops	367 (99.2%)	3 (0.8%)	370 (100%)	96.04	0.0001
Reintroduction of indigenous crop varieties	356 (96%)	15 (4%)	371 (100%)	84.64	0.0001
Reintroduction of fast-maturing crops	369 (98.9%)	4 (1.1%)	373 (100%)	96.04	0.0001
Diversification of crops	322 (89.7%)	37 (10.3%)	359 (100%)	64.0	0.0001
Use of improved farm inputs and empowerment through education and training	344 (94.8%)	19 (5.2%)	363 (100%)	81.0	0.0001
Construction and management of water infrastructure (pans, dams, reservoirs)	327 (91.1%)	32 (8.9%)	359 (100%)	67.24	0.0001
	330	29	359	70.56	0.0001

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Activity	Yes	No	Total	χ^2	*p*
Watershed management through tree planting, agroforestry, stream bank rehabilitation, soil conservation, runoff and drainage management, etc.	(91.9%)	(8.1%)	(100%)		
Irrigated agriculture	358	12	370	88.36	0.0001
	(96.8%)	(3.2%)	(100%)		
Rain-fed agriculture	309	43	352	57.76	0.0001
	(87.8%)	(12.2%)	(100%)		
Predict and manage responses to floods and drought.	319	42	361	57.76	0.0001
	(88.4%)	(11.6%)	(100%)		

Community Perception on Implementation and Involvement

Despite the high uptake of adaptation practices, implementation remains uneven. A majority of respondents (53.7%) believed that information on adaptation and mitigation measures had reached the wider community, though only 38.1% affirmed that the information was clearly understood. Notably, 66.8% of respondents reported being involved in designing these measures, as shown in Table 4.

Table 4: Community Views on Implementations of the Measures

Statement	Attribute	Frequency	Percent	χ^2	*P*
Do you think the information disseminated has reached the entire population who were supposed to implement it?	Strongly agree	79	20.9	25.2	0.0001
	Agree	124	32.8		
	Not sure	63	16.7		
	Disagree	99	26.2		
	Strongly disagree	13	3.4		
	Total	**378**	**100.0**		
Do you think information on the climate change adaptation and mitigation measures passed to the community was clearly understood.	Strongly agree	54	14.3	27.95	0.0001
	Agree	90	23.8		
	Not sure	100	26.5		
	Disagree	123	32.5		
	Strongly disagree	11	2.9		
	Total	**378**	**100.0**		
Was the community involved in coming up with the climate change adaptation and mitigation measures?	Yes	247	66.8	11.56	0.0001
	No	123	33.2		
	Total	**370**	**100.0**		

Communication and Awareness Approaches

The main avenues used to inform and involve communities were through local chiefs (38.5%) and radio programs (35.4%). Other methods, such as workshops, farmer field days, and government extension services, were less frequently used. The distribution of outreach methods is illustrated in Figure 2.

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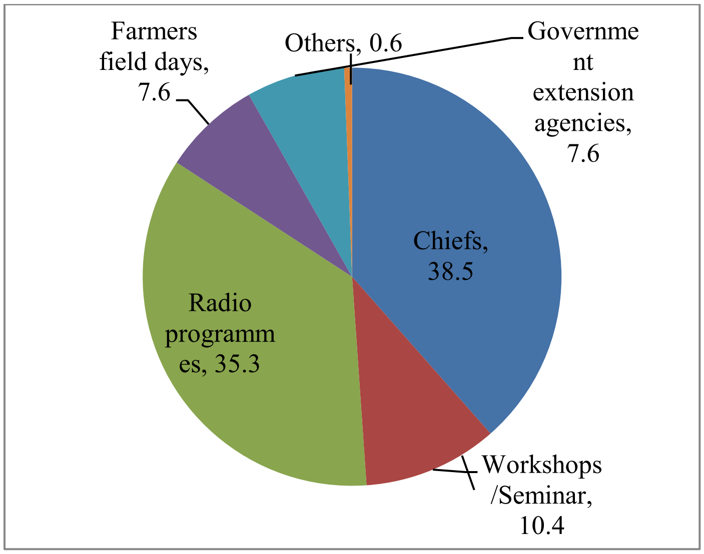
Figure 2: Approaches Used to Engage Communities on Adaptation and Mitigation Measures



Challenges to the Adoption of Adaptation and Mitigation Measures for Food Crops

Key informant interviews and focus group discussions showed that the main challenges faced in the adoption of adaptation and mitigation measures in the production of vegetables during the flood season included vegetables being swept away (36.3%), while during the drought, this included drying up of vegetables (36.9%). Both floods and droughts also resulted in low maize yields. Millet was also affected by a lack of adequate resources during floods, while drought led to destruction by birds and invasion by pests and diseases. Sorghum was swept away during the floods, and this resulted in low yields in the drought period. Rice prices went up during the flood season since a lot was swept away, while during the drought season, irrigation was expensive (19.7%), and this resulted in low yields. Beans were swept away by floods, while drought resulted in low yields. Lastly, caring for green grams was difficult during the floods because of too much water, while drought resulted in withering. Focus group discussions also revealed that a lack of finances to practice the adaptation strategies, for example, irrigation, and a lack of skills to carry out the strategies were also limiting factors to practising the adaptation strategies.

DISCUSSION

The study findings provide critical insights into the adaptation and mitigation measures adopted in the Lower Nyando Basin (LNB) and the challenges households face in sustaining food security under recurrent floods and droughts. While the results demonstrate high awareness and adoption of climate-smart strategies, the persistence of food insecurity reveals structural, institutional, and economic barriers that limit their effectiveness.

The socio-demographic profile of respondents reveals that the majority of households are male-headed, with relatively large family sizes and modest education levels. Farming was the dominant livelihood, supplemented by fishing and business. These characteristics are important in shaping adaptive capacity. Education, for instance, plays a critical role in awareness and interpretation of climate information; yet in the LNB, most respondents had only attained primary education, which may constrain their ability to implement complex adaptation practices. Similar findings were reported by Tazeze et al. (2012) in Ethiopia and Juana et al. (2013) in South Africa, where higher education levels were positively correlated with the adoption of climate change adaptation practices. Household size also influences vulnerability, as

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larger families face higher food demands while having limited resources for adaptation (Legesse et al., 2013). Thus, socio-demographic characteristics in the LNB reinforce the dual vulnerability to climatic stress and economic limitations.

The results show that households in the LNB have adopted a broad set of strategies, including drought-resistant and early-maturing crops, reintroduction of indigenous varieties, crop diversification, irrigation, water harvesting, and watershed management. Adoption levels for most strategies were above 70%, with irrigation and drought-resistant crops reaching over 90%. These findings indicate high levels of awareness and willingness to adapt, aligning with evidence from other parts of Kenya where farmers have embraced climate-smart agriculture to mitigate the effects of rainfall variability (Mutunga et al., 2017; Muriuki et al., 2021). The emphasis on indigenous varieties is particularly noteworthy, as these crops often possess traits that enhance resilience to local climatic and ecological conditions (Asfaw et al., 2015). Similar to studies in West Africa (Sofoluwe et al., 2011; Akponikpè et al., 2010), diversification also emerged as a dominant strategy, reflecting risk-spreading behaviour among households vulnerable to climate extremes.

Respondents reported that strategies such as planting drought-resistant crops, irrigation, and diversification were strongly associated with improvements in household food security. This was consistent with the Household Food Insecurity Access Scale (HFIAS) findings, where households employing multiple strategies experienced reduced anxiety over food shortages. The positive relationship between adaptation and food security is consistent with findings from Ethiopia and Tanzania, where households adopting multiple climate-smart practices reported more stable food access and reduced hunger periods (Wondimagegn et al., 2021; Tessema et al., 2020). However, in the LNB, food adequacy and accessibility still varied significantly between flood and drought periods, with households experiencing shortages for up to four months. This underscores the partial effectiveness of adaptation strategies in buffering against extreme events. Dawson et al. (2016) similarly noted that while adaptation reduces immediate losses, it rarely eliminates vulnerability where climatic shocks are recurrent and severe.

While most households reported exposure to adaptation information, only 38.1% clearly understood the messages. Chiefs' barazas and radio programs were the most trusted sources, whereas extension services and farmer field schools were underutilised. This points to a gap between dissemination and comprehension of climate information. Studies by Mersha & van Laerhoven (2016) highlight that information clarity and participatory engagement are as important as the content itself in determining adoption outcomes. In the LNB, limited involvement of marginalised groups in planning processes reflects governance gaps that constrain inclusive adaptation. This finding echoes Nyakundi et al. (2010), who observed that exclusion from planning heightens vulnerability in flood-prone Kenyan communities.

Despite high adoption rates, several barriers continue to limit the effectiveness of adaptation measures. Financial constraints were the most reported, particularly in relation to irrigation, which was described as prohibitively expensive by 19.7% of respondents. This corroborates Khan et al. (2019), who found that the high costs of water-based interventions restrict adoption among smallholders in arid regions. Crop losses due to floods and droughts were another critical challenge; vegetables were swept away during floods, maize yields declined under drought stress, and sorghum and millet faced pest attacks and bird damage. These findings align with earlier studies by Mastrorillo et al. (2016), who emphasised that seed selection, early planting, and land management are critical in reducing such losses, yet they require technical and financial support to be effective. Knowledge and skill gaps were also evident, with

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farmers acknowledging limited technical expertise in advanced soil and water conservation measures. This reinforces the need for capacity building, as noted by Nkiaka et al. (2019), who argued that training and extension are pivotal for enabling the transition from awareness to effective action.

Overall, the results demonstrate that adaptation in the LNB is both widespread and deeply constrained. Households are aware of the risks and actively adopt multiple strategies, yet their capacity to withstand floods and droughts remains inadequate. The findings affirm that adaptation is not only a technical challenge but also a socio-economic and institutional one. Unless systemic barriers—particularly financial exclusion, limited extension services, and weak participatory governance—are addressed, adaptation will remain incremental and insufficient to secure food security in the Basin. Strengthening climate communication, improving access to affordable technologies, and embedding community voices in planning processes are therefore essential pathways to enhance resilience.

CONCLUSION AND POLICY IMPLICATION

This study provides compelling evidence that while households in the Lower Nyando Basin (LNB) have widely adopted climate change adaptation and mitigation measures, food insecurity persists due to recurrent floods, droughts, and entrenched systemic barriers. The socio-demographic profile of respondents—characterised by male-dominated households, modest education levels, and dependence on subsistence farming—reveals limited adaptive capacity. Although adoption of strategies such as drought-resistant and early-maturing crop varieties, crop diversification, indigenous seed reintroduction, irrigation, and watershed management was reported at high levels, food adequacy and accessibility remained unstable, with households experiencing shortages for up to four months annually. These findings demonstrate that adaptation in the Basin has largely been incremental, buffering immediate shocks but failing to secure long-term resilience. Moreover, the study revealed that while awareness of adaptation messages was relatively high, comprehension remained low, with only 38.1% of households reporting a clear understanding. Reliance on local barazas and radio programs as dissemination channels limited the technical depth and inclusivity of climate information, thereby weakening its impact. Financial exclusion, particularly the high costs associated with irrigation, compounded by crop losses during extreme events and knowledge gaps in advanced soil and water conservation, further constrained effective adaptation. Taken together, the results affirm that although local communities are proactive in adopting coping strategies, structural, institutional, and economic barriers continue to undermine their transformative potential. Unless these barriers are addressed, the resilience of households in the Basin will remain precarious under intensifying climate variability.

To translate widespread awareness into effective and transformative resilience, there is an urgent need to address the systemic barriers limiting the potential of local adaptation strategies in the LNB. Improving financial access for smallholder farmers through targeted credit schemes, cooperative financing, and subsidies for irrigation technologies is critical in enabling broader and sustained adoption of climate-smart agriculture. Strengthening extension services and climate communication beyond traditional channels such as barazas and radio will also be essential to bridge the gap between awareness and comprehension, with farmer field schools, demonstration plots, and digital platforms providing more participatory and inclusive learning opportunities. Investment in climate-resilient infrastructure, particularly affordable irrigation systems, flood-control structures, and watershed rehabilitation, is equally crucial for stabilising food production across flood and drought seasons. Further, promoting wider adoption of indigenous crop varieties and livelihood diversification, including aquaculture and integrated farming systems, can spread risk and enhance both nutrition and income security. Equally important is the need to embed local voices—especially those of women and marginalised groups—into adaptation planning to ensure inclusive governance and equitable access to resources. Finally, fisheries must be mainstreamed into climate adaptation frameworks through sustainable management practices and aquaculture promotion to safeguard nutritional security. Aligning these localised strategies with national policy frameworks such as Kenya's Climate Change Act (2016) and the National Climate Change Response Strategy, as well as global commitments under the Sustainable Development Goals and Agenda 2063, will be essential in bridging the gap between grassroots adaptation and broader development priorities. By integrating financial, institutional, and infrastructural support with local adaptive practices, adaptation in the LNB can shift from short-term coping mechanisms to transformative resilience capable of securing sustainable food systems under climate change.

Limitations of the Study

While this study provides critical insights into adaptation and food security dynamics in the LNB, it was limited by its cross-sectional design, which constrains causal inference, and its reliance on self-reported data, which may be subject to recall bias. Future research should employ longitudinal designs to capture adaptation trajectories over time, integrate biophysical assessments of climate impacts on agriculture and fisheries, and explore the role of gender, youth, and social networks in shaping adaptive capacity. Such approaches would generate deeper insights into the long-term effectiveness and equity of adaptation strategies in climate-vulnerable regions.

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