EVALUATING ECOSYSTEM-BASED ADAPTATION STRATEGIES IN MITIGATING CLIMATE CHANGE VULNERABILITIES AMONG SMALLHOLDER MAIZE FARMERS IN MOIBEN SUB-COUNTY, UASIN GISHU COUNTY, KENYA

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A Thesis Submitted to the Institute of Postgraduate Studies of Kabarak University in Partial Fulfillment of the Requirements for the Award of Master of Science in Environmental Science Degree

KABARAK UNIVERSITY

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The thesis entitled **"Evaluating the Ecosystem-Based Adaptation Strategies in Mitigating Climate Change Vulnerabilities among Smallholder Farmers in Moiben Sub-County, Uasingishu County, Kenya,''** written by **Abigael Jepkorir Kibet,** is presented to the Institute of Postgraduate Studies of Kabarak University. We have reviewed the thesis and recommend it be accepted in partial fulfilment of the requirements for the award of the Master of Science in Environmental Science Degree.

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DEDICATION

I dedicate this thesis to my family and friends for their support and Love.

ABSTRACT

In Moiben Sub-County, climate change poses significant challenges, particularly impacting the agricultural community. As a major agricultural hub in Kenya, Uasin Gishu County experiences shifting precipitation patterns, prolonged droughts, and erratic rainfall, adversely affecting crop yields and livestock. Smallholder maize farmers, who heavily depend on rain-fed agriculture, face reduced productivity, increased vulnerability to pests and diseases, and heightened water scarcity. The main objective of the study was to evaluate ecosystem-based adaptation strategies in mitigating climate change vulnerabilities among smallholder maize farmers in Moiben Sub-County, Uasin Gishu County. The study was guided by the following specific objectives: to assess the current climate change vulnerabilities in Moiben Sub-County, Kenya; to identify and evaluate existing ecosystem-based adaptation strategies implemented among smallholder maize farmers in Moiben Sub-County; to analyze the effectiveness of these ecosystem-based adaptation strategies in improving climate resilience and reducing vulnerability among smallholder maize farmers in Moiben Sub-County. The study was guided by Resilience Theory. The study used a mixed-methods research design. The total target population was 7536 respondents, including smallholder maize farmers, local government officials, and community leaders. The sample size of 390 respondents was determined using the Krejcie and Morgan formulae. The study used systematic random sampling to select smallholder maize farmers (residents) and a purposive sampling technique to select the key informants. This study used questionnaires for farmers to collect quantitative data, interviews with government officials, and focus group discussions with community leaders and maize farmers to collect qualitative data. Quantitative data from filled questionnaires were entered into SPSS version 24 for descriptive statistical analysis. Qualitative data from interviews and focus group discussions were analyzed using thematic analysis to gain insights into respondents' perspectives and perceptions. Quantitative data were analyzed using descriptive statistics in the form of means, standard deviations, and percentages, and presented in tables and figures. Inferential statistics, including Pearson's correlation and multiple linear regression, were conducted at a 0.05 level of significance to determine the relationships and predictive power of the study variables. The analyzed data were presented in the form of tables and charts. Study findings indicate that there was a positive and statistically significant relationship between ecosystem-based adaptation strategies implemented and climate change vulnerabilities ($\beta1 = .227$, $p = .001$). There was a statistically significant effect of rate of adoption of the ecosystem-based adaptation strategies on climate change vulnerabilities (β_2=.265, p=.000), ecosystem-based adaptation strategies have a positive significant effect on climate change vulnerabilities (β_3=.359, p=.000). The study concluded that small holder maize farmers in Moiben Sub-County have embraced positively a number of ecosystem-based adaptation (EbA) practices that include soil conservation, agroforestry, rain water harvesting, as well as crop diversification practices, that have led to positive agricultural sustainability and decreased climate change risks. The research suggests that agricultural stakeholders and county agricultural departments can improve the adoption of EbA through improvement of extension services. The research recommends that further evaluation on scalability of EbA strategies, contextual effectiveness and adoption barriers in other farming systems should be carried out in other counties and agro-ecological zones in Kenya.

Keywords: *Ecosystem-Based, Adaptation Strategies, Mitigating, Climate Change, Vulnerabilities, Smallholder Maize Farmers, Moiben Sub-County.*

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CONCEPTUAL OPERATIONAL DEFINITION OF TERMS

Climate Change Vulnerabilities refer to the degree to which a system (smallholder maize farmers) is susceptible to, or unable to cope with, the adverse effects of climate change.

Ecosystem-Based Adaptation (EbA) involves the use of biodiversity and ecosystems to help smallholder maize farmers adapt to the adverse impacts of climate change. It focuses on the sustainable management and restoration of ecosystems to provide climate resilience and reduce vulnerability.

Ecosystem-Based Adaptation Strategies involve the active participation, involvement, and collaboration of smallholder maize farmers in decision-making processes, projects, or initiatives that affect them. It emphasizes inclusivity, dialogue, and cooperation to ensure that diverse perspectives are considered and that the community's needs and concerns are addressed.

Mitigating Climate Change Vulnerabilities involves implementing strategies to reduce or prevent the impacts of climate change on the ecosystems and Livelihoods (smallholder maize farmers). The goal is to enhance resilience and promote sustainable practices to limit the extent and severity of climate-related consequences.

Natural Ecosystems play a crucial role in maintaining ecological balance and providing essential services to both the environment and smallholder maize farmers. These ecosystems include forests, wetlands, oceans, and various terrestrial habitats.

Smallholder Maize Farmers are small-scale producers who cultivate maize on a limited scale, typically on farms smaller than 10 hectares. They are characterized by farming on a family-owned enterprise, often relying on relatives' labor to meet production needs

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Climate change is a pressing global challenge with far-reaching impacts on ecosystem sustainability (Garg, 2023). The rise in global temperatures, altered precipitation patterns, and increased frequency of extreme weather events pose substantial risks to communities and ecosystems worldwide (Raihan, 2023). In response to these challenges, the concept of ecosystem-based adaptation (EbA) has gained prominence as a nature-based approach to enhance resilience. The global discourse on climate change resilience has shifted towards integrating nature-based solutions, acknowledging that healthy ecosystems can act as buffers against climate-induced impacts (Scarano, 2019). Protecting and restoring natural habitats, such as forests, wetlands, and mangroves, can act as buffers against extreme weather events and provide essential services like water regulation (Muthee et al., 2021).

Ecosystem-based adaptation is a strategy that uses biodiversity and ecosystem services as part of an overall approach to help people adapt to the adverse effects of climate change. This strategy recognizes the importance of healthy ecosystems in increasing resilience and reducing vulnerability to climate change impacts (Donatti, Harvey, et al., 2020). Unlike traditional or "hard" engineering approaches, which often involve building infrastructure, ecosystem-based adaptation focuses on the sustainable management and restoration of ecosystems. Preserving and promoting biodiversity, as diverse ecosystems tend to be more resilient to change. Biodiversity provides a range of options for adaptation, as different species may respond differently to climate variation (Donatti et al., 2020).

Ecosystem-based Adaptation offers a valuable yet underutilized approach to climate change adaptation, complementing traditional actions such as infrastructure development, community-based adaptation, and integrated natural resource management (Omwenga, 2019). Baig, Rizvi, et al., (2016) observes that although there are cases where hard engineering (Hard engineering approaches in environmental ecosystem conservation involve the use of physical structures or technologies to manage and protect ecosystems) solutions for adaptation are necessary, there are many instances where nature-based approaches provide cost effective and/or economically beneficial, as well as longer term solutions, with a range of co-benefits in terms of the goods and services provided by ecosystems. Triyanti and Chu (2018) observe that interventions in policy-making, planning, institutional capacity building, the implementation of ecosystem transformation actions, and the management of residual effects are key principles of a successful Ecosystem-based adaptation strategy.

In Europe, over 50% of countries had developed national adaptation strategies as of 2020, yet there is no mention of how these strategies are performing or of the tangible outcomes (Fuchs & Noebel, 2022). In Italy, the reliance on data from 2020 may not accurately reflect current trends or progress (Davies, 2021). The absence of a critical analysis of the impact and effectiveness of these strategies, as well as their integration with other adaptation measures, leaves a gap in understanding the holistic contribution of EbA to climate resilience (Reid et al., 2019). Addressing these gaps with up-to-date data, diverse geographic examples, and comprehensive impact assessments would enhance global understanding of EbA strategies (Raihan, 2023).

In the realm of international climate policy, there is growing recognition that ecosystem-based approaches "can provide cost-effective, proven, and sustainable solutions, contributing to and complementing other national and regional adaptation strategies"

(Nalau & Becken, 2018). The foundation of Ecosystem-based Adaptation (EbA) lies in the understanding that adaptation strategies must simultaneously address both ecosystems and livelihoods, recognizing their critical interdependence and the shared vulnerability they face due to climate change (Wolf, Pham, Matthews, & Bubeck, 2021). Prominent global organizations, including the International Union for Conservation of Nature (IUCN) and the United Nations Environment Programme – World Conservation Monitoring Centre (UNEP-WCMC), are actively engaged in efforts to effectively integrate EbA into the implementation of the Paris Agreement (Wolf et al., 2021).

Ecosystem-based adaptation (EbA) is a heterogeneous approach that draws on various interconnected factors to enhance the resilience of both ecosystems and human communities in the face of climate change (Malhi et al., 2020). One fundamental factor is biodiversity conservation. The relationship here is intricate, as diverse ecosystems tend to exhibit greater adaptability and resilience (Manrique, 2023). EbA strategies prioritize the protection of biodiversity, recognizing the role of different species in maintaining ecosystem functions and ecological balance (Karki et al., 2021). Safeguarding biodiversity, EbA contributes to the overall stability of ecosystems and their capacity to withstand climate-induced stressors (Chaudhary, Adhikari, et al., 2021).

Sustainable ecosystem management is another critical factor integral to EbA. This involves practices that ensure the long-term health and functionality of ecosystems (Muthee et al., 2021). The relationship lies in the acknowledgment that sustainable management not only preserves ecosystem services but also helps ecosystems adapt to changing environmental conditions (Castaldo et al., 2021). EbA strategies, by promoting sustainable resource use and preventing degradation, foster ecosystems that can provide essential services, such as water purification, soil fertility, and carbon sequestration, crucial for climate resilience (Ariza-Montobbio & Cuvi, 2020).

Ecosystem-based adaptation strategies and local knowledge form a third pivotal factor in EbA. The relationship is participatory, involving collaboration with local communities in planning and implementing adaptation measures (Nalau, Becken et al., 2018). EbA recognizes that communities, often on the front lines of climate impacts, possess valuable traditional knowledge about their environments. Involving local stakeholders, EbA not only ensures the relevance and effectiveness of adaptation strategies but also strengthens social cohesion and empowers communities to take an active role in building their resilience to climate change. These factors collectively underscore the holistic, integrated nature of EbA, emphasizing the interconnected relationships that are essential to effective climate adaptation (Vasseur, 2021).

In England, climate change impacts are evident in rising temperatures, changing precipitation patterns, and increased frequency of extreme weather events (Seneviratne, Zhang, et al., 2021). The European continent has witnessed disruptions in agriculture, altered ecosystems, and threats to water resources (Fowler, Ali, et al.,2021). Ecosystem-based adaptation (EbA) strategies have gained traction as a means to address these challenges. For example, European countries have implemented projects focused on reforestation, wetland restoration, and sustainable land management to enhance ecosystem resilience (Keesstra et al., 2018). According to the European Environment Agency, these initiatives contribute to biodiversity conservation and carbon sequestration, showcasing the potential effectiveness of EbA strategies in mitigating climate change vulnerabilities in the region (Kumar, 2022).

China, as the world's largest emitter of greenhouse gases, faces complex challenges in addressing climate change. The country experiences extreme weather events, water scarcity, and disruptions to agriculture (Wang & Azam, 2024). China has integrated EbA into its national policies, emphasizing afforestation, ecological restoration, and sustainable urban planning. Statistics from the National Climate Change Assessment Report (2019) indicate that China has allocated significant financial resources to climate adaptation projects, including those focusing on ecosystem protection. Statistical evidence from the National Forestry and Grassland Administration indicates that China's afforestation efforts have increased forest coverage, contributing to carbon sequestration and enhanced ecosystem services (Cai, Zhang, et al., 2021).

Sub-Saharan Africa is particularly vulnerable to the impacts of climate change due to its dependence on rain-fed agriculture, high exposure to extreme weather events, and limited adaptive capacity (Ayanlade et al., 2022). The region faces challenges such as desertification, water scarcity, and disruptions to agricultural productivity (Kalimba & Culas, 2020). African countries are increasingly turning to EbA strategies to build ecosystem and community resilience (Armani et al., 2022). Ecosystems in Sub-Saharan Africa provide critical services, including water regulation, maintenance of soil fertility, and biodiversity conservation. These services are fundamental to the region's socio-economic development. The implementation of EbA strategies in Sub-Saharan Africa involves not only adapting to climate change but also addressing broader issues such as poverty reduction and sustainable resource management (Berhanu & Wolde, 2019).

In South Africa, climate change impacts are pronounced, affecting vulnerable communities and ecosystems. The country faces challenges such as prolonged droughts, heatwaves, and increased frequency of wildfires (Armani et al., 2022). South Africa has implemented EbA strategies, including water management projects, sustainable agriculture practices, and community-based conservation initiatives (Swanepoel & Sauka, 2019). The South African Weather Service indicates shifts in precipitation patterns and temperature extremes (Van Der Walt & Fitchett, 2022). The National Climate Change Adaptation Strategy for South Africa highlights the importance of ecosystem-based adaptation in addressing these challenges (Busayo, Kalumba, et al., 2022). Statistics from the South African National Biodiversity Institute (SANBI) indicate ongoing efforts to incorporate EbA into land-use planning (Goodbrand, Scholes, & Vogel, 2019).

Namibia, characterized by arid and semi-arid landscapes, is highly susceptible to the impacts of climate change, including desertification and water scarcity. The country has embraced EbA measures such as sustainable land management and community-based adaptation projects (Ruppel-Schlichting, 2022). According to data from the Namibia Statistics Agency, rainfall patterns and temperatures are changing across various regions (Busayo et al., 2022). The Namibian National Climate Change Strategy emphasizes the significance of ecosystem-based approaches to enhance resilience (Kalimba & Culas, 2020). According to the United Nations Framework Convention on Climate Change (UNFCCC), Namibia has initiated projects focusing on sustainable land management and community-based adaptation (Nikodemus, Hájek, Ndeinoma, & Purwestri, 2022).

Ethiopia, with its diverse climatic zones, faces challenges such as unpredictable rainfall, land degradation, and threats to agriculture. The country has implemented EbA strategies, including watershed management, reforestation, and sustainable agricultural practices (Seddon, Chausson, et al., 2020). The Central Statistical Agency of Ethiopia indicates trends in land-use change and shifts in agricultural productivity (Betru, Tolera, et al., 2019). The country has integrated ecosystem-based adaptation into its climate resilience initiatives, as reflected in its Climate Resilient Green Economy Strategy. According to the Global Environment Facility (GEF), Ethiopia has received funding for projects aimed at sustainable land management and biodiversity conservation (Walz et al., 2021).

In Kenya, climate change poses a significant threat to sectors such as agriculture, water resources, and biodiversity. The country has experienced shifts in precipitation patterns, prolonged droughts, and increased frequency of extreme weather events (Seneviratne et al., 2021). Kenya's diverse ecosystems, ranging from arid and semi-arid lands to mountainous regions, offer a unique context for studying the effectiveness of EbA (Marigi, 2018). The country has implemented projects focused on restoring degraded landscapes, promoting agroforestry, and enhancing community-based conservation initiatives (Seddon et al., 2020). Evaluating the outcomes of these initiatives in Kenya provides valuable insights into the scalability and adaptability of EbA strategies within specific national contexts.

Uasin Gishu County in Kenya is known for its agricultural importance, but climate change poses risks to crop yields and water availability. The County's Climate Change Action Plan emphasizes the integration of ecosystem-based adaptation strategies to enhance the resilience of agricultural systems (Biwott, 2023). The county has implemented EbA strategies, such as agroforestry and soil conservation practices, but their effectiveness in reducing climate change vulnerabilities among smallholder farmers remains uncertain due to limited resources, inconsistent adoption rates, and the lack of long-term monitoring and evaluation mechanisms (Yatich, 2023).

Smallholder maize farmers in Moiben Sub-County face various climate change vulnerabilities that impact their agricultural activities and livelihoods (Busolo, Koech & Wemali, 2023). These risks include increased food insecurity, poverty, loss of livelihoods, and vulnerability to climate variability such as droughts and floods. The reliance of smallholder farming on rainfall makes them particularly susceptible to changes in weather patterns (Kosgei & Kipkorir, 2021). Climate change scenarios demand adaptation to changing water availability, climatic instability, and extreme weather events. Prolonged droughts can lead to famine, affecting vulnerable groups like the elderly, women, and children. Non-climatic factors, such as population displacement, migration to towns, and crop damage, further compound the impacts of climate change on smallholder maize farmers (Murgor, 2021).

Despite the global recognition and growing implementation of ecosystem-based adaptation (EbA) strategies to bolster resilience against climate change, several notable research gaps remain. First, there is a lack of localized studies that assess specific climate change vulnerabilities faced by smallholder maize farmers, such as those in Moiben Sub-County, Kenya (Ounah, 2024). Current literature focuses broadly on global and continental scales, which may not capture the unique challenges and adaptation needs of these farmers. Second, while the effectiveness of EbA strategies is often highlighted, detailed evaluations of specific local practices such as agroforestry, conservation agriculture, wetland restoration, and sustainable water management are sparse (Gathogo, 2021).

This gap points to the need for an in-depth evaluation of the specific EbA strategies currently employed by these farmers to understand their applicability and adoption rates. Lastly, empirical studies measuring the tangible outcomes and effectiveness of EbA strategies in reducing climate vulnerabilities remain limited (Wandaka, 2020). Therefore, comprehensive impact assessments that analyze the success of these strategies in enhancing crop yields, soil health, and overall farm productivity are essential. Addressing these gaps through targeted research objectives will provide valuable insights into the practical application and effectiveness of EbA in specific, vulnerable regions, such as Moiben Sub-County, thereby contributing to the broader discourse on climate adaptation.

1.2 Statement of the Problem

In Moiben Sub-County, climate change presents severe challenges, particularly for the agricultural sector, which is vital to the region's economy. Smallholder maize farmers, who rely heavily on rain-fed agriculture, are increasingly vulnerable to shifting precipitation patterns, prolonged droughts, and erratic rainfall. These climatic changes lead to reduced crop yields, increased susceptibility to pests and diseases, and greater water scarcity, all of which contribute to economic losses and food insecurity. Although Ecosystem-based Adaptation (EbA) strategies, such as agroforestry and soil conservation, have been recognized in regional climate policy frameworks, there is a significant gap in understanding their actual effectiveness, success factors, and limitations in local contexts, such as Moiben Sub-County.

This study aims to fill this gap by thoroughly evaluating the effectiveness of EbA strategies in mitigating climate change vulnerabilities among smallholder maize farmers in Moiben Sub-County. In recent years, maize yields in Uasin Gishu County have declined by between 20–30% during prolonged droughts and by nearly 15% due to erratic rainfall patterns and pest infestations (Kosgei & Kipkorir, 2021). Although EbA strategies such as agroforestry, terracing, and water harvesting have been introduced, their adoption remains inconsistent, with uptake levels estimated at 25–35% among maize farmers (Busolo, Koech & Wemali, 2023). Moreover, while some farmers report yields improving by up to 20% when soil conservation and water harvesting are practiced**,** others experience little or no benefit due to poor implementation, limited extension support, or resource constraints.

This variation raises critical questions on the actual effectiveness of EbA strategies in improving both the quantity and quality of maize yields. By systematically assessing adoption rates, outcomes, and farmer experiences, this study seeks to provide evidence-based insights on whether current EbA strategies are truly mitigating climate-related vulnerabilities and how they can be optimized for greater impact.

1.3 Purpose of the Study

The main objective of the study was to evaluate ecosystem-based adaptation strategies in mitigating climate change vulnerabilities among smallholder maize farmers in Moiben Sub-County, Uasin Gishu County, Kenya.

1.4 Objectives of the Study

The specific objectives guiding the study were;

i. The study evaluated the existing ecosystem-based adaptation strategies implemented among smallholder maize farmers in Moiben Sub-County.
ii. The study assessed the rate of adoption of the ecosystem-based adaptation strategies among smallholder maize farmers in Moiben Sub-County
iii. The study analyzed the perceived effectiveness of the existing ecosystem-based adaptation strategies in reducing climate change vulnerability among smallholder maize farmers in Moiben Sub-County

1.5 Research Questions

i. What were the ecosystem-based adaptation strategies currently implemented among smallholder maize farmers in Moiben Sub-County?
ii. What was the rate of adoption of ecosystem-based adaptation strategies among smallholder maize farmers in Moiben Sub-County?
iii. How effective were the perceived existing ecosystem-based adaptation strategies in reducing climate change vulnerability among smallholder maize farmers in Moiben Sub-County?

1.6 Research Hypotheses

H_{01}: There are no significant ecosystem-based adaptation strategies implemented by smallholder maize farmers to mitigate climate change vulnerabilities in the study area.

H_{02}: There is no significant adoption of ecosystem-based adaptation strategies among smallholder maize farmers in the study area.

H_{03}: There is no significant effectiveness of ecosystem-based adaptation strategies in reducing climate change vulnerability among smallholder maize farmers in the study area.

1.7 Justification of the Study

Climate change continues to pose significant threats globally; understanding the efficacy of nature-based solutions is essential for informing sustainable, resilient adaptation measures. Ecosystem-based adaptation (EbA), which relies on the conservation and restoration of natural ecosystems, offers a promising alternative to traditional engineering approaches. Investigating its effectiveness provides crucial insights into whether such strategies can substantially reduce the vulnerabilities of smallholder farmers.

Secondly, this study is justified by the urgent need to address declining maize yields in Kenya's breadbasket counties. In Uasin Gishu County, maize production has fallen by between 20–30% during drought years and by nearly 15% due to erratic rainfall and pest invasions (Kosgei & Kipkorir, 2021; Biwott, 2023). Although EbA strategies such as agroforestry, terracing, and rainwater harvesting have been promoted, their adoption rates remain low, averaging only 25–35% among maize farmers (Busolo, Koech & Wemali, 2023). This study therefore provides empirical evidence on whether these strategies are translating into tangible yield improvements in Moiben Sub-County, where farming livelihoods are highly vulnerable to climate variability.

Thirdly, the research is justified by the potential cost-effectiveness and co-benefits of EbA compared to conventional methods. By assessing yield outcomes, soil health, and farmer perceptions, the study provides policymakers and development practitioners with valuable evidence on the long-term benefits of investing in ecosystem-based solutions that enhance both productivity and resilience.

Finally, this study addresses the knowledge gap on region-specific outcomes of EbA adoption. While global studies have shown positive impacts of EbA, limited empirical evidence exists on its localized performance in Kenya’s maize-growing regions. The findings will provide targeted recommendations to improve adoption rates, optimize implementation, and guide inclusive climate adaptation policies that align with Kenya’s national strategies for food security and climate resilience.

1.8 Scope of the Study

The study focused on smallholder maize farmers because they form the backbone of the local economy and have livelihoods closely tied to climatic conditions. As primary contributors to maize production, these farmers were particularly vulnerable to the adverse effects of climate change, making them a critical group for understanding its impacts and the potential of adaptation strategies to enhance resilience and sustainability. This focus ensures that the study's findings are directly relevant to the community most affected by these challenges.

The study's geographic scope was Uasin Gishu County, Kenya, with a specific focus on Moiben Sub-County. The study aimed to evaluate the effectiveness of ecosystem-based adaptation (EbA) strategies in mitigating climate change vulnerabilities, addressing the following objectives: to assess the existing EbA strategies implemented among smallholder maize farmers, to assess the rate of their adoption, and to assess their effectiveness in reducing climate change vulnerability. Moiben Sub-County is a prominent agricultural region within Uasin Gishu County, known for its maize production.

Moiben Sub-County was ideal for studying climate change vulnerabilities due to its heavy reliance on maize farming, which is highly sensitive to changing climatic conditions, such as erratic rainfall and droughts. As a key agricultural area within Uasin Gishu County, Moiben's smallholder farmers face significant climate risks, underscoring the need to evaluate how ecosystem-based adaptation strategies are implemented and their effectiveness in reducing these vulnerabilities. This focus ensures the study's findings are relevant to both local farmers and similar agricultural regions.

1.9 Limitations of the Study

The study timeframe was twelve months, used to collect data and analyze them for presentation. The study was limited by the vastness of the area, but it addressed this limitation by increasing data collection time to cover the entire region. Also, the study delimited this limitation by collecting data in portions, distributing a few questionnaires that could be filled out and returned on the same day.

1.10 Assumptions of the Study

In examining the effectiveness of ecosystem-based adaptation strategies in mitigating climate change vulnerabilities in Moiben Sub-County, Kenya, the study assumes that the implemented strategies, encompassing initiatives such as afforestation and sustainable land management, have been executed as planned and are actively addressing climate-related challenges. Ecosystem-based adaptation strategies and participation are presumed robust, with the local population actively involved and supportive of these measures. The study further assumes a well-established understanding of baseline climate change vulnerabilities and regional vulnerabilities, grounded in a comprehensive analysis of historical climate patterns and current vulnerabilities.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter covers a theoretical review, empirical reviews of current climate change vulnerabilities, existing ecosystem-based adaptation strategies for mitigating climate change vulnerabilities, the effects of ecosystem-based adaptation strategies on mitigating climate change vulnerabilities, and existing gaps in the literature and conceptual framework.

2.2 Ecosystem-Based Adaptation Strategies

Agroforestry systems have gained recognition globally for their role in enhancing resilience in agricultural practices. Catacutan, Van Noordwijk, et al. (2017) explored the role of agroforestry in climate change mitigation through participatory action research. Their study found that integrating trees and shrubs into maize farming systems significantly improved soil fertility, reduced erosion by up to 50%, and increased water retention by about 30%. Additionally, these systems contributed to carbon sequestration, with an average of 10-20 tons of carbon stored per hectare annually, and provided supplementary income through timber and non-timber products. This dual benefit aligns with resilience theory by demonstrating how agroforestry practices contribute to both environmental sustainability and economic resilience for smallholder farmers. However, the study identified a gap in addressing barriers to widespread adoption, such as initial costs and a lack of technical knowledge, which could hinder the scalability of these practices.

Conservation agriculture (CA) has also been recognized for its potential to enhance the resilience of smallholder maize farmers. Giller et al. (2018) conducted research on the impact of CA on smallholder maize production in Africa, revealing that CA practices, including minimal soil disturbance, maintaining soil cover, and crop rotation, increased maize yields by 20-50% and reduced soil erosion by 40%. These practices also improved soil health, with a 15% increase in organic matter and enhanced water retention, crucial for adapting to variable climatic conditions. The study supports resilience theory by demonstrating how adaptive agricultural practices can sustain productivity amid environmental change. However, the research did not thoroughly address socio-economic constraints, such as the high labor demands and the need for specific knowledge, which may limit the widespread adoption of CA among smallholder farmers.

Water management is another critical area of focus for enhancing maize farming resilience. Tollenaar and Lee (2020) investigated the effectiveness of rainwater harvesting on maize yields in semi-arid regions, finding that such techniques improved yields by up to 35% by providing a supplementary water source during dry periods. The study reported that rainwater harvesting systems enhanced water use efficiency, leading to a 25% increase in water availability during critical growing stages. This aligns with resilience theory by demonstrating how improved water management can help smallholder farmers adapt to climate variability and maintain maize productivity in regions prone to droughts. However, the study identified a gap in the economic feasibility of implementing rainwater harvesting systems, particularly for resource-constrained farmers who may struggle with the initial investment costs.

Soil fertility management has also been shown to play a vital role in sustainable agriculture and resilience building. Pretty, Moraes, and Morton (2018) explored the role of soil fertility management in sustainable agriculture, finding that incorporating organic fertilizers and composting into maize farming systems improved soil health, increased nutrient availability by 30%, and enhanced moisture retention, leading to a 15-40% increase in maize yields. These practices reduced reliance on chemical fertilizers and strengthened the resilience of farming systems by improving soil's capacity to sustain crop production under changing climatic conditions. However, the study did not evaluate the long-term sustainability of these practices or their impact on the overall ecosystem, leaving a gap in understanding the broader implications of soil fertility management.

Nalau, Becken, and Mackey (2018) conducted a comprehensive global review of ecosystem-based adaptation (EBA) strategies in coastal areas. Using a mixed-methods approach, they analyzed policy documents and interviewed stakeholders across 15 countries, including Bangladesh, Australia, and Brazil. Their findings highlighted a diversity of EBA strategies, ranging from mangrove restoration to community-based adaptation initiatives. Strong ecosystem-based adaptation strategies, effective governance structures, and the integration of traditional knowledge characterized successful cases. However, challenges such as limited financial resources and the need for adaptive management strategies were noted. The study identified a significant research gap: the lack of standardized metrics for assessing EBA success, which is crucial for advancing the field and informing evidence-based decision-making.

Doswald et al. (2019) examined ecosystem-based approaches for adaptation in the UK. Their study found that ecosystem-based approaches integrate biodiversity and ecosystem services into overall strategies for helping people adapt to climate change. Although the measures of effectiveness recorded positive results, the study noted limitations in discussing thresholds, limits, and timescales related to these interventions. The social, environmental, and economic benefits of EBA interventions were evident, though the discussion of costs was limited. The study highlighted that EBA initiatives are predominantly in their infancy, underscoring the need for monitoring and evaluation to assess their effectiveness and identify optimal practices for scaling up.

Kasecker, Ramos-Neto, and Scarano (2018) examined EBA in Brazil and defined hotspot municipalities for policy design and implementation. The study found that EBA is a holistic approach that leverages ecosystems' inherent capacity to enhance resilience and reduce vulnerability to climate change. Strategies implemented globally include the restoration and conservation of natural ecosystems, such as forests, wetlands, and mangroves, which play critical roles in regulating the climate, providing habitat for biodiversity, and offering essential services such as water purification and flood control. Protecting and restoring these ecosystems contributes to increased resilience against climate change impacts.

Bhattarai et al. (2021) discussed another key EBA strategy involving sustainable land management practices. The adoption of practices that promote soil health, reduce erosion, and enhance water retention helps mitigate the effects of climate change on agriculture and ensures food security. Agroforestry, which integrates trees and shrubs into agricultural landscapes, provides multiple benefits, including improved soil fertility, enhanced water-use efficiency, and increased biodiversity. This approach supports farmers in adapting to changing climatic conditions and contributes to carbon sequestration and ecosystem health. In urban areas, green infrastructure such as green roofs, parks, and permeable surfaces is becoming a popular EBA strategy, reducing the impact of extreme weather events, improving air and water quality, and enhancing urban resilience.

Doswald et al. (2019) provide specific insights into the UK’s approach to ecosystem-based adaptation. Their research underscores the positive outcomes of integrating biodiversity and ecosystem services into adaptation strategies. However, the study also reveals that while there are evident benefits, the discussion on implementation limits and thresholds remains underdeveloped. The need for comprehensive monitoring and evaluation is highlighted to advance EBA practices in the UK and beyond. Kasecker, Ramos-Neto, and Scarano (2018) focus on Brazil, where EBA strategies have been implemented to enhance resilience and reduce vulnerability to climate change. The study emphasizes the importance of ecosystem restoration and conservation, illustrating how these strategies contribute to increased resilience. The findings are particularly relevant for developing policies and initiatives that integrate EBA into sustainable development plans.

In Sub-Saharan Africa, agroforestry has been identified as a key adaptation strategy. Place, de Grassi, and Cooper (2020) studied the adoption and impact of agroforestry in the region, finding that agroforestry systems improved soil fertility, reduced erosion, and enhanced biodiversity, with a 20% increase in tree cover on farms. The study also found that these systems provided additional income, resulting in a 15-25% increase in household income from non-timber forest products. However, the adoption of agroforestry varied significantly across regions, with a noted gap in understanding the specific barriers to adoption, such as cultural practices or resource access, that could inform better-targeted interventions.

In Africa, ecosystem-based adaptation (EBA) strategies have been increasingly recognized as vital for managing climate change impacts, given the continent's high vulnerability to environmental change. Khatibi et al. (2021) examined EBA strategies in East Africa, highlighting the role of community-based initiatives in enhancing climate resilience. The study focused on integrated water and land management practices, including the restoration of degraded watersheds and the adoption of agroecological farming techniques. The findings indicated that these practices not only improve soil fertility and water availability but also support biodiversity conservation and enhance local livelihoods. Similarly, the work of Mwaura et al. (2020) on the Lake Victoria Basin emphasized the importance of wetland conservation and sustainable agricultural practices in mitigating the effects of climate change. Their research showed that protecting wetlands and promoting agroforestry systems in the region contribute significantly to flood regulation, carbon sequestration, and the maintenance of ecosystem services critical for local communities.

Moreover, the African Union's Climate Resilient Infrastructure Development (CRID) initiative has been pivotal in implementing EBA strategies across the continent. This program emphasizes the restoration of natural ecosystems, including mangroves and coastal wetlands, which provide essential services such as coastal protection and habitat for marine biodiversity (African Union, 2022). The initiative has facilitated various projects that integrate traditional knowledge with modern conservation practices to enhance community resilience against climate change. A study by Shiferaw et al. (2021) further supports these efforts by documenting the success of EBA projects in Ethiopia, where community-managed reforestation and watershed management practices have led to improved water resources and enhanced local food security.

Reid, Podvin, and Segura (2018) emphasized the importance of community-based adaptation in EBA Egypt. The study highlighted the role of local communities in developing context-specific strategies to cope with climate change impacts, incorporating traditional knowledge and practices. This participatory approach ensures that adaptation measures are culturally sensitive, socially inclusive, and sustainable. Economic incentives and policy frameworks are also crucial for promoting EBA, with governments and international organizations playing a role in implementing policies that incentivize sustainable land-use practices, conservation efforts, and ecosystem restoration. Programs such as payments for ecosystem services can further encourage the adoption of resilient practices.

Nalau, Becken, and Mackey (2018) and Bhattarai et al. (2021) highlight the relevance of diverse EBA strategies in Namibia, including mangrove restoration, sustainable land management, and green infrastructure. These strategies are essential for addressing climate change impacts in various contexts. They highlight the diversity of approaches, including mangrove restoration, sustainable land management, and green infrastructure, and emphasize the importance of integrating traditional knowledge and policy incentives. Reid, Podvin, and Segura (2018) add to this by emphasizing the role of community-based adaptation and the importance of economic incentives and policy frameworks. Despite valuable insights, significant research gaps remain, particularly in standardized assessment metrics, scalability of successful strategies, and detailed policy recommendations. Addressing these gaps is crucial for effectively integrating EBA into climate adaptation planning and advancing the field of ecosystem-based adaptation.

In Kenya, ecosystem-based adaptation strategies have been pivotal in addressing climate change impacts, particularly in regions prone to droughts and floods. A notable example is the National Climate Change Action Plan (NCCAP), which incorporates EBA approaches, such as restoring degraded lands and promoting climate-smart agriculture (Government of Kenya, 2021). The plan emphasizes the importance of integrating EBA into national and local development frameworks to enhance resilience. The research by Munang et al. (2019) on Kenya's Maasai Mara ecosystem highlights successful community-based projects that focus on rangeland restoration and sustainable grazing practices. These initiatives have been effective in improving soil health, increasing biodiversity, and reducing the vulnerability of pastoral communities to climate variability.

Additionally, the work of Nkonya et al. (2020) on Kenya's drylands presents a detailed analysis of the impacts of soil and water conservation techniques, such as rainwater harvesting and agroforestry, in enhancing agricultural productivity and climate resilience. Their findings indicate that these strategies not only mitigate soil erosion and improve water availability but also contribute to carbon sequestration and biodiversity conservation. The study underscores the need for scaling up these practices across Kenya's arid and semi-arid lands to achieve broader climate adaptation goals. The collaboration among local communities, government agencies, and non-governmental organizations has been crucial to implementing and sustaining these EBA strategies, underscoring the effectiveness of integrated approaches to managing climate risks and promoting sustainable development in Kenya.

Muriuki et al. (2021) conducted a study on the impact of CA on maize production in Kenya, finding that these practices improved maize yields by 30-50% and enhanced soil health, with reported increases in organic matter and reductions in soil erosion. The study also noted a 20% increase in farmer adoption in regions with supportive extension services, highlighting the role of institutional support in promoting CA practices. This aligns with resilience theory by demonstrating how adaptive practices can improve productivity and sustainability under changing climatic conditions. However, the study did not explore the long-term impacts of conservation agriculture on soil health or its scalability across different agro-ecological zones in Kenya, leaving a gap in understanding the broader applicability of these practices.

Water management strategies have also been critical in enhancing maize farming resilience in East Africa. Mwakalila and Mkonda (2022) studied the effectiveness of water management strategies in East African maize farming, finding that rainwater harvesting and efficient irrigation systems improved maize productivity by up to 40% and enhanced resilience to drought in arid and semi-arid regions. The study reported a 30% increase in water use efficiency and a significant reduction in crop failure rates.

This supports resilience theory by illustrating how technological innovations can mitigate the impacts of climate change on agriculture. However, the study highlighted a gap in addressing the financial constraints faced by smallholder farmers in implementing advanced water management technologies, which could limit their adoption and effectiveness.

In Kenya, agroforestry adoption has been studied extensively. Kiptot and Franzel (2019) explored the adoption and impact of agroforestry practices among Kenyan smallholder farmers, finding that these practices improved soil fertility, increased maize yields by up to 40%, and provided additional income through timber and non-timber products. The study also noted that adoption was influenced by factors such as access to extension services and market opportunities for tree products. However, low adoption rates were observed in certain regions, with a gap in understanding the socio-economic factors affecting implementation, such as land tenure systems and cultural preferences, which could inform more effective strategies for promoting agroforestry.

Finally, soil fertility management has been a focus in Kenyan maize farming. Muli, Nyangaga, and Mugendi (2020) studied the impact of soil fertility management practices on maize production in Kenya, finding that practices such as composting and the use of organic fertilizers improved soil fertility, increased maize yields by up to 35%, and reduced dependency on expensive chemical fertilizers. The study also noted a 20% improvement in soil health indicators, such as organic matter content and nutrient availability, supporting the resilience of maize farming systems. However, the research did not evaluate the long-term effects of these practices on the overall ecosystem or their potential impacts on soil biodiversity, leaving a gap in understanding the broader ecological implications of soil fertility management practices.

2.3 Rate of Adoption of the Ecosystem-Based Adaptation Strategies Among Small-Holder Maize Farmers

The rate of adoption of ecosystem-based adaptation (EbA) strategies among smallholder maize farmers varies significantly across regions and is influenced by factors such as access to resources, farmer awareness, and the effectiveness of extension services (Erezi, Ehi, & Ayodeji, 2023). Globally, studies indicate that while EbA strategies are gaining traction, the adoption rate remains uneven, often hindered by socio-economic constraints and a lack of robust support systems. For example, in a global assessment by Ngwira, Aune, and Mkwinda (2017), the adoption of conservation agriculture (a key EbA strategy) among smallholder maize farmers in Malawi was found to be relatively low, with only 30% of farmers consistently adopting the practices. The study highlighted that factors such as land tenure security, access to markets, and extension services played a crucial role in influencing adoption rates. Additionally, the researchers identified a knowledge gap: while farmers were aware of the benefits of conservation agriculture, they lacked the technical know-how and resources to implement it effectively.

In contrast, studies in Latin America have shown higher adoption rates of EbA strategies, particularly in regions with strong institutional support and farmer cooperatives. A study by Altieri and Nicholls (2017) in Mexico found that approximately 60% of smallholder maize farmers had adopted agroecological practices, including intercropping and organic soil management. The study attributed this relatively high adoption rate to the presence of robust farmer networks and government support programs that provided training and financial incentives. The researchers emphasized the importance of community-led initiatives in driving adoption, noting that peer learning and local leadership were critical factors in encouraging wider adoption of EbA strategies (Bedelian, Mulwa, et al., 2024). However, the study also noted that despite these successes, challenges such as market access and climate variability continued to pose significant barriers to sustained adoption.

In Asia, particularly in India, the adoption of EbA strategies among smallholder maize farmers has been mixed. Singh, Singh, and Yadav (2018) conducted a study in the state of Uttar Pradesh and found that only 25% of farmers had adopted EbA practices, such as organic farming and agroforestry. The study identified a lack of awareness and inadequate extension services as the primary barriers to adoption. Additionally, the researchers found that adoption rates were higher among farmers with access to irrigation and financial resources, suggesting that economic factors played a significant role in adoption. The study highlighted the need for more targeted interventions that address the specific needs and challenges faced by smallholder farmers in the region (Bedelian *et al.*, 2024).

In Africa, the adoption of EbA strategies among smallholder maize farmers has generally been slow, with significant regional variations. In a study conducted in Zambia by Kaczan, Arslan, and Lipper (2019), the adoption rate of conservation agriculture was found to be around 20%, with significant differences between regions. The study identified factors such as the availability of extension services, farmer education, and the perceived benefits of the practices as key determinants of adoption. The researchers noted that in regions where farmers had received training and support, adoption rates were significantly higher. However, the study also highlighted the challenges of scaling up these practices, particularly in areas with limited access to markets and financial resources. This underscores the need for comprehensive support systems that address both the technical and economic aspects of adoption.

In East Africa, the adoption of EbA strategies has also been relatively low, particularly among smallholder maize farmers. A study by Nyasimi et al. (2017) in Kenya and

Tanzania found that less than 30% of farmers had adopted EbA practices such as agroforestry and soil conservation. The study identified several barriers to adoption, including a lack of awareness, limited access to inputs, and the high cost of implementing these practices. The researchers emphasized the need for targeted interventions that equip farmers with the resources and knowledge to effectively adopt EbA strategies. Additionally, the study highlighted the importance of integrating local knowledge and practices into EbA strategies to enhance their relevance and uptake among smallholder farmers.

In Kenya, the adoption of EbA strategies among smallholder maize farmers has been particularly slow, with studies showing varying rates of adoption across different regions. A study by Muriuki, Njeru, and Karanja (2021) found that only 18% of smallholder maize farmers in central Kenya had adopted conservation agriculture practices. The study identified factors such as land fragmentation, limited access to extension services, and a lack of financial resources as significant barriers to adoption. Additionally, the researchers noted that farmers who had adopted these practices reported positive outcomes, including increased yields and improved soil fertility, suggesting that wider adoption is possible if the barriers are addressed. The study called for more targeted interventions that provide farmers with the necessary support to adopt and sustain these practices.

In another Kenyan study, Kiptot and Franzel (2019) examined the adoption of agroforestry among smallholder maize farmers in western Kenya. The study found that about 25% of farmers had adopted agroforestry practices, with adoption rates varying significantly by factors such as access to training, land size, and farmer education. The researchers noted that while there was growing awareness of the benefits of agroforestry, many farmers were hesitant to adopt these practices due to perceived risks and the long-term commitment required. The study highlighted the need for more targeted outreach and education programs that address these concerns and provide farmers with the necessary skills and resources to implement agroforestry practices effectively.

Despite the recognized benefits of these strategies in enhancing resilience and improving agricultural productivity, the rate of adoption remains low in many regions (Makate, Mango & Siziba, 2019). Factors such as access to resources, farmer education, and institutional support play a critical role in influencing adoption rates. Addressing these barriers through targeted interventions and support systems was crucial in increasing the adoption of EbA strategies and ensuring their long-term sustainability. Additionally, there is a need for further research to understand the specific challenges faced by smallholder farmers across regions and to develop context-specific solutions that address them effectively (Jayne et al., 2021).

2.4 Effectiveness of Ecosystem-Based Adaptation Strategies in Improving Climate Resilience and Reducing Vulnerability

Catacutan et al. (2017) highlighted the effectiveness of agroforestry in mitigating climate change through participatory action research. Their findings showed that agroforestry not only sequesters carbon but also enhances community resilience by improving biodiversity, water regulation, and soil health. However, they stressed the need to scale up these practices in upcountry regions to achieve broader climate-mitigation impacts.

Whitmarsh, O'Neill, and Lorenzoni (2018) assessed public engagement with climate change and found that ecosystem-based adaptation (EBA) strategies benefit significantly from community involvement. Their research emphasized that empowering local stakeholders in decision-making processes enhances the success of EBA strategies by fostering sustainable behaviors and broadening participation in climate action. Engaging communities involves empowering individuals and local organizations to actively participate in decision-making related to climate change, reflecting the concept of 'scaling up' sustainable activities through interpersonal connections.

Sarzynski (2015) evaluated the effect of public participation, civic capacity, and climate change adaptation in cities. The study found that ecosystem-based adaptation strategies foster grassroots initiatives that contribute to behavioral change. However, it also highlighted the need for more robust civic capacity in urban climate adaptation efforts and emphasized that few cases illustrate sustained capacity in this area. The study noted that cities are increasingly involved in planning for climate change adaptation, although the role of public participation remains poorly theorized and understudied.

Bernados and Ocampo (2023) explored the role of social capital in advancing climate change mitigation and disaster risk reduction. Their findings showed that EBA strategies contribute to the development of social cohesion and resilience, and to the mitigation of climate change vulnerabilities. Engaged communities are better equipped to withstand and recover from climate-related events through collective responsibility and mutual support networks. Oktari et al. (2018) found that actively engaged communities exhibit higher resilience through collaborative disaster preparedness efforts.

Khatibi (2021) evaluated the importance of public knowledge and ecosystem-based adaptation strategies in climate change policy-making and planning. The study emphasized that participatory decision-making is crucial for effective EBA strategies. The practice of involving communities in climate-related governance increases acceptance and ownership of initiatives, leading to more sustainable outcomes. Engaging communities helps bridge the gap between scientific knowledge and local practices, fostering better understanding and adoption of science-informed climate practices.

Jin, Kim, and Chon (2022) examined the resilience of wetlands to climate change using a hydrological modeling approach. Their research found that well-preserved wetlands act as natural buffers against extreme weather events, providing flood control and supporting local water systems. The study highlighted the importance of maintaining and restoring upcountry wetlands for climate change adaptation and mitigation, noting their role in carbon sequestration and overall climate resilience.

Singh et al., (2019) investigated the effectiveness of climate change adaptations in the world's largest mangrove ecosystem through a comprehensive field survey and GIS analysis. Their results demonstrated that mangrove ecosystems act as natural barriers against storm surges and provide essential habitat for biodiversity. The study emphasized the need for targeted conservation efforts and policies recognizing the ecological value of mangroves. This highlights the importance of a holistic approach to ecosystem preservation and restoration, considering the variability in ecosystems' capacity to mitigate climate change.

In Africa, EBA strategies have been pivotal in improving climate resilience and reducing vulnerability. The study by Nhamo et al. (2021) on EBA in Southern Africa revealed that integrating ecosystem services into adaptation planning enhances community resilience. The research highlighted that well-managed wetlands, forests, and grasslands provide essential services such as water regulation, soil fertility, and flood control, which are crucial for sustaining agricultural productivity and protecting livelihoods. Despite these benefits, the study identified challenges, including inadequate funding and limited technical capacity for effective implementation. To improve resilience across Southern Africa, the study stressed the need for increased investment in ecosystem management and regional collaboration (Afriyie et al., 2021).

In East Africa, Kizito et al. (2020) emphasized the role of integrating local knowledge and traditional practices into EBA strategies. The study, which covered Kenya, Uganda, and Tanzania, found that community-based approaches that incorporate indigenous knowledge are more effective in managing natural resources and adapting to climate change. Traditional practices, such as indigenous forest management and water conservation techniques, complement modern EBA strategies and enhance their effectiveness. The study identified barriers, such as land tenure issues and the lack of formal recognition of traditional practices, that hinder the widespread adoption of these approaches. Addressing these barriers through supportive policies can enhance the effectiveness of EBA strategies in East Africa (Obedgiu et al., 2023).

In Kenya, the effectiveness of EBA strategies is evident in various contexts. Gichuki et al. (2019) examined EBA in Kenya's arid and semi-arid lands (ASALs), focusing on agroforestry, community-managed water resources, and restoration of degraded lands. Their research highlighted that these EBA strategies significantly enhance resilience to climate variability by improving vegetation cover and water availability. The study emphasized the importance of integrating local knowledge with scientific approaches to improve the success of EBA initiatives (Obedgiu et al., 2023). However, challenges such as inconsistent policy implementation and insufficient funding were noted, which hinder the scaling up of successful practices.

Mwangi et al. (2021) explored the role of mangrove restoration in coastal Kenya and found that mangrove ecosystems provide critical ecosystem services, including coastal protection and carbon sequestration. Their research demonstrated that community-led restoration projects have improved mangrove cover and increased resilience to coastal erosion and flooding. The study highlighted the need for integrated coastal management approaches that involve stakeholders at all levels, from local communities to national governments (Mtenga, 2021). Despite positive outcomes, challenges such as land-use conflicts and inadequate enforcement of conservation regulations were noted and need to be addressed to ensure the long-term success of mangrove restoration efforts.

The studies reviewed provide valuable insights into the role of ecosystem-based adaptation strategies in climate change mitigation and resilience. Catacutan et al. (2017) and Whitmarsh et al. (2018) emphasize the benefits of agroforestry and public engagement, respectively, in enhancing community resilience. Sarzynski (2015), Jin et al. (2022), and Singh et al. (2019) highlight the significance of grassroots initiatives, wetland preservation, and mangrove conservation. Despite these positive findings, gaps remain in understanding the full extent of public participation in urban climate adaptation and in the mechanisms for effectively scaling EBA strategies. Addressing these gaps is crucial for integrating EBA into comprehensive climate adaptation planning and enhancing community resilience.

2.5 Climate Change Vulnerabilities

According to Ferrazzi, Zwart, and Kalantzis (2021), the European Investment Bank (EIB) Climate Risk Country Scores provide a comprehensive assessment of the climate change vulnerabilities faced by more than 180 countries. The two sets of scores for physical and transition risks aggregate exposure to various risk factors, taking into account each country's adaptation and mitigation capacity. The scores confirm that climate risk is a relevant challenge for all countries. However, low-income economies are more vulnerable to physical risks, in particular to acute events, rising sea levels, and excessive heat, and, in parallel, have a lower ability to mitigate the challenges posed by the energy transition to a net-zero-carbon future; hence, financial and technical support are deemed crucial. High-income economies, which consume a large share of the world’s resources and generate significant emissions, generally face higher risks from the transition to a low-carbon future (Semieniuk, Campiglio, et al., 2021). Countries more dependent on fossil fuel revenues are also among the most exposed to transition risk (Scott, 2022).

Esperon-Rodriguez, Tjoelker et al. (2022) examined how climate change increases global risk to urban forests in New Delhi and Singapore. The study employed a mixed-methods approach, combining satellite data analysis with community surveys. The study found that climate change threatens the health and survival of urban trees and the benefits they provide to urban inhabitants. Findings show that 56% and 65% of species in 164 cities across 78 countries are currently exceeding the temperature and precipitation conditions within their geographic ranges, respectively. The study assessed 3,129 tree and shrub species using three metrics of climate vulnerability: exposure, safety margin, and risk. By 2050, under Representative Concentration Pathway 6.0, 2,387 (76%) and 2,220 (70%) species will be at risk from projected changes in mean annual temperature and annual precipitation, respectively (Esperon-Rodriguez, Tjoelker et al., 2022. Risk is predicted to be greatest in cities at low latitudes such as New Delhi and Singapore, where all urban tree species are vulnerable to climate change (Esperon-Rodriguez et al., 2022). These findings aid in evaluating the impacts of climate change on securing the long-term benefits provided by urban forests. Findings revealed that rapid urbanization contributes to increased vulnerability, with poorly planned infrastructure exacerbating the impacts of extreme weather events on urban populations. The study emphasizes the urgent need for sustainable urban development strategies that integrate climate-resilient infrastructure, green spaces, and community-based adaptation measures (Masson et al., 2020).

Cramer, Guiot, et al. (2018) assessed climate change and interconnected risks to sustainable development in the Mediterranean. Recent accelerated climate change has exacerbated existing environmental problems in the Mediterranean Basin, driven by a combination of land-use changes, increasing pollution, and declining biodiversity. For five broad and interconnected impact domains (water, ecosystems, food, health, and security), current changes and future scenarios consistently point to significant and increasing risks over the coming decades (Ruiz & Sanz-Sánchez, 2020). Policies for the sustainable development of Mediterranean countries need to mitigate these risks and consider adaptation options, but currently lack adequate information, particularly for the most vulnerable southern Mediterranean societies, where fewer systematic observation schemes and impact models are available. A dedicated effort to synthesize existing scientific knowledge across disciplines is underway and aims to provide a better understanding of the combined risks posed (Cramer, Guiot, et al., 2018).

Mach, Kraan et al. (2019) examine climate as a risk factor for armed conflict in Europe, exploring the intersectionality of climate risks, particularly focusing on the differential vulnerabilities of marginalized populations. Using a qualitative research design, including interviews and focus group discussions, the study highlighted how socioeconomic factors, such as poverty and lack of access to resources, amplify climate-related risks. The study results show that climate has affected organized armed conflict within countries. However, other drivers, such as low socioeconomic development and the state's limited capabilities, are judged to be substantially more influential, and the mechanisms underlying climate-conflict linkages remain a key uncertainty. Intensifying climate change is estimated to increase future risks of conflict. The research underscores the importance of developing equitable mitigation strategies that address the unique challenges faced by various social groups and calls for a more inclusive approach to climate change adaptation (Mach & Kraan, 2021).

In a study by Prusty and Farooq (2020), the implications of sea-level rise on coastal regions were thoroughly investigated. The study used a combination of geographic information systems (GIS) and modeling techniques, and the research demonstrated the escalating threats posed by flooding, saltwater intrusion, and erosion. The findings emphasize the urgent need for adaptive strategies that integrate both ecosystem-based and engineered solutions to enhance resilience in coastal regions. The study also discussed the potential cascading effects on critical ecosystems, such as mangroves and coral reefs. The findings emphasize the need for international collaboration and policies that address the global implications and the compounding effects of climate change on resource scarcity and migration, which may become significant drivers of conflict (Prusty & Farooq, 2020).

Audefroy and Sanchez (2020) examine the role of indigenous knowledge in climate change mitigation in Mexico. Employing a participatory action research approach, the study engaged indigenous communities and incorporated traditional practices into climate change adaptation strategies. Findings demonstrated that indigenous communities possess valuable insights into local ecosystems and sustainable resource management practices. The study highlights the importance of integrating indigenous perspectives into broader climate change mitigation efforts, promoting a more holistic and culturally sensitive approach.

Research by Zheng, Wei, et al. (2019) explored the effects of climate change on agriculture in China using a quantitative modeling approach. The study demonstrated the significant impact of unpredictable precipitation patterns on agricultural productivity, leading to potential food shortages and price fluctuations. The findings underline the critical need for adaptive agricultural practices and policies to address the challenges posed by climate change. The study also identified potential research gaps, emphasizing the need to further investigate the mechanisms linking climate change to food security and to explore innovative solutions for sustainable agriculture under changing environmental conditions.

In summary, the studies by Ferrazzi, Zwart, and Kalantzis (2021), Esperon-Rodriguez et al. (2022), Cramer et al. (2018), Mach et al. (2019), Prusty and Farooq (2020), Audefroy and Sanchez (2020), and Zheng et al. (2019) collectively underscore the pervasive impacts of climate change across various regions and sectors. They highlight vulnerabilities across urban forests and coastal regions, agricultural productivity, and the intersection of climate risks with socioeconomic factors and armed conflict. Common themes include the need for adaptive strategies, sustainable development, and the integration of local and indigenous knowledge into broader climate change mitigation efforts. However, these studies often lack detailed policy recommendations, regional-specific data, and a focus on the practical implementation of proposed solutions.

Despite their valuable insights, significant research gaps remain. There is a need for more granular, region-specific data to inform targeted interventions and for more comprehensive, actionable policy recommendations (Yang & Umair, 2024). Additionally, integrating traditional and indigenous knowledge into formal climate strategies is essential but underexplored. Combining quantitative and qualitative data could offer a more holistic understanding of climate risks and their socioeconomic impacts (Rising et al., 2022). Future research should also focus on the scalability and practical implementation of adaptation and mitigation strategies to address the pressing challenges posed by climate change effectively.

In the African context, the global findings on climate change vulnerabilities are particularly relevant. As highlighted by Ferrazzi et al. (2021), African countries, especially those with low incomes, face severe vulnerabilities to climate change, including heightened risks from extreme weather events and sea-level rise. The limited adaptation and mitigation capacities exacerbate these challenges, emphasizing the need for targeted financial and technical support. The impact on urban forests, as observed globally, also applies to African cities. Esperon-Rodriguez et al. (2022) suggest that rapid urbanization in African cities increases vulnerabilities, making it crucial to integrate sustainable urban planning and green infrastructure to mitigate the impacts of climate change.

Insights from the Mediterranean Basin's climate risks, as discussed by Cramer et al. (2018), are pertinent to northern African regions that face similar environmental and developmental challenges. The interconnected risks to water, ecosystems, and food security are significant for these regions, highlighting the need for comprehensive adaptation strategies. Mach et al. (2019) provide a useful framework for understanding how climate risks intersect with conflict in Africa. The research underscores that climate-related stresses can exacerbate socio-economic and political tensions, necessitating targeted mitigation and adaptation strategies that consider regional and local dynamics.

For Kenya, the global and regional insights translate into specific challenges and opportunities. Valencia, Wittman, and Blesh (2021) highlight Kenya's vulnerability to climate risks, including impacts on agriculture and water resources. Enhanced adaptation strategies are critical for addressing these challenges. In Kenyan cities, the impact on urban forests mirrors global findings. Esperon-Rodriguez et al. (2022) emphasize the importance of integrating climate-resilient infrastructure and green spaces into urban planning to safeguard the benefits of urban forests. Cramer et al. (2018) offer relevant insights for Kenya, particularly regarding interconnected risks to water, ecosystems, and food security. These insights should inform local adaptation strategies that address the specific vulnerabilities faced across Kenya's regions. Mach et al. (2019) provide a framework for understanding how climate change might exacerbate conflict in Kenya, highlighting the need for equitable and inclusive adaptation strategies that address socio-economic vulnerabilities.

In Uasin Gishu, the global and regional findings on climate change risks are particularly relevant. Yatich (2023) indicates that rural areas like Uasin Gishu are susceptible to climate impacts, especially those affecting agriculture and water resources. These broader insights should inform local adaptation strategies. Toroitich, Mironga, and Were (2021) underscore the importance of adaptive agricultural practices in Uasin Gishu. Given the region's critical role in agriculture, addressing the impacts of climate change on productivity is essential to ensuring food security and economic stability.

In Moiben Sub-County, the specific implications of climate change should be considered within the broader regional context. Toroitich et al. (2021) suggest that adaptation strategies for Moiben should address vulnerabilities in water, food security, and ecosystem health, drawing on insights from broader regional studies. Were et al. (2021) highlight the need for adaptive agricultural practices in Moiben, tailored to local conditions to maintain productivity and food security in the face of climate change.

The studies reviewed provide a comprehensive understanding of the pervasive impacts of climate change, ranging from urban forests and coastal regions to agricultural productivity and socio-economic factors (Ahmed & Khan,2023). While global and regional findings offer valuable insights, there is a need for more granular, local data to inform targeted interventions. Integrating both quantitative and qualitative data will be crucial for developing effective climate strategies in specific regions, such as Uasin Gishu and Moiben Sub-County (Murgor, 2021). Addressing research gaps and focusing on practical implementation will be essential to effectively tackle the pressing challenges posed by climate change.

2.6 Existing Gaps in Literature

In summary, while the existing research provides valuable insights, there are notable research gaps that require attention. Firstly, there is a need for longitudinal studies to assess the long-term sustainability of ecosystem-based adaptation strategies initiatives (Catacutan et al., 2017). This is crucial for understanding how these strategies perform over extended periods and under varying climatic conditions. Secondly, the impact of socio-economic factors on the success of community-based mitigation efforts warrants further exploration (Gilleran et al., 2021). Understanding these factors can help tailor strategies to local contexts and improve their effectiveness.

Additionally, research focusing on the role of technology in enhancing ecosystem-based adaptation strategies for climate change mitigation is relatively scarce. Technological innovations could offer new solutions and efficiencies in implementing these strategies (Zheng et al., 2019). There are also a limited number of studies that specifically focus on the economic valuation of ecosystem services in upcountry areas, hindering a comprehensive understanding of their overall contributions (Bice & Jones, 2023). More research is needed to explore the potential synergies and trade-offs among different ecosystem services in upcountry regions, while accounting for the complexities of climate change impacts (Ferrazzi et al., 2021). Addressing these gaps will contribute to the development of more effective, context-specific strategies for leveraging ecosystem-based adaptation to mitigate climate change vulnerabilities in upcountry areas. This study seeks to fill the gap by evaluating the effectiveness of ecosystem-based adaptation strategies in mitigating climate change vulnerabilities in Moiben Sub-County, Kenya.

2.7 Theoretical Framework

The study was guided by Resilience Theory. Resilience Theory, developed by Norman Garmezy in 1991, asserts that both ecological and social systems possess the capacity to absorb shocks, adapt to change, and persist in the face of disturbance (Kar, 2021). Emphasizing interconnectedness and adaptive capacity, the theory underscores the dynamic nature of systems, crucial for long-term sustainability. In the context of evaluating ecosystem-based adaptation (EbA) strategies for climate change, resilience theory suggests that successful adaptation involves more than mere resistance or recovery; it necessitates adaptive capacity, emphasizing ecosystems' and communities' ability to learn, evolve, and sustain functionality amidst environmental changes (Goodbrand, Scholes & Vogel, 2019).

Resilience theory assumes that systems inherently possess the capacity to adapt and reorganize, highlighting their dynamic nature, interconnectedness, and non-linear dynamics. While influential, the theory faces criticism for potentially overemphasizing stability and neglecting transformative change in the face of climate challenges. Critics also raise concerns about equitable resilience outcomes and the practical application of resilience concepts (Stroink, 2020). Despite these critiques, the theory remains relevant for studying EbA strategies, offering a conceptual framework that aligns with sustainable adaptation goals and emphasizes the holistic nature of climate change resilience. It enables exploration of how EbA strategies contribute to adaptive capacity and community resilience, and address the multifaceted challenges posed by climate change, informing the development of effective, integrated approaches for ongoing environmental changes (Adams, 2021).

Resilience Theory is particularly relevant to the study of ecosystem-based adaptation (EbA) strategies as it provides a framework for understanding how both ecological systems and human communities respond to and recover from environmental disturbances. Developed by Norman Garmezy, the theory emphasizes the capacity of systems to absorb shocks, adapt to changes, and persist despite disturbances (Kar, 2021).

In the context of evaluating EbA strategies, the theory highlights the importance of adaptive capacity, which refers to the ability of ecosystems and communities to learn from and respond to environmental changes effectively. This aligns with the study's focus on assessing how EbA strategies enhance resilience by improving ecosystems' functionality and communities' capacity to cope with climate change. By emphasizing the interconnectedness of ecological and social systems, Resilience Theory helps to frame the study's exploration of how integrated approaches to adaptation contribute to long-term sustainability.

Resilience Theory also addresses the dynamic and non-linear nature of systems, which is crucial for understanding the complexity of climate change impacts and adaptation strategies. The theory's focus on the ability of systems to reorganize and evolve in response to disturbances provides valuable insights into the effectiveness of EbA strategies in managing multifaceted climate challenges. For instance, EbA strategies often involve restoring natural ecosystems, such as wetlands or forests, which play a vital role in regulating climate and supporting biodiversity. The theory's emphasis on adaptive capacity and interconnectedness enables the study to assess how these strategies contribute to ecosystem functionality and community resilience amidst environmental changes (Goodbrand, Scholes & Vogel, 2019). Despite criticisms regarding the potential overemphasis on stability and neglect of transformative change (Stroink, 2020), Resilience Theory remains a robust framework for evaluating the holistic nature of climate adaptation efforts and guiding the development of effective, integrated approaches to climate change resilience (Adams, 2021).

2.8 Conceptual Framework

The conceptual framework is a diagrammatic presentation of the theory, presented as a model in which research variables and their relationships are translated into a visual picture to illustrate the interconnections between the independent and dependent variables (Bolte et al., 2021). In this study, the independent variables are the Existing Ecosystem-based Adaptation (EbA) strategies, the Adoption Rate of EbA Strategies and the Effectiveness of EbA Strategies. The dependent variable is climate change vulnerabilities.

Existing Ecosystem-based Adaptation (EbA) strategies, such as soil conservation, crop diversification, agroforestry, and water management, represent proactive measures adopted by smallholder maize farmers to address climate change impacts. These strategies directly influence the dependent variables by mitigating climate vulnerabilities through enhanced resilience in agricultural practices.

The rate at which farmers adopt EbA strategies, categorized as high, moderate, low, or none, plays a critical role in determining their overall effectiveness. A higher adoption rate generally correlates with more significant positive outcomes, such as improved water quality, better soil nutrient levels, diversified income sources, and increased soil carbon content. In contrast, lower adoption rates may result in less effective mitigation of climate change impacts.

The success of EbA strategies can be measured by their impact on water quality, soil nutrient levels, income sources, and soil carbon. Effective strategies lead to improved environmental conditions and economic stability, which, in turn, reduce climate change vulnerabilities. For instance, improved soil conservation practices can enhance soil nutrient levels, thereby boosting agricultural productivity and reducing farmers' vulnerability to extreme weather conditions and associated economic shocks.

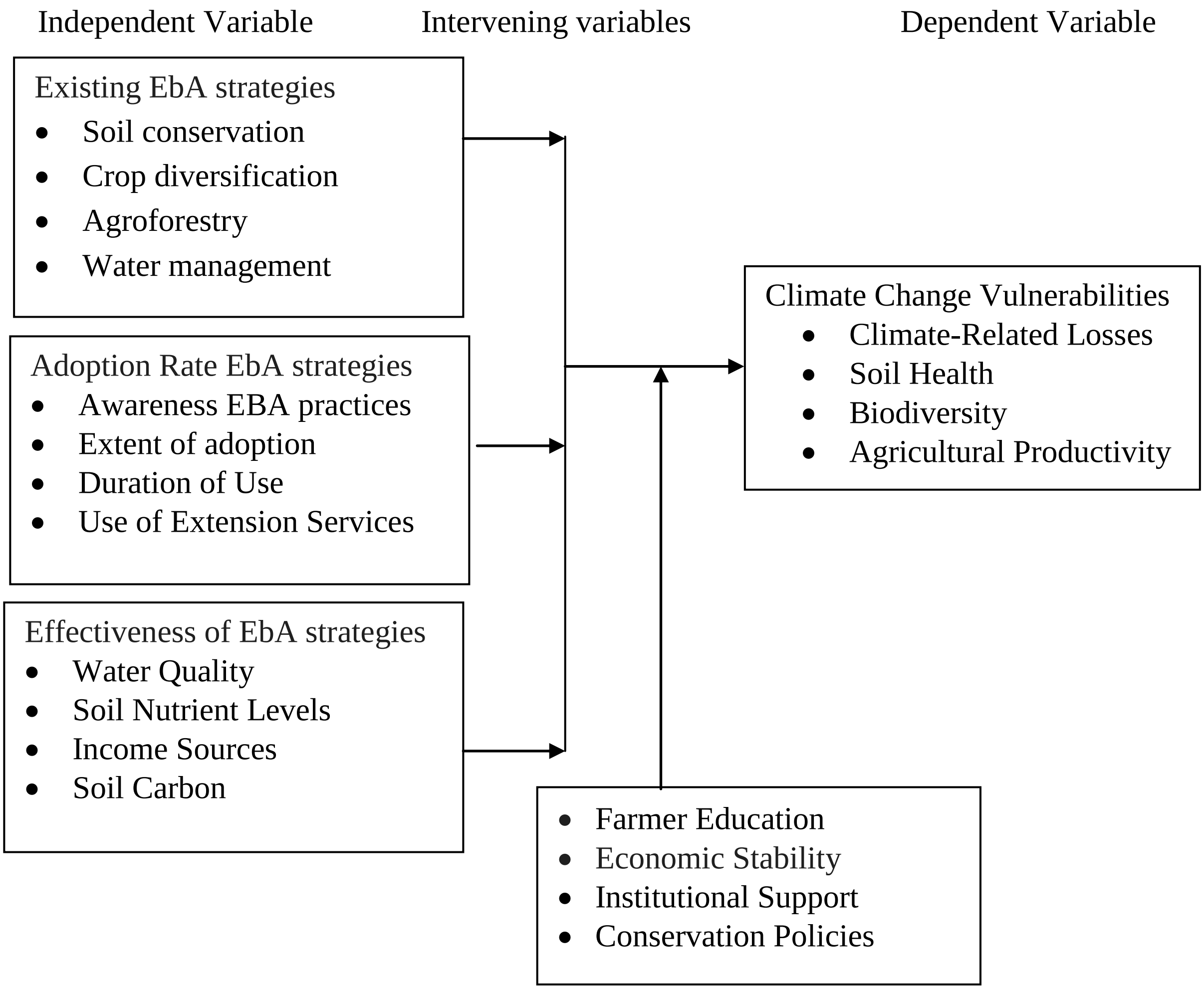
Climate change vulnerabilities, including extreme weather conditions, climate-related diseases, rising sea levels, and agricultural productivity, are directly influenced by the effectiveness of EbA strategies. The degree to which these vulnerabilities are mitigated depends on the successful implementation and adoption of the independent variables. Effective EbA strategies help reduce the negative impacts of these vulnerabilities, thereby enhancing the resilience of farming communities.

Factors such as farmer education, economic stability, institutional support, and conservation policies act as intervening variables that influence the relationship between EbA strategies and climate change vulnerabilities. For instance, well-educated farmers are more likely to understand and implement EbA strategies effectively. Similarly, strong institutional support and favorable conservation policies can facilitate the broader adoption of these strategies, enhancing their effectiveness in mitigating climate change vulnerabilities. Economic stability also enables farmers to invest in and sustain EbA practices, which can lead to more resilient agricultural systems.

The interplay among these variables underscores the importance of both the adoption and the effectiveness of EbA strategies in mitigating climate change vulnerabilities. The intervening variables further emphasize the role of external factors in either enhancing or hindering the success of these strategies.

Figure 1

Conceptual Framework



Source: Researcher (2025)

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter describes the methods used to conduct the study, including the research design applied, the target population, the sample size and sampling procedures used, the data collection instruments and procedures applied, the data management and analysis techniques used, and the ethical considerations.

3.2 Research Design

The study used a mixed-methods research design. This approach allows for the integration of both quantitative and qualitative methods to provide a comprehensive understanding of the effectiveness of Ecosystem-Based Adaptation (EbA) strategies in towns (Schoonenboom & Johnson, 2017). Quantitative measures, such as climate-related variables and resilience indicators, can be systematically collected and analyzed to assess the tangible outcomes of EbA strategies. Concurrently, qualitative methods, including interviews, focus groups, and case studies, can capture the nuanced perspectives of local stakeholders, policymakers, and residents (Plano Clark, 2017). This mixed-methods design not only enables a rigorous evaluation of the effectiveness of EBA interventions in towns but also allows for a deeper exploration of the contextual factors influencing implementation success or challenges.

3.3 Study Location/ Area

The study was carried out in Moiben Sub-County, one of the sub-counties in Uasin Gishu County, located in the Rift Valley region of Kenya, and it is known for its diverse and vibrant ecosystem. "It lies between longitudes 34 degrees 50' east and 35 degrees 37' West and latitudes 0 degrees 03' South and 0 degrees 55' North. It is a highland plateau with altitudes falling gently from 2,700 meters above sea level to about 1,500 meters above sea level. Moiben Sub-County has five wards: Moiben Ward, Sergoit Ward, Kimumu Ward, Tembelio Ward, and Karuna/Meibeki Ward.

The topography is higher to the east and declines gently towards the western border". Moiben Sub-County generally experiences a temperate climate. The temperatures are moderate, with average annual temperatures ranging from 10 to 26 degrees Celsius. The region typically has two distinct rainy seasons: the long rains occurring from March to May and the short rains from October to December. Soils: The county's soils are mainly fertile and well-suited for agricultural activities. The presence of volcanic ash in some areas enhances soil fertility, making Kenya a crucial agricultural hub. The fertile soils support a variety of crops, including maize, wheat, and other horticultural crops (Nying'uro, 2020).

Undulating plains and some hills characterize the topography of Uasin Gishu County. The landscape is suitable for various agricultural activities and is a major contributor to the county's economic activities. Social and Cultural Aspects: the county is home to diverse ethnic communities, including the Kalenjin, Maasai, Luo, and others. The residents celebrate their cultural diversity through traditional dances, music, and festivals. The Kalenjin community is predominant, and their cultural practices play a significant role in shaping the county's social fabric. Agriculture is the backbone of Uasin Gishu County's economy.

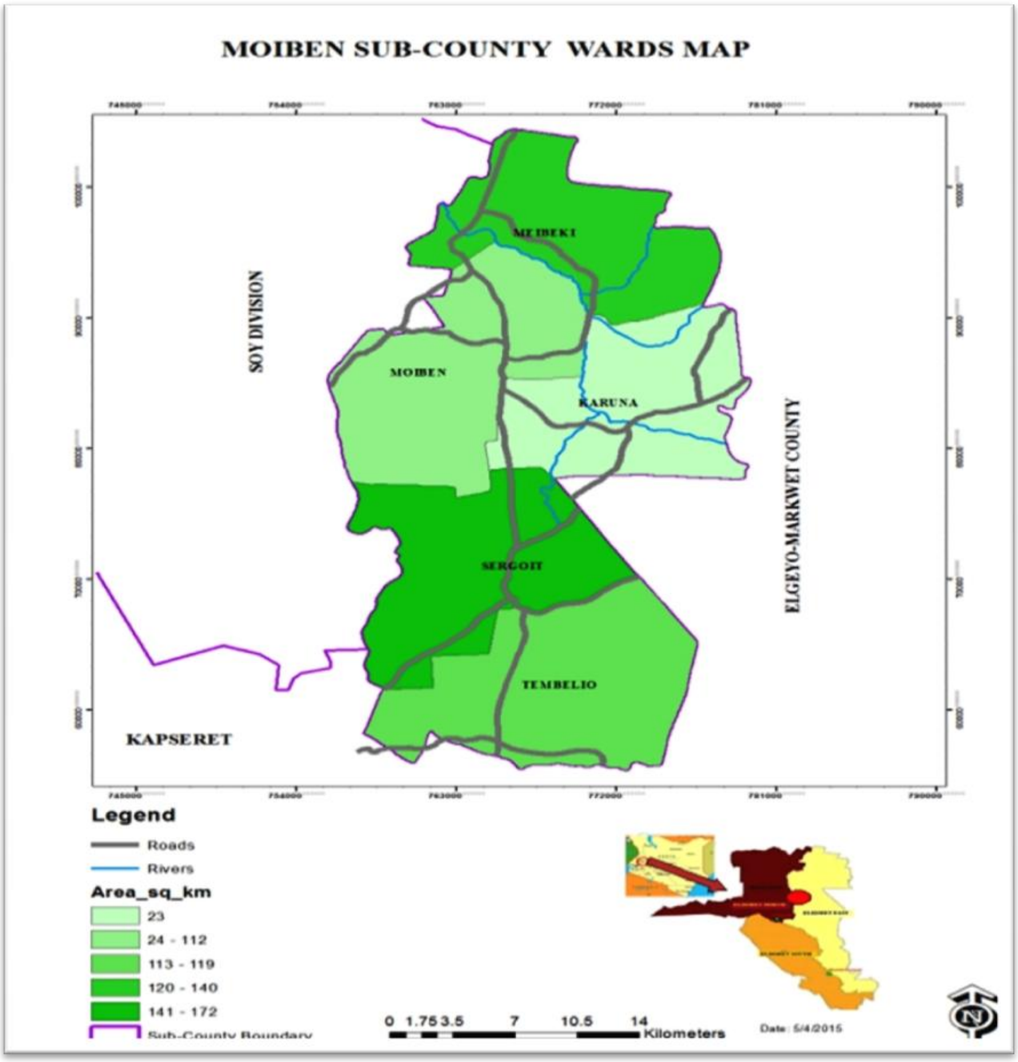
The fertile soils support the cultivation of crops such as maize, wheat, and sugarcane, as well as horticultural products. Livestock farming is also prevalent. The county is known as the "Grain Basket of Kenya" due to its significant contribution to the country's food production. The county is characterized by religious diversity, with a mix of Christianity, Islam, and traditional African religions. There are various churches, mosques, and other places of worship that cater to the religious needs of the diverse population (Adolwa, Mutegi, et al., 2023).

Uasin Gishu County has a mix of natural habitats, including farmlands, forests, and grasslands. The Burnt Forest, located in the county, is an important ecological feature. It contributes to the region's biodiversity and supports various plant and animal species. The county is well connected by road, with Eldoret as a major transportation hub. The Eldoret International Airport facilitates both domestic and international travel. The road network ensures the smooth flow of goods and people, enhancing economic activities in the region. Uasin Gishu has 300 kilometers of tarmac roads, 549 kilometers of murram roads and 377 kilometers of earth roads. It also has 17 kilometers of railway line, 8 railway stations, and an inland container depot. The Eldoret International Airport and two airstrips are also located in the county, all combining to make it the region's service hub. The major urban center in Moiben Sub-County is Eldoret, which serves as an administrative, economic, and educational hub. Other smaller towns and rural settlements contribute to the overall landscape of human habitation in the county. The settlements are characterized by a mix of traditional and modern housing structures (Wanjira & Muriuki, 2020).

Moiben Sub-County faces various climate change challenges, including erratic rainfall, droughts, floods, and extreme temperatures (Uasin Gishu County PCRA report,2023). These vulnerabilities threaten agricultural productivity, livelihoods, and overall community resilience. Implementing and evaluating EbA strategies in Moiben Sub-County, which is directly impacted by climate change, can provide crucial insights into effective adaptation practices and mitigation measures.

Figure 2

Map of the Study Area Moiben Sub- County



Source: Uasin Gishu County Government GIS/Planning Department

3.4 Target Population

The target population of the study was 7,538 respondents. The target population include 7,512 smallholder maize farming households, 9 county government officials and 17 community leaders in Moiben Sub-County (Ministry of Agriculture Uasin Gishu County, 2024).

Table 1

Target Population

Sub County	Target Population
Smallholder maize farmers	7,512
County Government Officials	9
Community leaders	17
Total	7,538

Source: Ministry of Agriculture, Uasin Gishu County (2024)

3.5 Sample Size

According to Peres and Fogliatto (2018), sampling is the process of selecting a subgroup from a population to participate in a study; it is the selection of a number of individuals for a study in such a way that the individuals selected represent the larger group from which they were selected. To determine the sample size for residents of the selected sub-locations, the study used the Krejcie & Morgan (1970) formulae. Sample size for smallholder maize farmers was determined using the formulae as follows:

$$n = \frac{X^2 NP(1-P}{d^2(N-1) + X^2P(1-P)}$$

Where: n = required sample size.

X^2= the table value of chi-square for 1 degree of freedom at the desired confidence level (1.96^2).

N = the population size (7512)

P = the population proportion (assumed to be .50 since this would provide the maximum sample size).

d = the degree of accuracy expressed as a proportion (.05).

$$n = \frac{3.8416 * 7512 * 0.5 * 0.5}{0.05 * 0.05(7512) + 3.8416 * 0.5 * 0.5}$$

$$n = \frac{7237.5744}{18.8375 + 0.9604}$$

$$n = \frac{7237.5744}{19.7979}$$

$$n = 366$$

Using the formulae, a sample size of 366 smallholder maize farmers was arrived at. as presented in Table 2.

Table 2

Sample Size Table

Sub County	Sample Size
Smallholder maize farmers	366
County Government Officials	9
Community leaders	17
Total	390

Source: Researcher (2024)

3.6 Sampling Techniques

3.6.1 Sampling of County Government Officials

To ensure that the views of key stakeholders are adequately represented in the study, purposive sampling was employed to select the 9 county government officials. Purposive sampling involves the intentional selection of individuals with specific knowledge and insights relevant to the study's focus. This method enhances the depth and relevance of the findings by targeting those most likely to provide valuable insights into smallholder farming and ecosystem-based adaptation (EbA) strategies. Purposive sampling is particularly beneficial in this context as it enables the researcher to select participants based on their expertise and roles within the county government.

This includes officials from the Department of Agriculture, the Department of Environment, and other relevant units that oversee or implement policies related to smallholder farming and ecosystem-based adaptation (EbA) strategies. These officials are chosen because they possess valuable insights into the implementation, challenges, and effectiveness of these strategies at the county level (Etikan, Musa, & Alkassim, 2016).

3.6.2 Sampling of Community Leaders

Purposive sampling was used to select 17 community leaders in Moiben Sub-County. Purposive sampling is a nonprobability sampling technique in which participants are selected based on specific characteristics, roles, or knowledge relevant to the study's objectives. This method is particularly useful when the study requires in-depth insights from individuals with expertise or significant influence in the area under investigation (Palinkas et al., 2015).

These 17 community leaders, who may include village elders, heads of farmer cooperatives, and respected local figures with influence over community decision-making, are chosen for their deep understanding of local agricultural practices and for their role in mobilizing and guiding smallholder farmers in adopting EbA strategies. Their insights provide critical perspectives on community-level adoption and the socio-cultural factors influencing the implementation of EbA strategies (Gentles, Charles, Ploeg, & McKibbon, 2015).

According to Campbell, Greenwood, et al. (2020), the purposive sampling approach ensures that the selected informants are those most knowledgeable about the subject matter, thereby providing rich, relevant data to address the study's objectives. Their contributions were essential in understanding the local context and the practical realities of implementing and adopting EbA strategies among smallholder maize farmers in Moiben Sub-County.

Community leaders were included in the Focus group discussion since these individuals possess unique and critical insights into the local context. Since these leaders, such as village elders or heads of farmer cooperatives, have a direct influence on community decision-making and are well-versed in local farming challenges, their participation yields in-depth, context-specific data essential for the study.

By engaging community leaders in focus group discussions, the study can gather collective insights into community dynamics, barriers to implementing ecosystem-based adaptation (EbA) strategies, and how socio-cultural factors shape farming decisions. The diverse experiences provide a more nuanced understanding of the adoption of EbA strategies, which might be missed with broader random sampling methods. As noted by Campbell et al. (2020), purposive sampling ensures that informants are selected for their expertise, thereby maximizing the depth and relevance of the data collected, which is crucial for addressing the study's objectives.

3.6.3 Sampling of Smallholder Maize Farmers

In the study of smallholder maize farmers in Moiben Sub-County, random sampling involves creating a comprehensive list of all eligible farmers and selecting participants at random. To apply simple random sampling in the study of smallholder maize farmers, a complete list of eligible farmers was compiled from the Ministry of Agriculture, Uasin Gishu County (2024). Each farmer on the list was assigned a number, and a random number generator was used to select the sample. This ensures that each farmer has an equal chance of being included in the study, minimizing bias and making the sample representative of the entire farming population (Šūmane et al., 2018).

The primary advantage of random sampling is that it reduces bias and yields a representative sample of the entire population, which is crucial for generalizing findings to the broader population. In this study, random sampling enables an unbiased assessment of the adoption rate of ecosystem-based adaptation (EbA) strategies among smallholder maize farmers. By employing this method, the study can accurately reflect the diverse practices and experiences of the farmers in Moiben Sub-County. Furthermore, random sampling facilitates statistical analysis by ensuring that each participant has an equal chance of being selected, thereby supporting the validity and reliability of the research outcomes (Creswell, 2014; Kothari, 2004).

3.7 Data Collection Instruments

This study used a questionnaire for smallholder maize farmers, interviews for county government officials and focus group discussions for community leaders and smallholder maize farmers to collect data.

3.7.1 Questionnaires for Smallholder Farmers

Questionnaires are carefully designed instruments for collecting data directly from people through questions or statements. The advantage of using this type of instrument is the ease it provides the researcher during analysis. Moreover, questionnaires are easy to administer and cost-effective, especially when collecting data from a large sample (Artino Jr et al., 2014).

The questionnaire used for this study consisted of both closed-ended questions. Closed-ended questions ensured data consistency, while open-ended questions gave respondents the freedom to express themselves. The questionnaire used in this study was divided into sections. Section A of the questionnaires contained closed-ended questions that collected personal data from respondents. The remaining sections contained questions intended to elicit responses on specific objectives and ultimately to achieve the study's goal, which is to evaluate the effectiveness of ecosystem-based adaptation strategies in mitigating climate change vulnerabilities in Moiben Sub-County, Kenya.

3.7.2 Interviews

Interviews were used to collect data from County Government Officials. Interviews were used to clarify some aspects that may not have been captured in the questionnaires. This method also helps in checking the occurrence of data obtained by other methods (Smith,2020). The interview guide included open-ended questions aimed at eliciting information from county officials on the effectiveness of ecosystem-based adaptation strategies in mitigating climate change vulnerabilities in the study area. Open-ended questions help the researcher gain in-depth information about the problem under study. The interviews targeted the following departments: five officers from the County Department of Agriculture and five officers from the County Department of Environment and Natural Resources.

These interviews utilized a semi-structured interview guide with open-ended questions, allowing for comprehensive exploration of the effectiveness of EbA strategies in mitigating climate change vulnerabilities. This approach ensured that the research captures detailed, qualitative data to complement the quantitative data obtained through other methods (Smith, 2020).

3.7.3 Focus Group Discussion (FGDs)

Focus Group Discussions (FGDs) were used to gather qualitative information from 17 community leaders and 40 smallholder maize farmers. The study used open-ended questions for the focus group discussion guide. Among the community leaders participating in the focus group discussion are eight village elders, two local area chiefs, three religious leaders, and four heads of cooperatives, both current & former. For the smallholder maize farmers, the study focused on 8 members, 4 females and 4 males per group, based on the statistical data present at the county government. The researcher conducts five (5) FGDs to cover the study area, which comprises 5 wards: Moiben Ward, Sergoit Ward, Kimumu Ward, Tembelio Ward, and Karuna/Meibeki Ward. One (1) FGD per ward, with a range of 8 to 12 members per group, yielded a total of 40 respondents from the sample. Each focused group comprised 8 smallholder maize farmers and 3 or 4 community leaders.

FGD was conducted with the help of either the area chief/the head of cooperatives/the village elders/religious leader who organized meetings where the researcher conducted the FGD. Area chiefs, religious leaders, village elders, and the head of society cooperatives were briefed early enough to call for meetings per village on different days. The discussions were recorded using audio and video recording. FGD is widely used and applauded mainly for its convenience, economic advantages, high face validity, and speedy results. In addition, focus groups were used to generate information on collective views and to gather in-depth insights into the meanings behind those views (Boateng, 2018).

The Focus Group Discussions (FGDs) in the study comprised five sessions, each held in a different village within Moiben Sub-County. The FGDs aim to harness local knowledge and perspectives, facilitated by community leaders who convene and guide discussions among participants. This method ensures a diverse representation of community voices and allows for in-depth exploration of agricultural practices, challenges, and sustainable solutions relevant to the study area. Audio recordings captured the dialogues, enabling thorough qualitative analysis to uncover shared experiences and collective insights that inform the study's findings.

3.8 Reliability and Validity of Instruments

3.8.1 Reliability

Reliability refers to the extent to which a research instrument produces consistent results after repeated trials (Mugenda and Mugenda, 2003). To ascertain the reliability of the research instruments, the researcher piloted them among residents of Kwanza Sub-County in Trans-Nzoia County, which shares similar features with Moiben Sub-County in Uasin Gishu County but was not part of the sample of this study. The pilot respondents represent 10% of the sample size (36 participants). The results of the piloted research instruments enabled the researcher to determine the consistency of responses to be made by respondents and adjust the items accordingly by revising the document. Pearson's Product-Moment formula (Cronbach’s Alpha value) was used to obtain the correlation coefficient (r). A reliability coefficient of 0.70 or higher indicates that the instruments are dependable enough to be adopted for the study, as demonstrated by Taber (2018).

3.8.2 Validity

Validity of a research instrument refers to the degree to which it measures what it purports to measure (Kothari and Garg 2019). Content validity was established by submitting the research instruments to university supervisors, experts in the field. Their views and suggestions were incorporated into the research instruments before the actual data collection.

3.9 Data Analysis

The data analysis process for this study encompasses both quantitative and qualitative methodologies, each tailored to extract meaningful insights from the specific data collected. Quantitative data obtained from the structured questionnaires undergo meticulous cleaning procedures to ensure accuracy and reliability. This includes identifying and rectifying any errors or inconsistencies in the responses. Once cleaned, the data were coded and entered into SPSS version 24 for statistical analysis. Descriptive statistics, such as means, standard deviations, frequencies, and percentages, were computed to summarize the central tendencies and variability of variables related to the study's objectives. These statistical measures were crucial for quantifying aspects such as smallholder maize farmers' perceptions of climate change risks and their attitudes towards ecosystem-based adaptation strategies. The findings from these analyses were presented in tables and figures, providing clear visual representations of the quantitative results and enabling comparisons across different respondent groups.

The study used inferential statistics, in addition to descriptive statistics and thematic analysis. This included correlation analysis and regression analysis. According to Mugenda and Mugenda (2003), the correlation technique is used to analyze the degree of relationship between two variables. The study used multiple regression analysis to conduct inferential statistics, which aim to determine relationships between variables, whether a group of variables predicts a given dependent variable, and hence to increase the accuracy of the estimate (Cox, 2018).

The multiple regression model for this study is as follows: Multiple linear regression model with dependent variable (Y) – mitigating climate change vulnerabilities, and the independent variables X_1 (ecosystem-based adaptation strategies), X_2 (rate of adoption EbA), X_3 (effectiveness of EbA strategies), was used to show whether the stated independent variables significantly influence mitigation of climate change vulnerabilities among smallholder maize farmers. The regression model is as illustrated:

Equation 1: Statistical Measurement Model

$Y= \beta_0 + \beta_1X_1+ \beta_2X_2+\beta_3X_3+ \varepsilon$

Where;

Y= mitigating climate change vulnerabilities

β_0=Constant

β_i=is the coefficient for Xi (Where i = 1,2,3)

X_1 =Ecosystem-based adaptation strategies

X_2=Rate of adoption EbA

X_3 =Effectiveness of EbA strategies

ε=Error term

β_1=Regression coefficient of variable X_1,

β_2= Regression coefficient of variable X_2,

β_3=Regression coefficient of variable X_3.

Qualitative data, to be derived from key informant interviews and focus group discussions, were transcribed verbatim to capture the richness of participants' perspectives and experiences. Thematic analysis, a systematic approach to identifying and interpreting patterns or themes within qualitative data were employed. This process involves immersion in the data to familiarize oneself with its content, followed by the generation of initial codes to categorize segments of text. These codes were systematically organized into potential themes, which were refined through iterative review and comparison across the dataset. Themes were developed from recurring patterns and meaningful connections identified in participants' narratives. Through this qualitative analysis, the study aims to uncover nuanced insights into how local government officials and community leaders perceive the effectiveness of existing ecosystem-based adaptation strategies in Moiben Sub-County. The integration of qualitative findings with quantitative results provided a comprehensive understanding of the complex dynamics surrounding climate change adaptation efforts in the study area.

Table 2

Data Analysis Plan

Objective	Hypothesis	Data Source	Analysis Methods
1: Ecosystem-based adaptation strategies	H01: There are no significant ecosystem-based adaptation strategies implemented by smallholder maize farmers to mitigate climate change vulnerabilities in the study area.	Household surveys with farmers	Descriptive statistics: Frequencies, means, SD; Regression analysis; show Relationship analysis between variables
2: Rate of adoption of the EBA strategies	H02: There is no significant adoption of ecosystem-based adaptation strategies among smallholder maize farmers in the study area.	Household surveys with farmers	Descriptive statistics: Frequencies, means, SD; Regression analysis; Relationship analysis between farmer characteristics and EBA adoption rates.
3: Assess the effectiveness of ecosystem-based adaptation strategies	H03: There is no effectiveness of ecosystem-based adaptation strategies in reducing climate change vulnerability among smallholder maize farmers in the study area.	Household surveys with farmers	Regression analysis: Relationship between EBA practices and vulnerability index scores.

3.10 Expected Outcomes:

i. Assessment of current climate change vulnerabilities faced by Uasin Gishu County.

ii. Evaluation of the effectiveness of the implemented ecosystem-based adaptation strategy in reducing climate change vulnerabilities.

iii. Analysis of the existing ecosystem-based adaptation strategies in enhancing adaptive capacity and reducing vulnerability in Moiben Sub-County.

iv. Identification of challenges and opportunities associated with implementing ecosystem-based adaptation strategies in an urban context.

v. Recommendations for improving the effectiveness and scalability of ecosystem-based adaptation strategies in Moiben Sub-County and similar urban areas.

Table 3

Operationalization of Variables

Variables	Unit of Measurement	Tools used to measure
Dependent Variable		
Mitigating Climate change vulnerabilities	• Climate-Related Losses • Soil Health • Biodiversity • Agricultural Productivity	Descriptive statistics Multiple regression analysis Thematic analysis
Independent Variables		
Existing EbA strategies implemented	• Soil conservation • Crop diversification • Agroforestry • Water management	Descriptive statistics Multiple Regression Analysis Thematic analysis
Rate of adoption EbA strategies	• Awareness EBA practices • Extent of adoption • Duration of Use • Use of Extension Services	Descriptive statistics Multiple Regression Analysis Thematic analysis
Effectiveness of EbA strategies	• Water Quality • Soil Nutrient Levels • Income Sources • Soil Carbon	Regression analysis Correlation analysis
Intervening Variables	• Farmer Education • Economic Stability • Institutional Support • Conservation Policies	

Source: Researcher (2024)

3.12 Ethical Considerations

To uphold ethical considerations, the study implemented several key strategies. First, informed consent was prioritized by providing all participants with clear, comprehensive information about the study's objectives, procedures, and potential risks and benefits. Consent forms were distributed and explained in detail, allowing participants to ask questions before agreeing to participate. Importantly, participants were informed that they could withdraw from the study at any time without repercussions, ensuring voluntary participation throughout the research process.

Confidentiality was maintained by anonymizing all collected data. Instead of using personal identifiers like names, unique identification codes were assigned to each participant. This anonymized data was stored securely using encrypted digital storage systems, and any physical data was kept in locked facilities accessible only to the research team. Upon completion of the study, sensitive data were archived or securely destroyed in accordance with institutional ethical guidelines, minimizing the risk of unauthorized access or breaches.

To ensure voluntary participation, the study clearly communicates that participants have the right to withdraw at any time. This was reinforced periodically to avoid any pressure on participants, especially when addressing sensitive topics like climate change vulnerabilities. Moreover, participants were not required to answer questions that made them uncomfortable, further protecting their autonomy.

To safeguard participants' emotional well-being, especially given the potentially distressing nature of the subject matter, the research team implemented protocols to provide support. This may include offering access to counseling or referral services for participants who experience distress during the study. Researchers received training on handling such situations with empathy and sensitivity, ensuring participants are respected and supported throughout the research.

The study ensured cultural sensitivity by engaging local stakeholders and community leaders before data collection. This engagement helps researchers understand and respect local customs and cultural practices, fostering trust between participants and the research team. By approaching the research with cultural awareness, the study ensured that the findings are both relevant and respectful of the communities involved.

Before beginning the research, ethical approval was obtained from an Institutional Review Board (IRB) or Ethics Committee. This step ensures that the study adheres to all relevant ethical standards, protecting participants' rights and welfare. In addition, participants were given opportunities to review the findings and provide feedback, ensuring transparency and reinforcing their role as key contributors to the research process.

Finally, data management was carefully handled during and after the study. All collected data was stored securely in encrypted databases, with access restricted to authorized personnel only. After the research was completed, the data were securely archived for a designated period, after which they were destroyed in accordance with ethical guidelines. This comprehensive approach to data management ensures that participants' confidentiality is protected long after the research has concluded.

CHAPTER FOUR

DATA ANALYSIS, FINDINGS AND DISCUSSIONS

4.1 Introduction

In Chapter Four, the data analysis, findings, and discussions are presented to delve into the research outcomes and their implications.

4.2 Response Rate

The research evaluated participants' response rates in relation to the data collection approach. The discussion included the percentage of individuals who engaged in the study and its potential impact on the research's overall validity. Table 4 presents the findings.

Table 4

Instrument Response Rate

	Frequency	Percentage
Responded	323	88.25
Not responded	43	11.75
Total	366	100

The study findings in Table 4 shows the instrument response rate: of a total of 366 (100%) respondents, 323 (88.25%) provided responses, while 23 (17.03%) did not participate in the survey. This distribution indicated a relatively high level of engagement from participants in the study.

4.3 Demographic Information of the Respondent

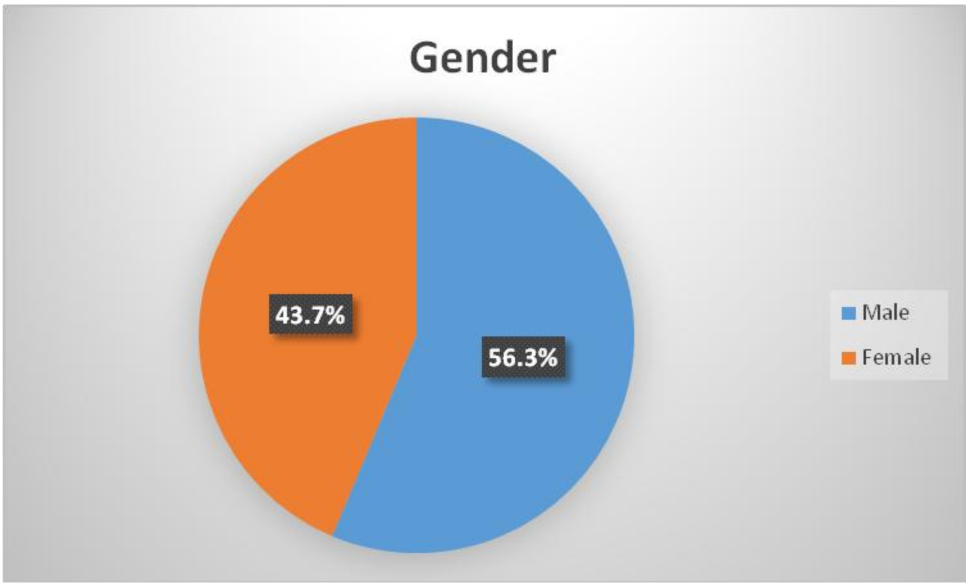
In Section 4.3, the demographic characteristics of the respondents are examined. This analysis offers insights into the diverse profiles of participants, including age, gender, educational background, and other relevant factors.

4.3.1 Gender Distribution of the Respondents

The study evaluated the gender distribution of respondents, shedding light on the representation of different genders among participants. Figure 4.1 presents the results of the study.

Figure 3

Gender of the Respondents



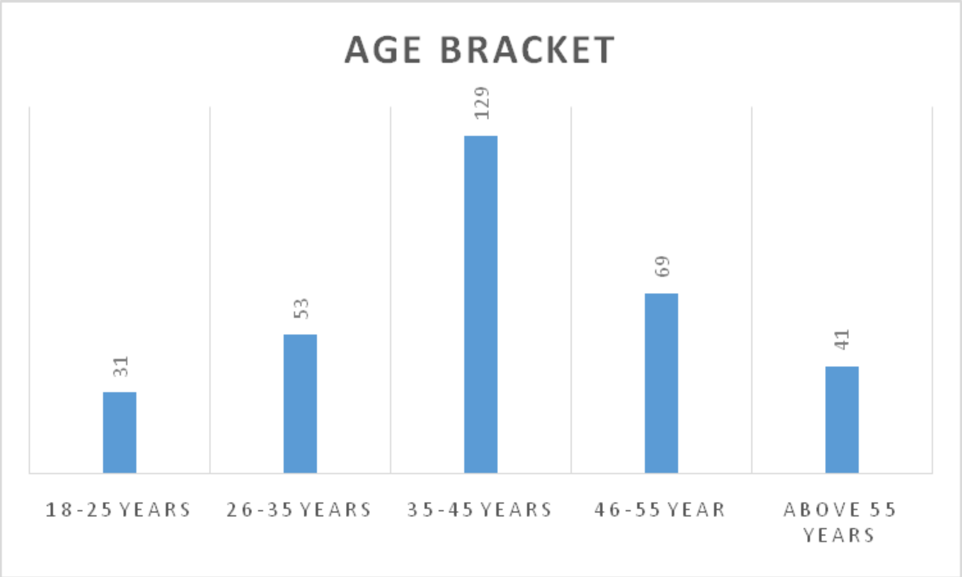
The findings in Figure 3 reveal that the majority of respondents were male, accounting for 182 (56.3%), while female respondents accounted for 141 (43.7%) of the total 323 participants. This indicates that males constituted a slightly higher proportion of the study sample than women. The higher male representation may reflect the gender roles typically associated with smallholder maize farming in Moiben Sub-County, where male respondents may have more access to land, decision-making authority, or engagement in agricultural programs.

4.3.2 Age of the Respondents

The ages of those who responded to the survey were considered to provide an in-depth understanding of the age distribution within the participant group. Figure 4.2 presents the findings.

Figure 4

Age of the Respondents



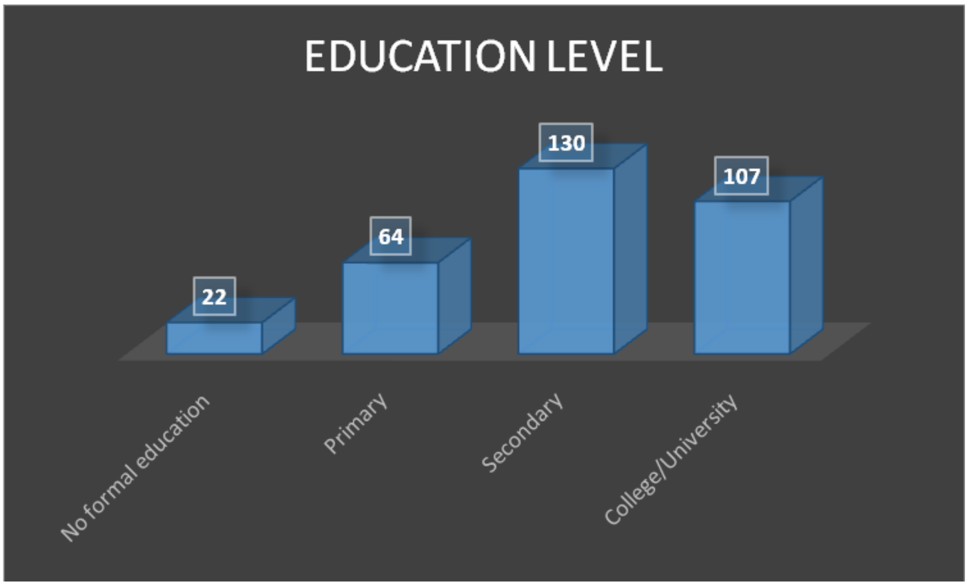
Study findings in Figure 4 present the distribution of respondents' ages. Among the 323(100%) participants, 31(9.6%) were aged between 18–25 years, 53(16.4%) fell within the 26–35 years age group, 129(39.9%) were between 35–45 years, 69(21.4%) belonged to the 46–55 years bracket, and 41(12.7%) were above 55 years. This distribution illustrates a diverse age composition in the sample, with the highest representation in the 35–45 age group. Such a trend may suggest that this age bracket forms the core of active smallholder maize farmers in Moiben Sub-County.

4.3.3 Education Level of the Respondents.

The researcher also sought to determine respondents' educational levels. Figure 5 presents the study results.

Figure 5

Education Level



Study findings in Figure 5 present the distribution of respondents' education levels. Out of the 323(100%) participants, 22(6.8%) had no formal education, 64(19.8%) had attained primary education, 130(40.2%) had secondary education, while 107(33.1%) had reached college or university level.

This distribution shows that the majority of respondents had at least secondary education, indicating a relatively educated farming population in Moiben Sub-County. The high proportion of respondents with post-primary education may contribute to better understanding and uptake of ecosystem-based adaptation strategies.

4.3.4 Farm Size

The outcome of the research on the farm size of research participants was summarized in Table 5.

Table 5

Farm Size

Farm Size	Frequency	Percentage
1-5 acres	130	40.2
6-10 acres	75	23.2
11-15 acres	57	17.6
More than 15 acres	61	18.9
Total	323	100.0

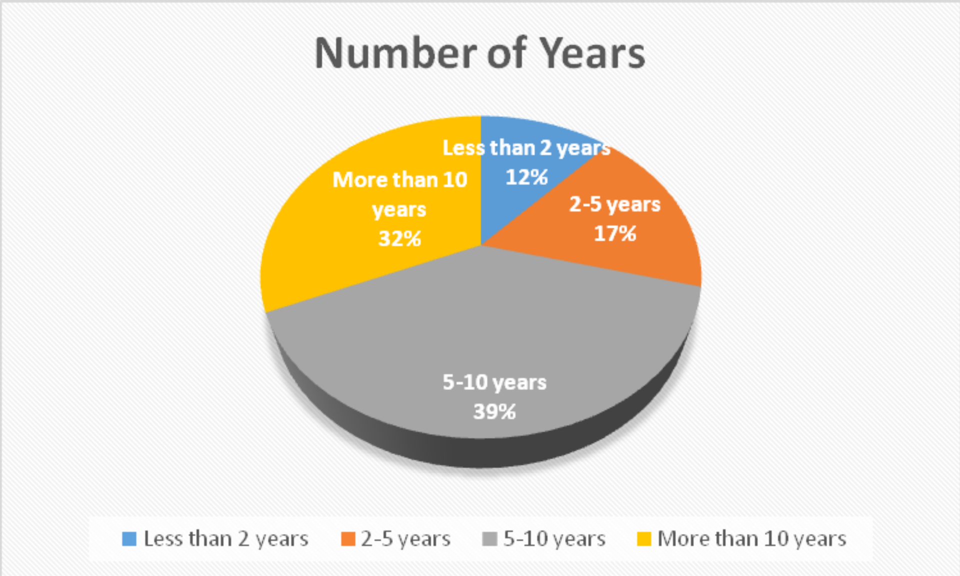
Study findings in Table 5 present the distribution of respondents by farm size. Out of the 323(100%) participants, 130(40.2%) owned farms ranging from 1–5 acres, 75(23.2%) had 6–10 acres, 57(17.6%) managed 11–15 acres, while 61(18.9%) cultivated more than 15 acres. This distribution shows that the majority of respondents were small-scale farmers operating on less than 6 acres. However, the majority of respondents also engaged in medium- to relatively large-scale maize farming. Farm size is a crucial factor influencing both exposure to climate change vulnerabilities and the capacity to implement ecosystem-based adaptation strategies.

4.3.5 Farming Experience

In Section 4.3.3, the number of years that respondents have been farming. Figure 6 presents the results.

Figure 6

Farming Experience



The study findings in Figure 6 present the distribution of respondents by farming experience. Out of the 323(100%) participants, 38(11.8%) had less than 2 years of farming experience, 56(17.3%) had between 2–5 years, 127(39.3%) had 5–10 years, while 102(31.6%) had been farming for more than 10 years. This finding reveals that the majority of respondents had considerable farming experience, having more than 5 years of practice. This suggests that most participants were seasoned farmers, likely exposed to multiple climate events and varying agricultural practices over time.

4.3.6 Household Income from Farming.

The outcome of the research on household Income from Farming of research participants was summarized in Table 6.

Table 6

Household Income from Farming

	Frequency	Percentage
Less than 10,000 KES per month	62	19.2
10,001-20,000 KES per month	135	41.8
20,001-30,000 KES per month	76	23.5
More than 30,000 KES per month	50	15.5
Total	323	100.0

The study findings in Table 6 present the distribution of respondents by their monthly household income from farming. Out of the 323(100%) participants, 62(19.2%) earned less than 10,000 KES per month, 135(41.8%) earned between 10,001–20,000 KES, 76(23.5%) earned between 20,001–30,000 KES while 50(15.5%) earned more than 30,000 KES per month.

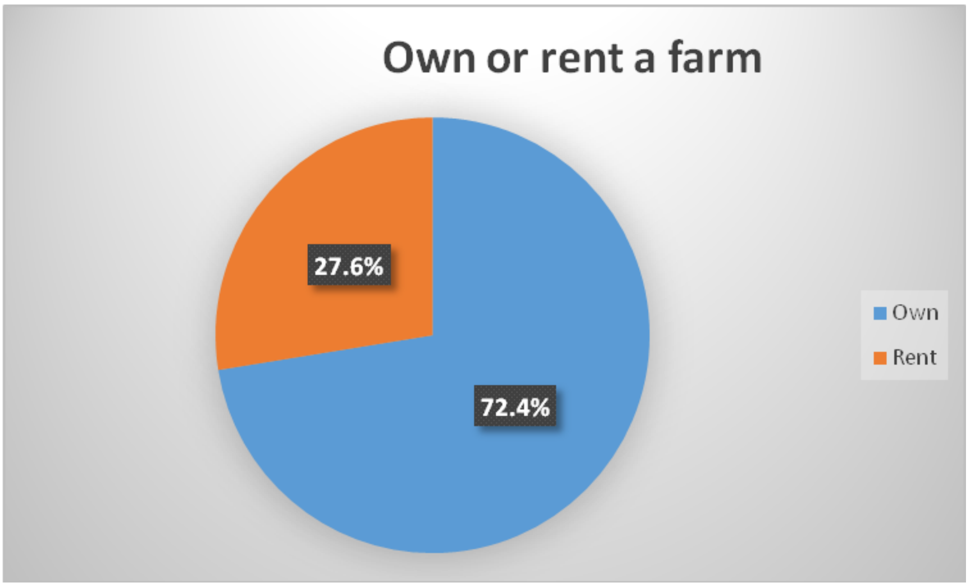
This distribution indicates that the largest proportion of respondents earned modest incomes from farming, with the majority earning below 20,000 KES. This suggests that many smallholder farmers in Moiben Sub-County operate at a subsistence or near-subsistence level.

4.3.7 Do You Own or Rent the Farm?

The study sought to determine if the respondents own or rent a farm. A summary of results is presented in Figure 7.

Figure 7

Own or Rent a Farm



The study findings in Figure 7 present the distribution of respondents by farm ownership. Out of the 323(100%) participants, 234(72.4%) reported that they owned the land they farmed, while 89(27.6%) indicated they rented the land. This distribution shows that a majority of respondents were landowners, suggesting greater control over land-use decisions, including the adoption of long-term ecosystem-based adaptation strategies.

4.4 Discussions of Descriptive Statistics and their Results

In Section 4.4, the discussions focus on the outcomes of the descriptive statistics analysis. This examination involves interpreting and deliberating on the key findings from the collected data, offering insights into the dataset's central tendencies, distributions, and patterns.

4.4.1 Descriptive Statistics Findings for Existing Ecosystem-Based Adaptation Strategies Implemented

Section 4.4.1 sought to evaluate the existing ecosystem-based adaptation strategies implemented among smallholder maize farmers in Moiben Sub-County. Table 4.9 showed the study findings. Key: For the sake of this chart, SD means Strongly Disagree, D means Disagree, N means Neutral, A means Agree, and SA means Strongly Agree. Analysis of the response mean scores was conducted on a continuous scale: <1.5 represents strongly disagree; 1.5-2.4 disagree; 2.5-3.4 neutral; 3.5-4.5 agree; and>4.5 strongly agree. Responses were elicited on a 5-point Likert scale as shown in Table 7.

Table 7

Ecosystem-Based Adaptation Strategies Implemented

Statements		SD	D	N	A	SA	Mean	Stdv
1. I practice soil conservation techniques (for example terracing, contour farming) on my farm.	F	21	25	37	112	128	3.93	1.19
	%	6.5	7.7	11.5	34.7	39.6		
2. Crop diversification is a key strategy I use to increase resilience to climate variability.	F	12	23	48	145	95	3.89	1.03
	%	3.7	7.1	14.9	44.9	29.4		
3. I have integrated agroforestry practices (for example trees interplanted with crops) on my farm.	F	14	37	40	106	126	3.91	1.17
	%	4.3	11.5	12.4	32.8	39.0		
4. Water management strategies such as rainwater harvesting or irrigation are in place.	F	16	37	34	102	134	3.93	1.19
	%	5.0	11.5	10.5	31.6	41.5		
5. I implement cover cropping or mulching to improve soil moisture retention.	F	27	25	25	125	121	3.89	1.23
	%	8.4	7.7	7.7	38.7	37.5		
6. My farm benefits from mixed farming, combining crops and livestock as part of EbA.	F	12	13	32	114	152	4.18	1.02
	%	3.7	4.0	9.9	35.3	47.1		
7. I actively participate in community programs promoting soil and water conservation.	F	15	20	48	125	115	3.94	1.08
	%	4.6	6.2	14.9	38.7	35.6		
8. The use of organic farming practices is part of my overall strategy to adapt to climate change.	F	13	20	37	109	144	4.09	1.08
	%	4.0	6.2	11.5	33.7	44.6		

The study results in Table 7 showed that the majority, 240 (74.3%), of the respondents agreed that they practice soil conservation techniques (for example, terracing, contour farming) on their farms. On the contrary, 46 (14.2%) of the respondents disagreed that they practice soil conservation techniques (for example, terracing, contour farming) on their farm. Further, the study results showed, in terms of mean and standard deviation, that the respondents agreed with the statement that they practice soil conservation techniques (for example, terracing, contour farming) on their farm (Mean=3.93, standard deviation=1.19). The study's findings agreed with those of Telles et al. (2022), who found that most farmers in the study lacked sufficient knowledge of the pillars of CA. As a result, there is little crop rotation diversification, and the soil is continually disturbed by chiselling.

County Government Officials [1] said that:

> *"Many smallholder maize farmers in Moiben Sub-County have adopted* soil conservation techniques *as part of their long-term land management, often with guidance from agricultural extension officers. The department actively promotes soil conservation through farmer training programs and demonstration plots."*

Ngele (2015) noted that 77.9% of the farmers were adopting soil conservation measures. Cost involved, low contact with farmer extension officers, poor road network, and lack of adequate knowledge of extension services were some of the challenges highlighted by the farmers that hindered their access to extension services.

Also, the study found that 240 (74.3%) of the respondents agreed that crop diversification is a key strategy for increasing resilience to climate variability, while 35 (10.8%) disagreed. Further, the study results also showed, in terms of mean and standard deviation, that the respondents agreed that crop diversification is a key strategy they use to increase resilience to climate variability (Mean=3.89, standard deviation=1.03). These findings are consistent with the study by Vernooy (2022), which reveals ample evidence of positive outcomes, including increased yields and household incomes, improved nutrition and food security, new marketing opportunities, reduced poverty, and strengthened adaptive and innovative capacity.

County Government Officials [2] said that:

> *"Farmers often diversify with legumes, vegetables and drought-resistant crops alongside maize to spread risk and stabilize household income. Our department supports diversification through seed distribution programs and agronomic advice, although uptake is sometimes constrained by market access and the perception that maize remains the safest economic crop."*

Mihrete and Mihretu (2025) noted that these diversification tactics (spatial, temporal, genetic, and intercropping diversification) are effective, as they improve soil health and pest management and increase resilience to climate variability. The review points out some guiding principles, namely ecological resilience, risk distribution, and resource optimization. This can be achieved through the adoption of heterogeneous crops by the farmer, which will reduce soil degradation, pest outbreaks, and stabilize income. Other diversification case studies, such as integrated rice-fish farming and agroforestry across different regions, have also been successful and have shown the ability to enhance productivity and sustainability.

Mustafa, Mayes, and Massawe (2019) note the impacts of climate change, including shifts in crop production zones and reduced yields due to increasingly unpredictable and harsher weather conditions. The dwindling of crops that feed the world has also been linked to reported decreases in agricultural biodiversity and a subsequent rise in the genetic homogeneity of yield characters in crop plants. This would be harmful, as it might make crops more susceptible to pests and diseases. One solution to these issues is crop diversification, including greater use of underutilized and minor crops. Underutilized, minor, or neglected crops are native plant species rather than domesticated arrivals and usually constitute an intricate component of the cultures concerned in growing them. Utilizing underutilized crops on a broader scale would enhance agricultural biodiversity (genetic, species, and ecosystem) to prevent vulnerability to climate change, pests, and diseases. It would provide high-quality food and a varied food source to address both food and food security.

The study further revealed that 232 (71.8%) of the participants agreed that they have integrated agroforestry practices (for example, trees interplanted with crops) on their farms. On the contrary, 41 (15.8%) of the respondents disagreed that they have integrated agroforestry practices (e.g., trees interplanted with crops) on their farm. Further, the study results showed, in terms of mean and standard deviation, that the respondents agreed they have integrated agroforestry practices (e.g., trees interplanted with crops) on their farms (Mean=3.91, standard deviation=1.17).

County Government Officials [3] said that:

> *"Agroforestry is promoted both for its ecological benefits and as a source of alternative income through timber, fodder, and fruit production. Partnerships with NGOs have provided tree seedlings and training, although challenges remain in ensuring long-term maintenance of planted trees."*

Raj et al. (2019) found that the agroforestry sector provides up to 65.0 per cent of timber and 50.0 per cent of fuelwood. Thus, agroforestry too holds the possibility of alleviating poverty, boosting income earning, and providing economic alternatives. The other advantages include agroforestry practices being economically viable for farmers and creating employment. Different options are presented to farmers for adopting various AFM, with the integration of a number of tree crops and livestock across different agroclimatic regions. Farmers can choose AFM based on socio-physical conditions (i.e., landholding, economic conditions, climatic conditions, resource availability, market conditions).

The study also showed that 236 (73.1%) of the participants agreed that water management strategies, such as rainwater harvesting or irrigation, are in place. Contrary to those findings, 53 (16.5%) of the respondents disagreed that water management strategies, such as rainwater harvesting or irrigation, are in place. Further, the study results showed, in terms of mean and standard deviation, that the respondents agreed with the statement that water management strategies, such as rainwater harvesting or irrigation, are in place (Mean=3.93, standard deviation=1.19). These findings are consistent with the study by Velasco-Muñoz, Aznar-Sánchez, Batlles-delaFuente, and Fidelibus (2019), which reveals that this line of research is becoming increasingly important within research on irrigation. Environmental sciences and agricultural and biological sciences are the most relevant subject areas.

County Government Officials [4] said that:

> *"Water harvesting tanks, small irrigation kits, and drainage systems have been introduced through collaborative programs between the county government and development partners."*

Furthermore, 246 (76.2%) agreed that they implement cover cropping or mulching to improve soil moisture retention, while 52 (16.1%) disagreed. Regarding mean and standard deviation, the respondents agreed that they implement cover cropping or mulching to improve soil moisture retention (mean=3.89, standard deviation=1.23). The study's findings agreed with those of Demo and Asefa Bogale (2024), who noted that mulching has several advantages for dryland agriculture, such as reducing soil water loss, soil erosion, weed growth, water droplet kinetic energy, and competition for nutrients and water with nearby fields.

County Government Officials [5] said that:

> *"Mulching is widely promoted for its role in reducing soil erosion, suppressing weeds, and conserving moisture during dry spells. Some farmers have adopted cover crops; others find the practice labor-intensive and lack sufficient biomass material."*

El-Beltagi et al. (2022) found that various mulching materials have major impacts on the soil hydrothermal regime by modifying soil moisture and temperature, which ultimately affect soil microbiology and plant growth. Straw, plastic film, sand, and gravel mulches save water, reduce evaporation, and help protect against erosion. Different types have their own advantages and limitations and are based on availability, durability, and cost. Plastic mulch will warm the soil in early spring, whereas straw mulch cools the soil in summer, and all this enhances crop growth. The right choice of mulch can promote moisture retention, prevent weed growth, improve soil health, and contribute to long-term food security.

Further, 266 (82.4%) of the respondents agreed that their farm benefits from mixed farming, combining crops and livestock as part of EbA, while 24 (7.7%) disagreed. Furthermore, the study's findings revealed that participants agreed (mean=4.18, standard deviation=1.02) that their farm benefits from mixed farming, combining crops and livestock as part of EbA.

The study further revealed that 240(74.3%) of the respondents agreed that they actively participate in community programs promoting soil and water conservation. However, 35(10.8%) of the respondents disagreed that they actively participate in community programs promoting soil and water conservation. Additionally, the study's results on the mean and standard deviation indicated that the respondents agreed they actively participate in community programs promoting soil and water conservation (Mean=3.94, standard deviation=1.08). These findings are consistent with the study by Biratu and Asmamaw (2016), which found that farmers perceived the existence of a soil erosion problem on their farmland and had strong motives to participate in SWC activities. The respondents noted that soil erosion, its causes, and productivity decline were the major indicators of soil erosion. The majority of respondents (76%) participated in conserving soil out of their own interest.

County Government Officials [6] said that:

> *Community programs are often coordinated through farmer groups, with community workdays focused on erosion control and water-harvesting structures.*

Arora, Bhatt, Sharma, and Hadda (2023) found that the region's fragile ecosystem, which is prone to erosion, is the main limitation to agricultural production in terms of soil and water resources. The cultivation of the topsoil, however, due to intense rains and hilly terrain, has eroded and become the main problem in speeding up sustainable agricultural practices in the region, further dividing the land, land fertility, and land yields. The intense rains over a short period on bare, sloping hillsides are the root cause of the immense erosion in the area, and addressing the issue in both directions can minimize the erosion they cause. Socio-economically, the farmers are illiterate and poor, and they are reluctant to adopt innovative methods of land and water conservation. All of this makes minimizing erosion losses very demanding.

Finally, 253 (78.3%) agreed that using organic farming practices is part of their overall strategy to adapt to climate change. However, 33 (10.2%) of the respondents disagreed that using organic farming practices is part of their overall strategy to adapt to climate change. Further, the study results also showed, in terms of mean and standard deviation, that the respondents agreed that the use of organic farming practices is part of their overall strategy to adapt to climate change (Mean=4.09, standard deviation=1.08). The study results agreed with Fadina and Barjolle (2018), who found that farmers have a developed perception of climate change. These changes are translated into rainfall disturbances (rainfall delays, early cessation, poor rainfall distribution, etc.), a shortening of the small dry season, increased temperatures, and sometimes violent winds.

County Government Officials [7] said that:

> *"Organic farming is encouraged to maintain soil health, reduce dependency on chemical inputs, and improve market value for produce."*

Findings from the study's focus group discussion (FGD) clearly indicated that farmers at the study site have changed and now know different ecosystem-based adaptation (EbA) strategies to address climate change problems. The participants were able to offer insights into the strategies in practice, whether they are perceived as effective, and the reasons behind their adoption. The discussions presented the strengths and challenges of current practices and provided a complex overview of how EbA approaches can be incorporated into local farming systems.

Theme 1: Awareness of Existing EbA Strategies

The focus group discussions revealed that both community leaders and smallholder maize farmers in the study area were aware of a variety of ecosystem-based adaptation (EbA) strategies. These were soil conservation practices such as terracing, mulching, and contour farming; crop diversification through intercropping maize and legumes; an agroforestry system using nitrogen-fixing and fruit trees; and water management systems such as rainwater harvesting and small-scale irrigation.

A group of community leaders stated:

> *"We have been practicing terracing and mulching for years now, and many farmers also intercrop maize with beans to ensure we get something to harvest even when rains fail."* (Community Leader 4, FGD 1)

A group of farmers added:

> *"Trees have become part of our farms. We plant grevillea and fruit trees along the boundaries because they give shade, stop soil erosion, and later we can sell them."* (Farmer 2, FGD 3)

Participants emphasized that awareness of these strategies had grown mainly through agricultural extension officers, NGOs, and peer farmer groups. Findings by Burke et al. (2018) indicate that awareness is often the first step towards adoption, but consistent technical support is necessary for widespread uptake. The integration of both indigenous practices and introduced methods mirrors EbA promotion trends across sub-Saharan Africa (Rawlins, 2023).

Theme 2: Perceived Effectiveness of EbA Strategies

The results of the focus group discussions indicated strong support among the community for the benefits that can be achieved through an ecosystem-based adaptation (EbA) strategy in mitigating the effects of climate change, such as droughts, floods, and soil erosion. Respondents also confirmed that integrated approaches, rather than following a single strategy, make farming more resilient and sustainable.

Farmers emphasized the need for soil conservation methods such as terracing, mulching, and terrace farming, as these have reduced soil erosion, prevented loss of soil fertility, and maintained moisture throughout the rainy season and long dry spells.

One farmer explained:

> *"Terraces and ridges help keep the soil in place and retain water for our crops. Even when the rains come late, our maize and vegetables survive better than before."* (Farmer 1, FGD 1)

Community leaders noted that:

> *"When farmers maintain grass strips or cover crops, the soil stays fertile, and the community can produce food consistently. These practices also protect our land from washing away during heavy rains."* (Community Leader 2, FGD 2)

Crop diversification was also viewed as an important strategy to improve resilience. According to the respondents, when maize is intercropped with legumes or another crop, the risk of complete crop failure is mitigated, so households would have food and income despite the poor performance of one of the crops.

A farmer noted:

> *"When we intercrop, if the maize fails, at least the beans survive. It is better than depending on one crop."* (Farmer 5, FGD 2)

Community leaders observed that:

> *"Agroforestry helps in so many ways: shade for the crops, windbreaks during storms, and even fruits for our children. It protects both our land and our livelihoods."* (Community Leader 2, FGD 1)

The participants also reinforced the idea that water management interventions involving rainwater harvesting, small dams, and irrigation make other strategies more effective in such situations, as they can provide water to crops and trees during the dry seasons. It was also found that farmers reported a synergistic effect that strengthens overall climate resilience, achieved through these practices in combination with soil conservation and crop diversification.

The results from the FGDs are also supported by another study by Nkonya, Kato, Msimanga, and Nyathi (2023), which found that smallholder farmers who develop few or many EbA strategies have higher yields and are less vulnerable to climate shocks. On the same note, Amusa, Avana-Tientcheu, and Awazi (2024) also observe that the joint application of soil conservation, crop diversification, agroforestry, and water management improves ecological and socio-economic impacts, as diverse income flows are available, soil fertility increases, and food security is strengthened. The respondents' experiences support the multifunctional nature of EbA, as it has primary significance in the construction of climate-resilient farming.

Theme 3: Most Effective Strategies for Improving Farming Practices

The focus group discussions demonstrated that farmers and community leaders believe that some strategies of ecosystem-based adaptation could be very effective in facilitating the development of farming practices. Among them, agroforestry, crop diversification, and water conservation practices were consistently ranked among the most constructive. The introduced agroforestry was lauded for its many benefits, including improving soil fertility, reducing erosion, providing shade, and generating supplementary income through the sale of timber, fruits, and fodder. The participants noted that agroforestry is a long-term investment that protects the present and future productivity of farms.

Community leaders stated that:

> *"Trees improve the soil and give us extra products like firewood and fruits. Even during drought, the shade helps the maize survive longer. It protects the farm now and ensures resources for our children."* (Community Leader 1, FGD 2)

Farmers echoed similar sentiments:

> *"I like planting maize with beans or groundnuts. It saves space, feeds the soil, and gives us two harvests. I feel safer knowing I will not lose everything if the weather changes. It also keeps pests down and makes the farm more productive overall."* (Farmer 3, FGD 4)

Crop diversification was another highly valued strategy. Respondents observed that intercropping and crop rotation would eliminate reliance on a single harvest, thereby limiting the risk of complete crop failure following droughts, pests, or diseases (Shah et al., 2021). This practice is also environmentally friendly, as it leads to alterations in nutrient requirements and consequent sustainable land resource management.

Farmers noted that:

> *"Mixing crops like maize, beans, and groundnuts works well for us. Even if one crop suffers from pests or poor rainfall, the others survive. It's about spreading risk and feeding the soil naturally."* (Farmer 2, FGD 1)

Water management strategies such as rainwater harvesting, mulching, and small-scale irrigation were often cited as important for maintaining crop growth during the dry seasons (Nouri et al., 2019). According to the farmers, the activities enable them to prolong the seasons, increase soil moisture, and increase their yields regardless of climate change. Leaders in the communities explained that community ponds and trenches are among the organized systems of water management that can reduce runoff and store water for use in farming activities.

Community leaders stated:

> *"Water is life for our crops. Collecting rainwater and using it wisely has made a big difference, especially during the long dry spells. It keeps our gardens green and our families fed."* (Community Leader 3, FGD 3)

Participants also stressed that a synergistic effect is achieved when agroforestry, crop diversification, and water management are combined in a way that increases both farm productivity and resilience to climate change. Through this concerted effort, the farms will remain productive, the environment will be less degraded, and food security will be enhanced among community members.

These findings align with previous studies by Kpenekuu et al. (2025), which have noted agroforestry, diversification, and water management as low-risk, high-reward practices that reduce risks and improve resilience and sustainability in East African rural agriculture. It was highlighted in the discussion that although individual strategies are helpful, convergence among strategies leads to a holistic approach to climate-related issues, thereby enabling adaptable and sustainable farming systems.

Theme 4: Challenges in Implementing EbA Strategies

Although participants identified various advantages of adopting ecosystem-based adaptation approaches, the discussions highlighted issues that impede their efficient implementation. The main constraints were the high prices of tree seedlings, limited access to water for irrigation, limited land, and limited employment to construct soil conservation structures. These impediments were perceived to curtail the magnitude and sustainability of the interventions, thereby influencing the overall success of climate response operations in the society.

Farmers explained:

> *"We want to plant more trees, but seedlings are expensive, and water is not enough for both crops and trees. Sometimes we have to choose between feeding our families or planting trees."* (Farmer 4, FGD 1)

Community leaders highlighted additional difficulties:

> *"Terracing needs a lot of labour, and some farmers give up halfway because they cannot manage. Even when the government or NGOs offer support, it's not enough to cover the whole farm."* (Community Leader 3, FGD 2)

The respondents added that they had limited access to inputs such as high-quality seeds, fertilizers, and organic manure, which affects crop productivity and the effective implementation of some strategies (Ng'ang'a, 2024). The problem of small-scale landholdings was cited as one specific obstacle to adopting practices such as crop rotation and agroforestry, which require space to plant trees and multiple crops.

Farmers further stated:

“On my small piece of land, it’s hard to plant trees and still grow enough maize or beans. Sometimes we plant, but the yields go down, so we are hesitant to continue.” (Farmer 2, FGD 3)

Moreover, inadequate technical training was mentioned as an obstacle. The participants mentioned that they knew about some strategies, including mulching and intercropping, but did not have specific information on how to do them correctly, which, in some cases, resulted in negative consequences. The limited availability of diversified crops and tree products on the market also posed a challenge, reducing farmers' incentive to implement such strategies.

Community leaders added that:

“Even when farmers produce more variety or plant trees, selling the extra fruits, timber, or beans is difficult. Without a market, motivation drops, and some give up on adaptation strategies.” (Community Leader 1, FGD 4)

These findings are consistent with Fanadzo and Ncube (2018), who noted that one of the gaps in smallholder irrigation development has been capacity building and that most failures have been linked to an inadequate level of training among farmers and extension workers, particularly in irrigation water management. There has been a single instance of land tenure insecurity as one of the greatest institutional vices hindering the performance of irrigation schemes.

The schemes offer various alternatives that require various forms of action to meet different demands, resources, and agricultural conditions. The above findings show that there is a need to align the soft and hard components of the irrigation schemes to render them sustainable. It becomes evident to the government that it must redefine its priorities regarding the revitalization of SIS. There is an absolute necessity of formulating land tenure policies that will provide smallholders with access to arable land, as well as instituting alternative cropping systems that offer appropriate solutions in the smallholder farming sphere.

According to the respondents, addressing those difficulties would require organized inputs, such as government subsidies for seedlings and irrigation channels, as well as ongoing farmer training and the development of stable market connections. According to Vikas and Hari (2023), enabling environments that provide both financial and technical support are vital to facilitate the uptake of EbA strategies. Participants inferred that, with favorable support, most existing obstacles would be alleviated, and climate adaptation practices would be more affordable and lasting for smallholder farmers.

4.4.2 Descriptive Statistic Findings for Rate of Adoption of the Ecosystem-Based Adaptation Strategies

In Section 4.4.2, the study sought to assess the rate of adoption of ecosystem-based adaptation strategies among smallholder maize farmers in Moiben Sub-County. Table 4.10 showed the study findings. Key: For the sake of this chart, SD means Strongly Disagree, D means Disagree, N means Neutral, A means Agree, and SA means Strongly Agree. Analysis of the response mean scores was conducted on a continuous scale: <1.5 represents strongly disagree; 1.5-2.4 disagree; 2.5-3.4 neutral; 3.5-4.5 agree; and>4.5 strongly agree. Responses were elicited on a 5-point Likert scale as shown in Table 8.

Table 8

Rate of Adoption of the Ecosystem-Based Adaptation Strategies

Statements		SD	D	N	A	SA	Mean	Stdv
1. I am aware of ecosystem-based adaptation (EbA) strategies available for smallholder farmers.	F	23	25	58	121	96	3.75	1.17
	%	7.1	7.7	18.0	37.5	29.7		
2. I have adopted EbA strategies such as soil conservation and agroforestry on my farm.	F	7	25	40	154	97	3.96	0.96
	%	2.2	7.7	12.4	47.7	30.0		
3. I have been using EbA strategies consistently for more than two seasons.	F	17	47	51	117	91	3.67	1.18
	%	5.3	14.6	15.8	36.2	28.2		
4. I regularly use extension services to learn about new EbA strategies.	F	20	44	37	122	100	3.74	1.21
	%	6.2	13.6	11.5	37.8	31.0		
5. The adoption of EbA strategies in my farming practice has increased in the last few years.	F	18	18	59	109	119	3.91	1.18
	%	5.6	5.6	18.3	33.7	36.8		
6. My knowledge of EbA strategies has improved through training programs or workshops.	F	14	32	41	140	96	3.84	1.09
	%	4.3	9.9	12.7	43.3	29.7		
7. The duration of time I have been using EbA strategies has significantly impacted my farm's performance.	F	7	15	49	147	105	4.02	0.93
	%	2.2	4.6	15.2	45.5	32.5		
8. I believe the rate of adoption of EbA strategies among my neighbors is steadily increasing.	F	6	23	41	142	111	4.02	0.96
	%	1.9	7.1	12.7	44.0	34.4		

The study results in Table 8 showed that the majority, 217 (67.2%), of the respondents agreed that they are aware of ecosystem-based adaptation (EbA) strategies available to smallholder farmers. On the contrary, 48 (14.8%) of the respondents disagreed that they were aware of ecosystem-based adaptation (EbA) strategies available to smallholder farmers. Further, the study results showed, in terms of mean and standard deviation, that the respondents agreed they are aware of ecosystem-based adaptation (EbA) strategies available to smallholder farmers (Mean=3.75, standard deviation=1.17). The study's findings agreed with Dong-Uuro and Peprah (2024), who revealed that farmers use a combination of practices rather than a single practice. Farmers integrated crops and trees and kept a local breed of farm animals.

County Government Officials [9] said that:

> *"Most farmers are now aware of EbA practices such as soil conservation, agroforestry, and crop diversification, crediting ongoing sensitization campaigns and demonstration farms. Awareness is often higher among farmers who belong to organized producer groups, though isolated farmers may still lack access to timely information."*

Onyancha (2024) concludes that both farmers' participation and perceptions of NGO interventions are predictors of household food security. The willingness of NGOs to involve farmers in needs identification, intervention selection, monitoring, implementation, capacity development, and power dynamics influenced farmers' participation. The affordability of interventions shaped farmers' perceptions, the technologies applied, markets, labour requirements, and the envisioned success. Funding agency conditions mediate the relationships among farmers' participation, perceptions of NGO interventions, and household food security.

Also, the study found that 251 (77.7%) of the respondents agreed that they have adopted EbA strategies such as soil conservation and agroforestry on their farms, and 32 (9.9%) disagreed. Further, the study results also showed, in terms of mean and standard deviation, that the respondents agreed with the statement that the quality of tools and equipment used in aircraft maintenance is important for safety (Mean=3.96, standard deviation=0.96).

County Government Officials [4] said that:

> *Adoption of EbA strategies has been encouraged through targeted training, seedling provision, and the establishment of soil conservation structures.*

The study further revealed that 208 (64.4%) of the participants agreed that they have been using EbA strategies consistently for more than 2 seasons. On the contrary, 64 (19.9%) of the respondents disagreed that they have been using EbA strategies consistently for more than 2 seasons. Further, the study results showed, in terms of mean and standard deviation, that the respondents agreed they have been using EbA strategies consistently for more than 2 seasons (Mean=3.67, standard deviation=1.18). These findings concur with Agol, Reid, Crick and Wendo (2021), who show that EbA approaches such as ecosystem restoration have the potential to generate multiple adaptation benefits, as well as synergies and trade-offs, occurring at different temporal and spatial scales and affecting various stakeholder groups.

County Government Officials [7] said that:

> *"Farmers who see tangible benefits such as improved soil fertility or higher yields are more likely to maintain these practices over time. Challenges like fluctuating weather patterns and high input costs sometimes lead farmers to revert to conventional methods, breaking the continuity of adoption."*

According to Verma, Singh, Pathania, and Aggarwal (2019), Indian farmers are becoming poor due to the daily deterioration in agriculture, with the main reasons being the lack of quality seeds, delays in water irrigation, reduced soil fertility, and excessive use of chemical fertilizers. In order to address these problems, we have been developing a new strategy that will double farmers' incomes and make the soil fertile without the use of chemical fertilizers.

The study further shows that 222(68.8%) of the participants agreed that they regularly use extension services to learn about new EbA strategies. In contrast to those findings, 64 (19.8%) of the respondents disagreed that they regularly use extension services to learn about new EbA strategies. Further, the study results showed, in terms of mean and standard deviation, that the respondents agreed they regularly use extension services to learn about new EbA strategies (Mean=3.74, standard deviation=1.21). These findings are consistent with Phuong et al. (2024), which indicate a significant relationship between the perceptions and understanding of EbA among policymakers and farmer households, and the adoption of EbA practices.

Also, 228 (60.5%) of the respondents agreed that the adoption of EbA strategies in their farming practices has increased in the last few years. However, 36 (11.2%) of the respondents disagreed that the adoption of EbA strategies in their farming practices has increased in the last few years. Analysis of the mean and standard deviation revealed that the respondents agreed that the adoption of EbA strategies in their farming practices has increased in the last few years (Mean = 3.91, Std. dev = 1.13). These findings are consistent with the study by Dong-Uuro et al. (2024), which revealed that farmers use a combination of practices rather than a single practice. Farmers integrated crops and trees and kept a local breed of farm animals. Benefits of EbA included improvements in soil fertility, leading to higher crop yields and greater food and income availability.

County Government Officials [8] said that:

> *"Successful partnerships between the county government, NGOs, and farmer cooperatives have facilitated resource mobilization and training."*

However, Kumar, Wankhede, and Gena (2015) reported that members of cooperatives have established suitable farming systems to generate year-round employment and sustainable income through crops, vegetables, fruits, and livestock. Initiatives have been taken to adopt Agro Forestry, combining the plantation of fruit trees, fuel trees, and forest trees, to improve the overall climate on wastelands by cooperatives like IFFDC (Indian Farm Forestry Development Cooperative Ltd.).

However, 236 (73.0%) of the participants agreed that their knowledge of EbA strategies had improved through training programs or workshops. On the contrary, 46 (14.2%) of the participants disagreed that their knowledge of EbA strategies had improved through training programs or workshops. Further, the study results also showed, in terms of mean and standard deviation, that the respondents agreed that their knowledge of EbA strategies has improved through training programs or workshops (Mean=3.84, standard deviation=1.09). The study's findings agreed with Joshi et al.'s (2024) results: a statistically significant number of students were aware of the impact of climate change adaptation measures, while teachers lacked adequate training and pedagogical knowledge in their disciplines, thus calling for the promotion of field-based and project-based learning activities.

Similarly, 252 (78.0%) of the participants agreed that the duration of time they have been using EbA strategies has significantly impacted their farm's performance. Conversely, 22 (6.8%) of the respondents disagreed that the duration of time they have been using EbA strategies has significantly impacted their farm's performance. Further, in terms of mean and standard deviation, the respondents agreed that the duration of time they have been using EbA strategies has significantly impacted their farm's performance (Mean=4.02, standard deviation=0.93).

County Government Officials [2] said that:

> *"Farmers who have consistently applied EbA strategies over several seasons report improved yields, reduced erosion, and better resilience to drought"*

Kloos and Renaud (2016) found that droughts not only destroy crops and livestock and degrade natural resources but also impact a wide range of ecosystem services. However, ecosystems can also frequently be powerful agents for drought mitigation and resilient livelihoods. Ecosystem-based approaches mitigate drought impacts while providing multiple co-benefits, which contribute to poverty alleviation and sustainable development, food security, biodiversity conservation, carbon sequestration, and livelihood resilience.

Finally, 253 (78.4%) agreed that the rate of adoption of EbA strategies among their neighbours is steadily increasing. However, 29 (9.0%) of the respondents disagreed that the rate of adoption of EbA strategies among their neighbours is steadily increasing. Further, the study results showed, in terms of mean and standard deviation, that the respondents agreed that the rate of adoption of EbA strategies among their neighbours is steadily increasing (Mean=4.02, standard deviation=0.96). The study's findings agreed with Reid, Podvin, and Segura (2018), who identified an emerging trend toward stakeholder participation, a catchment-based approach, and knowledge-based adaptation planning at the national level, which can potentially serve as entry points for wider-scale EbA implementation.

County Government Officials [5] said that:

> *"Peer influence plays a significant role in driving adoption, as farmers often replicate practices that they observe yielding good results nearby."*

Tran-Nam and Tiet (2022) argue that peer influence, such as the frequency of communication and the presence of organic farming neighbors, is a critical component of organic agriculture. Moreover, social and personal norms could also play a key role in incentivizing environmentally concerned farmers to convert to organic farming. Therefore, policymakers should encourage neighborhood collaboration, establish a channel for farmers to interact, and foster farmers' recognition of the importance of organic agriculture to effectively drive them toward sustainable adoption of organic farming.

The study findings from focus group discussions explored the rate of adoption of ecosystem-based adaptation (EbA) strategies among smallholder maize farmers in Moiben Sub-County. Participants shared their experiences regarding awareness, motivations, consistency of use, and the support they received in adopting and maintaining these practices.

Theme 1: Familiarity and Awareness of EbA Strategies

The findings of the focus group discussions indicate that farmers' knowledge levels in the Moiben Sub-County concerning ecosystem-based adaptation (EbA) strategies have greatly improved over the years. Respondents also agreed that organized farmers, through cooperatives or other groups, would be better informed about soil conservation, agroforestry, crop diversification, and water management techniques. In contrast, lone farmers would not always have information at hand (Chuma et al., 2022). Awareness was considered one of the determinants of farmers' adoption of these strategies.

Farmers insisted that it was easier to practice EbA by learning about these methods through demonstration farms and attending community trainings.

Farmer stated that:

> *"I learned about planting trees alongside my crops from a demonstration farm. Seeing it on someone else's farm helped me understand how it works: the shade protects the soil, and the trees give fruits and firewood."* (Farmer 3, FGD 1)

Another farmer also added that:

> *"Being part of the local cooperative really helps. We share what we learn from trainings and try new techniques together. It makes it easier to adopt the practices correctly."* (Farmer 6, FGD 4)

There was also emphasis on the significance of awareness, which promoted adoption among community leaders. They observed that continuous sensitization programs, peer training, and learning played important roles in increasing the number of farmers who became aware of these strategies.

One community leader observed:

> *"Most farmers know about agroforestry and soil conservation* now. *The ones who attend training or belong to farmer groups adopt them faster, but isolated farmers sometimes miss out. There is a big need to reach those who are left behind."* (Community Leader 1, FGD 2)

Another community leader added:

> *"Demonstration farms have been very effective. When farmers see the results themselves, such as better soil and healthier crops, they become more interested in adopting these practices."* (Community Leader 2, FGD 3)

The participants also affirmed that simply being aware is not enough; it is valuable to know how to apply the strategies properly and recognize their advantages (Nilson & Zimmerman, 2023). Farmers stated that being exposed to the practical demonstrations contributed to avoiding errors, building confidence, and making them more confident in using EbA practices regularly.

Šūmane et al. (2018) indicated that experienced farmers tend to teach others, which sparked informal learning channels that will increase understanding throughout the community. The observable positive effects, such as soil enrichment, increased productivity, and increased drought resistance, were improvements proven to reinforce the value of these practices and encouraged others to implement the same techniques.

Theme 2: Motivations and Barriers to Adoption

The focus group discussions evidenced that some factors and barriers push farmers to adopt ecosystem-based adaptation (EbA) strategies. Adoption (Participants unanimously emphasized) also has real payoffs, manifested in enhanced soil fertility, increased yields, greater drought and flood tolerance, and reduced risks through crop diversification. Farmers have reported that being aware of the fruitful results on farms they own or their neighbours' farms can enhance their acceptance of such strategies.

One farmer explained that:

> *"I use terracing and crop rotation because I noticed my maize grows better and beans survive even if the maize fails. Seeing my neighbour's farm doing well also encouraged me to try new techniques."* (Farmer 5, FGD 3)

Another farmer added:

> *"Planting trees along the farm edges has protected my crops from wind and improved soil fertility. It motivates me to continue, but not all farmers have the money or time to start."* (Farmer 7, FGD 1)

Community leaders also noted that adoption is often constrained by environmental conditions and resource constraints (Liu, Bruins, and Heberling, 2018). They noted that although numerous farmers are willing to use EbA practices, there are challenges related to the high prices of seedlings, small plots of land, poor water access, and a shortage of labour that negatively affect uptake.

One community leader observed:

> *"Some farmers want to plant trees or try new methods, but seedlings are expensive and land is small. These challenges slow adoption despite willingness."* (Community Leader 2, FGD 4)

Community leader added:

> *"Even with training, some farmers struggle to apply what they learn because they lack tools or labour. Support from cooperatives or government programs can make a big difference."* (Community Leader 3, FGD 2)

Barriers were also cultural beliefs and traditional practices. Other members said that older farmers might not be keen to learn new practices, since they might believe in the old ways that have been in use over the generations. Other values were observed to be in place where they affect adoption because women have little to no resources or decision authority on the farm.

The discussions emphasized that awareness needs to be integrated with avenues to resources, mentorship, and viable support to increase adoption rates (Awuah et al., 2024). As mentioned by farmers, expected outcomes in the form of visible success, the presence of support among peers, and the influence of extension officers or cooperation chains incentivize them to act sensibly and coherently in a bid to adopt EbA practices. On the other hand, resources, labor, or culturally acceptable practices may be lacking, thereby preventing uptake despite the farmers' willingness.

In general, the results indicate that the adoption of EbA strategies can be seen as the product of a multifaceted interaction among motivation, perceived benefits, observation, peer pressure, resource availability, and cultural factors (Nalau, Becken, and Mackey, 2018). These obstacles are important to overcome with targeted support and enabling conditions to boost adoption and sustain climate-resilient agricultural practices.

Theme 3: Duration and Consistency of EbA Strategy Use

The focus group discussions also pointed out that the time span and proper consistency in the adoption of the ecosystem-based adaptation (EbA) measures play an essential role in the success of applying the strategies. Farmers repeatedly stated that with extended use of various practices, such as agroforestry, soil conservation, terracing, crop rotation, and water management methodologies, they observe significant alterations in the intensity of the soil, moisture retention, and overall tolerance to climate variations. The repetition of the practice across seasons also enables farmers to perfect their skills and streamline resource use and the inclusion of several approaches to reap the best benefits (Swargiary, 2025).

One farmer explained:

> *"I have been using agroforestry and soil conservation for several seasons. Now the soil is richer, retains more water, and I see more crops surviving even during dry spells."* (Farmer 2, FGD 1)

Another farmer added:

> *"Farmers who stick with these strategies report better results over time. Those who try and then revert to old ways don't see the same benefits. You really notice a difference after two or three years of consistent practice."* (Farmer 4, FGD 3)

The community leaders noted that the long-term practice builds knowledge and credibility among the farmers, as they express the ability to coordinate labour, land, and crop combinations. They observed that farmers who implement EbA measures over multiple seasons respond more effectively to seasonal fluctuations and extreme events, thereby enhancing productivity and resilience.

One community leader remarked:

> *"Farmers who apply these practices regularly learn what works best for their land. They can predict how to plant crops, where to place trees, and how to conserve water efficiently. Their farms are healthier, and yields are more reliable."* (Community Leader 1, FGD 2)

Another community leader added:

> *"Those who have practiced EbA for many seasons become examples in the community. Neighbors notice their success and often follow their lead, which gradually increases adoption rates across the area."* (Community Leader 3, FGD 4)

Respondents also pointed out that partial or irregular adoption tends to be ineffective. For example, when farmers stop soil conservation or agroforestry practices halfway through the season, they often end up facing erosion, loss of fertility, and crop losses. On the other hand, continuous practice supports the long-term sustainability of the farm ecosystem, enhances water infiltration, and strengthens soil structure.

In the discussions, there was also a perceived long-term adoption effect with a cumulative effect. As the farmers practiced more seasons of the EbA strategies, they reported gaining more knowledge and confidence, which enabled them to experiment with practices that can act in pairs, such as intercropping, using legumes under tree cover, or pairing intercropping with water-harvesting systems and terracing. It was said that these integrated strategies enhanced farm performance and economic returns, as well as community food security.

Shah, Zhou, and Shah (2019) confirm the importance of the extent and persistence of the implementation of EbA strategies as one of the core determinants of ecological and economic outcomes. The long-term practice helps farmers gain the maximum benefits from these strategies, facilitates learning, experimentation, and peer influence, thereby helping the community adopt them.

Theme 4: Support from Extension Services and Agricultural Programs

The discussions in the focus group showed that the assistance of extension officers, training sessions, and a demonstration farm were significant in easing the transition and the long-term use of ecosystem-based adaptation (EbA) strategies. Participants noted that instructions from experienced staff, hands-on practice, and demonstrations on the farms were instrumental in helping farmers learn the methods, understand how to use them correctly, and sustain them in the long run.

A community leader explained that:

> *"Extension officers visit regularly to show us how to use soil conservation, plant trees, and manage water. They not only teach the methods but also advise on*

timing and combinations of practices. Their guidance helps farmers adopt these strategies correctly and see tangible results." (Community Leader 3, FGD 2)

Makamane (2023) reported that frequent visits by extension officers to farmers, supplemented with continuous mentorship, also contributed to making farmers more confident and ensured that the EbA strategies were applied properly. This constant mentorship reduced the number of mistakes, increased efficiency, and increased the likelihood of long-term adoption.

Another community leader added:

> *"Farmers often try new practices after seeing them in demonstration plots. They can ask questions, learn from mistakes in a controlled environment, and then apply the techniques to their own farms with confidence."* (Community Leader 1, FGD 4)

This assertion captures the usefulness of demonstration plots as real learning grounds. Observer practices in a controlled environment enabled farmers to internalize good practices, pose clarifying questions, and develop skills in strategies they could easily apply when implementing them independently, thereby reducing risks and increasing adoption rates.

One farmer noted:

> *"The trainings and field demonstrations give practical skills. Without them, some farmers wouldn't know how to start or maintain these strategies. It's different when you see someone doing it correctly and can ask questions along the way."* (Farmer 6, FGD 4)

Kilmartin (2022) emphasizes that knowledge transfer through interactive training enhances farmers' technical competence. Practical exposure combined with mentorship ensures that theoretical concepts are translated into effective on-farm practices, thereby improving outcomes.

Another farmer emphasized the importance of ongoing support:

> *"It's not enough to be shown once. Extension officers check back on our farms, help solve problems, and give advice when things go wrong. This follow-up keeps us motivated and ensures the strategies work long-term."* (Farmer 2, FGD 1)

This observation explains why follow-up support is important in maintaining adoption. Active participation contributes to preparing for unexpected difficulties, supports correcting incorrect practices, and encourages farmers to be diligent in incorporating EbA strategies throughout their lives (Marggraf, Chumacero de Schawe & Reichel, 2024).

In addition to traditional ecosystem-based adaptation practices, the study findings also highlight the importance of support systems that enhance farmers' awareness and confidence in adopting new practices. Respondents emphasized that cooperation among extension services, local agricultural programs, and farmers' cooperatives created a favorable climate for adoption. Initiatives such as demonstration plots, subsidizing tree seedlings, and providing manuals on resource use reduced key obstacles, including ignorance, low input, and fear of failure. These findings align with Place, de Grassi, and Cooper (2020), who found that collective action and farmer-to-farmer learning accelerate the uptake of climate-smart practices.

However, the present study did not explicitly explore the role of digital farming tools in enhancing yields, farmer knowledge, and the adoption of climate adaptation strategies. Emerging evidence suggests that digital systems are transforming agriculture by providing real-time weather forecasts, pest and disease alerts, soil monitoring, and mobile-based extension services (World Bank, 2021; Ayanlade et al., 2022). Incorporating ICT solutions into extension services could strengthen EbA adoption by overcoming information gaps and resource constraints. For instance, mobile platforms can deliver training modules, while apps linked to satellite data can help farmers make informed decisions on planting, irrigation, and fertilizer use.

Therefore, while the current study focused on ecosystem-based practices, future discussions and interventions should integrate digital farming innovations to complement EbA strategies. Combining traditional knowledge with ICT-enabled services could not only increase adoption but also improve efficiency, productivity, and resilience among smallholder farmers facing climate change challenges.

Finally, the results highlight that effective extension services and agricultural program support are associated with the lack of interruption contact, practical presentations, technical assistance, and revisitations. This is essential in providing adequate support to ensure that farmers can embrace, uphold, and enjoy EbA practices in a sustainable manner, thereby enhancing farm resilience and productivity.

4.4.3 Descriptive Statistics Findings for Effectiveness of Ecosystem-Based Adaptation Strategies

The study evaluated descriptive statistics to analyze the effectiveness of ecosystem-based adaptation strategies in reducing climate change vulnerability among smallholder maize farmers in Moiben Sub-County. Table 4.11 showed the study findings. Key: For the sake of this chart, SD means Strongly Disagree, D means Disagree, N means Neutral, A means Agree, and SA means Strongly Agree. Analysis of the response mean scores was conducted on a continuous scale: <1.5 represents strongly disagree; 1.5-2.4 disagree; 2.5-3.4 neutral; 3.5-4.5 agree; and>4.5 strongly agree. Responses were elicited on a 5-point Likert scale as shown in Table 9.

Table 9

Effectiveness of Ecosystem-Based Adaptation Strategies

Statements		SD	D	N	A	SA	Mean	Stdv
Since adopting EbA strategies, the water quality on my farm has significantly improved.	F	14	43	33	125	108	3.84	1.16
	%	4.3	13.3	10.2	38.7	33.4		
Soil nutrient levels on my farm have increased due to the use of EbA strategies.	F	12	15	33	155	108	4.03	0.98
	%	3.7	4.6	10.2	48.0	33.4		
My household income has diversified as a result of using EbA strategies.	F	13	31	40	161	78	3.81	1.04
	%	4.0	9.6	12.4	49.8	24.1		
The use of soil conservation practices has increased the soil carbon content on my farm.	F	5	19	44	133	122	4.08	0.94
	%	1.5	5.9	13.6	41.2	37.8		
EbA strategies have improved crop yields and overall productivity on my farm.	F	8	18	34	118	145	4.16	0.99
	%	2.5	5.6	10.5	36.5	44.9		
Adopting EbA strategies has reduced the vulnerability of my farm to extreme weather events.	F	26	37	43	132	85	3.66	1.21
	%	8.0	11.5	13.3	40.9	26.3		
Water and soil management practices have enhanced my farm's resilience to climate change.	F	5	22	23	163	110	4.09	0.90
	%	1.5	6.8	7.1	50.5	34.1		
I have observed long-term positive changes in my farm's ecosystem since adopting EbA strategies.	F	8	18	22	141	134	4.16	0.95
	%	2.5	5.6	6.8	43.7	41.5		

Table 9 showed that of the respondents, 233 (72.1%) agreed that, since adopting EbA strategies, the water quality on their farm has significantly improved. However, 57 (17.6%) of the respondents disagreed that, since adopting EbA strategies, the water quality on their farm has significantly improved. Further, the study results showed, in terms of mean and standard deviation, that the respondents disagreed with the statement that, since adopting EbA strategies, the water quality on their farm has significantly improved (Mean=3.84, standard deviation=1.16). The study's findings agreed with those of Shah, Zhou, and Shah (2019), who found that the majority of farmers reported a decline in water quality and the depth of the underground water table. We used a double-hurdle model for adoption and adaptation intensity. The results show that farmers' social capital and institutional access increase the probability and intensity of adoption of EbA practices. The study suggests that a majority of smallholder farmers in Pakistan are already using certain EbA strategies, but there is still scope for larger implementation.

County Government Officials [4] said that:

> *"Awareness and knowledge of water quality management varied among farmers, with those who regularly engaged with extension services being more informed about strategies such as rainwater harvesting, runoff control, and the use of sediment traps."*

Also, 263 (81.4%) of the respondents agreed that soil nutrient levels on their farm have increased due to the use of EbA strategies, and 27 (8.3%) disagreed. Further, the study results showed, in terms of mean and standard deviation, that the respondents agreed that soil nutrient levels on their farm have increased due to the use of EbA strategies (Mean=4.03, standard deviation=0.98). A study conducted by Muthee, Duguma, Nzyoka, and Minang (2021) noted that EbA practices were established as key to promoting water, energy, and food balance; enhancing ecosystem restoration and biodiversity conservation; and supporting livelihoods.

County Government Officials [1] said that:

> *"Farmers practicing crop rotation, incorporation of organic matter, and agroforestry had reported visible improvements in soil fertility."*

Alemayehu et al. (2020) showed that soil properties and crop productivity were markedly improved through three-year interventions of crop rotation and manure application.

Further, 239 (73.9%) of the respondents agreed that their household income had diversified as a result of using EbA strategies. On the contrary, 44 (13.6%) of the respondents disagreed that their household income has diversified as a result of using EbA strategies. Further, the study results also showed, in terms of mean and standard deviation, that the respondents agreed that their household income has diversified as a result of using EbA strategies (Mean=3.81, standard deviation=1.03). Research conducted by Gebru, Ichoku, and Phil-Eze (2018) found that 43% of farmers' annual income comes from off-farm and non-farm activities. This implies that non-farm and off-farm activities have a significant impact on improving farmers' livelihoods.

County Government Officials [10] said that:

> *"Diversification was achieved through higher yields, sale of surplus produce, and engagement in secondary enterprises such as poultry, beekeeping, and tree nurseries."*

Keshri and Srivastava (2024) reported that integration usually occurs when the outputs of one enterprise are used as inputs by another within the context of the farming system. The successful implementation of IFS requires organizational and/or institutional support to create new marketing opportunities and to facilitate adoption. Government policies provide capital, markets, and educational services to subsistence farmers.

The study further showed that 255 (79.0%) of the participants agreed that the use of soil conservation practices has increased soil carbon content on their farms. However, 24 (7.4%) of the respondents disagreed that the use of soil conservation practices has increased soil carbon content on their farms. Further, the study results showed, in terms of mean and standard deviation, that the respondents agreed that the use of soil conservation practices has increased soil carbon content on their farm (Mean=4.08, standard deviation=0.94). The study findings agreed with Abbas et al. (2020), who found that agricultural management in arid and semi-arid regions, which have specific characteristics related to high temperatures and low rainfall conditions, requires different practices for maintenance and restoration of SOC and for control of soil erosion compared to those used in Mediterranean and tropical regions.

Furthermore, 263 (81.4%) of the respondents agreed that EbA strategies have improved crop yields and overall farm productivity. However, 26 (8.1%) of the respondents disagreed that EbA strategies have improved crop yields and overall farm productivity. From the mean and standard deviation, the respondents agreed that EbA strategies have improved crop yields and overall productivity on their farm (Mean = 4.16, Std. dev = 0.99).

County Government Officials [7] said that:

> *"Integrated soil fertility management, timely planting, and water harvesting were key drivers of yield increases. Adoption rates were higher among farmers who received regular extension visits, suggesting that technical guidance was critical for success."*

Ndegwa et al. (2023) show that ISFWM strategies have not been properly adopted, probably due to inadequate awareness among farmers. In addition, there is limited documentation on the importance of ISFWM in enhancing soil fertility, water-use efficiency, and sustainable crop production in SSA.

Also, 217 (67.2%) of the respondents agreed that adopting EbA strategies has reduced the vulnerability of their farms to extreme weather events. However, 63 (19.5%) of the respondents disagreed that adopting EbA strategies has reduced the vulnerability of their farms to extreme weather events. Analysis of the mean and standard deviation revealed that the respondents agreed that adopting EbA strategies has reduced the vulnerability of their farm to extreme weather events (Mean = 3.66, Std. dev = 1.21). The study's findings agreed with those of Sultana, Irfanullah, Selim, and Budrudzaman (2023), who found that increased temperatures, limited water availability, changes in rainfall patterns, and limited availability of drought-resistant crop seeds increased farmers' vulnerability to drought. Farmers were shifting from traditional farming practices to more ecosystem-based, integrated farming practices that are less climate-sensitive.

County Government Officials [6] said that:

> *"Drought-resistant varieties, mulching, and diversified cropping patterns experienced less crop loss during dry spells. However, lack of timely access to quality seeds and unpredictable rainfall patterns limited the full benefits for some"*

Nadeem et al. (2024) state that environmental conditions are widely acknowledged as posing significant threats to crop productivity. Plants have developed diverse adaptive mechanisms at the cellular and metabolic levels to counteract and recuperate from the deleterious consequences of abiotic stress.

However, 273 (84.6%) of the participants agreed that water and soil management practices have enhanced their farms' resilience to climate change. On the contrary, 27 (8.3%) of the participants disagreed that water and soil management practices have enhanced their farm's resilience to climate change. Further, the study results showed that, in terms of mean and standard deviation, respondents agreed that water and soil management practices have enhanced their farm's resilience to climate change (Mean=4.09, standard deviation=0.90). The study's findings agreed with those of Srivastav et al. (2021), who found that water management through increased storage capacity (rainwater storage), fair policies for water supply and distribution, river health, and watershed management can reduce the negative effects of climate change on water resource availability.

County Government Officials [3] said that:

> *"Farmers practicing rainwater harvesting, terracing, and integrated watershed management observed more stable yields during erratic weather."*

Ray et al. (2020) reported yield enhancement in IFS for cereals (29%), oilseeds (40.7%), pulses (15%), fruits (9.9%), vegetables (298%), and spices (53.6%). On-farm fodder cultivation supplemented 39.3% and 28.6% of feed requirements for piggery and poultry, respectively. The RWH and IFS increased average cropping intensity from 100 to 168%. Introduction of vermicompost technology in IFS enabled the recycling of about 3.17 t of biomass to produce about 1.24 t of mature compost annually. The inclusion of livestock components in the model contributed to an enhancement of net income as high as 56.59%.

Finally, 275 (85.2%) of the participants agreed that they had observed long-term positive changes in their farm's ecosystem since adopting EbA strategies. However, 26 (8.1%) of the respondents disagreed that they had observed long-term positive changes in their farm's ecosystem since adopting EbA strategies. Further, the study results also showed, in terms of mean and standard deviation, that the respondents agreed with the statement that they have observed long-term positive changes in my farm's ecosystem since adopting EbA strategies (Mean=4.16, standard deviation=0.95). In contrast to the findings, a study by Reid, Podvin, and Segura (2018) found that wetland restoration had improved access to water, reduced the risk of disasters, and thus improved the resilience and adaptive capacity of some community members.

According to Tripathi and Ogbazghi (2016), in a watershed at Hamelmalo, Eritrea, all rainwater was conserved as soil moisture through slope-by-slope conservation measures. This land, which was apportioned into three types of slope, initially experienced significant runoff losses and deep soil erosion. Runoff was eradicated, land viability was enhanced, and soils acquired the ability to hold more water than the largest rainfall recorded after the use of bunding, ridging, bench terracing, and runoff storage canals, among others. Watershed development has proven effective in overcoming land degradation, as sorghum yields increased and net returns during the first year far surpassed the development costs, indicating that watershed development is an effective tool for overcoming degradation and increasing agricultural productivity.

The focus group discussions sought to understand farmers' experiences with the effectiveness of ecosystem-based adaptation (EbA) strategies in enhancing farm productivity, improving soil and water management, and reducing vulnerability to climate-related shocks. Respondents gave examples of their own improvements in water quality, soil fertility, crop production, and household income, and indicated the success stories as well as the problems associated with implementing these strategies.

Theme 1: Improvement in Water Quality and Soil Nutrient Levels

According to the participants, the implementation of EbA has achieved great success through the use of soil conservation, agroforestry, and rainwater harvesting on their farms, improving water quality and soil fertility. However, Sarkar et al. (2020) noted that storing water and supplementing the soil with organic matter and crop residue improved their land and made it less vulnerable to erosion.

A farmer explained that:

> *"Since planting trees and using mulching, the water we collect in our ponds is cleaner, and the soil feels richer. Even during dry spells, the crops don't dry out as fast."* (Farmer 3, FGD 2)

Another farmer added:

> *"Cover crops and composting have increased the fertility of our soil. We don't need as much fertilizer as before, and the crops grow stronger." (Farmer 5, FGD 1)*

Brust (2019) states that cover crops are used to add nutrients to the soil, improve soil structure, suppress weed growth, and protect the soil from wind- and water-induced erosion. The overall challenge for organic growers is to time nitrogen release to coincide with the vegetable crop's demand. Growers accomplish this by selecting appropriate combinations that fit the specific needs of their vegetable production system.

Additionally, White, Brennan, Cavigelli, and Smith (2020) suggest that intensive commercial-scale vegetable crops, with multiple tillage and bed-forming practices, along with irrigation and soil fertilizer applications, are important processes for decreasing SOC stocks in the Salinas Valley of California. Urban yard waste compost was applied annually and contributed to preventing SOC losses through elevated carbon-resistant pools, but applied in excess can result in phosphorus buildup and environmental issues. Cover cropping was demonstrated to increase carbon inputs directly through shoot incorporation and indirectly by enhancing autotrophic recycling of vegetable biomass and residues, with a probable improvement in nutrient cycling and crop yields. Although compost had the greatest impact on total SOC stocks, the enhanced frequency of cover crops altered the composition of SOC (toward more labile carbon), which is key to soil fertility.

A community leader observed:

> *"Farmers who consistently apply these methods notice visible differences. Water that used to run off and wash away nutrients now stays in the soil, feeding the crops."* (Community Leader 1, FGD 3)

Another community leader noted that:

> *"Demonstration plots have shown the benefit of adding organic matter and terracing. Farmers can see the difference in soil and water quality before adopting the methods themselves."* (Community Leader 2, FGD 4)

Theme 2: Impact on Household Income and Crop Yields

The focus group discussions indicated that ecosystem-based adaptation (EbA) measures significantly increase crop productivity and household income, with a positive impact. Farmers kept reporting that the use of farming practices such as intercropping, agroforestry, compost use, soil conservation, and mulching had helped them reap more, improve soil fertility, and diversify farm products. These shifts not only increased food availability at the household level but also raised revenues through the sale of surplus crops and other new farm produce, improving overall livelihood security.

One farmer noted:

> *"My maize yields have increased since intercropping with legumes and applying compost. The extra produce I sell helps pay for school fees and other household needs."* (Farmer 5, FGD 3)

Verma, Singh, Pathania, and Aggarwal (2019) reported that incorporating soil fertility enhancement practices and crop diversification directly increases household income. Through surplus production, farmers can access local markets and fulfil household budget needs, while minimizing reliance on a single product and the risks of economic loss from crop failure.

Another farmer added:

> *"Agroforestry has given me fruits and firewood. Combined with higher crop yields, this diversification supports my family income throughout the year."* (Farmer 7, FGD 1).

The findings show that integrating multiple EbA strategies can provide both subsistence and marketable products (Shah, Zhou & Shah, 2019). Agroforestry contributes not only to environmental sustainability by improving soil structure and moisture retention but also to year-round income through saleable products like fruits, timber, and firewood, thereby increasing the farm's economic resilience.

A community leader explained:

> *"Farmers who practice soil conservation, intercropping, and mulching report better yields and income. They often invest in secondary enterprises like beekeeping or poultry with the extra earnings."* (Community Leader 3, FGD 2)

Williams, Guikema, Brown, and Agrawal (2020) reveal that the successful implementation of EbA has a multiplier effect. In addition to direct gains in crop production, the extra income enables farmers to engage in other income-generating activities, further enhancing household economic stability and facilitating second activities, which are not only sources of income but also cushions against agricultural shocks, thereby strengthening livelihoods.

The community leader added that:

> *"Visible success in one farm encourages neighbors to adopt similar strategies, creating community-wide economic benefits."* (Community Leader 4, FGD 4)

Schaller et al. (2022) state that adoption is driven by peer pressure and the effects of demonstration. There is a greater likelihood of farmers adopting EbA measures when they see results being achieved on EbA on other farms around them. The effect of trickle-down adoption results in community-wide benefits, where a number of households may enjoy enhanced productivity, increased income, and greater aggregate knowledge, which would ultimately result in a positive impact on community-level economic stability and food security.

Muthee, Duguma, Nzyoka, and Minang (2021) show that the beneficial effects of EbA approaches are multifold and include increased crop production, diversified products, increased soil fertility, and opportunities to engage in side activities, which improve household earnings. Moreover, the demonstration effect and learning from others make adoption spread faster through the community and result in economic/social gains. The discussions highlight that the sustainable implementation of EbA strategies not only reduces the risk of climate change but also strengthens livelihoods, making smallholder farming more valuable and sustainable.

Theme 3: Reduction of Vulnerability to Climate Change Effects

The focus group discussions revealed that ecosystem-based adaptation (EbA) measures play a central role in ensuring that the vulnerability of smallholder farmers to climate-related shocks, such as droughts, floods, and pest or disease outbreaks, has significantly decreased. The farmers mentioned that the practices of soil conservation, intercropping, agroforestry, and water management enhanced their resilience to changing weather conditions, stabilizing crop production before they could stabilize their livelihoods amid the disappointing weather.

One farmer stated:

> *"During the last drought, my maize survived better than my neighbour's farm because I practiced mulching and intercropping. The soil retained moisture, and the crops were less affected by pests."* (Farmer 2, FGD 1)

Shah and Wu (2019) show that soil and crop management practices enhance resistance to moisture stress and pest pressure. Mulching and intercropping improve water retention and the creation of microclimates, which restrict the population of pests in direct relation to crop susceptibility to adverse conditions by preserving soil structure and fertility, which is a fundamental requirement to sustain both.

Another farmer noted:

> *"Agroforestry and water harvesting help protect my farm from floods. Even when rains are heavy, my terraces and grass strips prevent soil loss."* (Farmer 4, FGD 3). A community leader observed:
>
> *"Farmers who consistently apply these strategies are more resilient. They can predict what works on their land and mitigate losses, which strengthens food security across the community."* (Community Leader 1, FGD 2)

This interpretation holds that the continuity and periodicity of the practice of EbA are vital. Long-term adoption enables farmers to build experience regarding local microclimates and soil conditions, as well as how crops can work in synergy with a greater understanding (Ogwu & Kosoe, 2025). This experience enhances adaptive capacity, enabling farmers to make decisions to address challenges, forecast climate risks, and maintain more stable food production despite adverse conditions.

Another community leader emphasized:

> *"The cumulative effect of EbA practices means even smallholder farmers are less exposed to climate risks. Knowledge sharing and peer influence help maintain these practices."* (Community Leader 3, FGD 4)

Chavez-Miguel et al. (2022) show that a combination of strategies over time produces a synergistic effect. By integrating soil, water, and crop management processes, farmers increase ecological resilience, opening the door to community-based learning. Knowledge transfer and demonstration effects through peer-to-peer interaction strengthen the adoption process, so that the advantages of vulnerability reduction are felt within the broader community.

Vikas and Hari (2023) indicate that EbA measures undertaken play a significant role in reducing climate vulnerability. Implementing several observable practices that complement each other helps improve the farm ecosystem's ability to absorb shocks, maintain productivity, and safeguard livelihoods. The discussions highlight that the benefit of adaptability increases with sustained use, community-based learning, and the combination of other strategies, and that smallholder farms become more resistant to climate variability and extreme weather events as a result.

4.4.4 Descriptive Statistics Findings for Climate Change Vulnerabilities

The study sought to analyze climate change vulnerability among smallholder maize farmers in Moiben Sub-County. Table 4.11 showed the study findings. Key: For the sake of this chart, SD means Strongly Disagree, D means Disagree, N means Neutral, A means Agree, and SA means Strongly Agree. Analysis of the response mean scores was conducted on a continuous scale: <1.5 represents strongly disagree; 1.5-2.4 disagree; 2.5-3.4 neutral; 3.5-4.5 agree; and>4.5 strongly agree. Responses were elicited on a 5-point Likert scale as shown in Table 10.

Table 10

Climate Change Vulnerabilities

Statements		SD	D	N	A	SA	Mean	Stdv
I frequently experience significant yield losses due to unpredictable rainfall patterns	F	22	28	49	106	118	3.84	1.21
	%	6.8	8.7	15.2	32.8	36.5		
My farm is highly susceptible to soil erosion during heavy rains	F	13	24	43	145	98	3.90	1.04
	%	4.0	7.4	13.3	44.9	30.3		
Climate-related pests and diseases have increased and threaten my crops more often	F	16	37	53	122	95	3.75	1.14
	%	5.0	11.5	16.4	37.8	29.4		
Extreme weather events (for example floods, heatwaves) have become more common and damaging	F	8	36	48	106	125	3.94	1.10
	%	2.5	11.1	14.9	32.8	38.7		
I lack sufficient resources to cope with the effects of climate change on my farm	F	22	23	42	119	117	3.8854	1.17526
	%	6.8	7.1	13.0	36.8	36.2		
Climate change has negatively impacted the quality and quantity of my harvests	F	18	28	44	107	126	3.91	1.17
	%	5.6	8.7	13.6	33.1	39.0		
My farm income is highly unstable due to changing weather conditions	F	9	18	50	139	107	3.98	0.98
	%	2.8	5.6	15.5	43.0	33.1		
Changes in rainfall timing have disrupted my traditional planting calendar	F	11	22	40	113	137	4.06	1.06
	%	3.4	6.8	12.4	35.0	42.4		

According to the study in Table 10 the findings indicated that 224 (69.3%) of the respondents agreed that they frequently experience significant yield losses due to unpredictable rainfall patterns, while 50 (15.5%) disagreed. Further, the study results showed, in terms of mean and standard deviation, that the respondents agreed they frequently experience significant yield losses due to unpredictable rainfall patterns (Mean=3.84, standard deviation=1.21).

County Government Officials [3] said that:

> *"Erratic rainfall disrupts planting schedules and shortens the growing season, resulting in lower yields, particularly for maize."*

Lu, Xue, and Guo (2017) showed that the maize growth period was shortened with delayed planting. The vegetative growth stage and the overlapping vegetative-reproductive growth stages varied by 4–19 days across PD practices.

The study further revealed that 243 (75.2%) of the participants agreed that their farms are highly susceptible to soil erosion during heavy rains. On the contrary, 37(11.4%) of the respondents disagreed that their farm is highly susceptible to soil erosion during heavy rains. Further, the study results also showed, in terms of mean and standard deviation, that the respondents agreed that their farm is highly susceptible to soil erosion during heavy rains (Mean=3.90, standard deviation=1.04). The study's findings, which agree with Tesfahunegn, Ayuk, and Adiku (2021), show that there was significant variation in socioeconomic, farm, and institutional attributes among the farmers in the study regions. In the Eastern and Northern Regions, significantly higher proportions of the farmers (95.7% and 86.7%, respectively) perceived soil erosion as a serious problem.

County Government Officials [4] said that:

> *"Steep slopes, lack of terracing, and poor drainage systems* contribute to topsoil *loss, reducing soil fertility."*

Osman (2018) found that shallow, loose soils on impervious substrata are more likely to experience mass movement on steep slopes during intense storms. Man-made activities that destabilize soils on steep slopes include development, settlement, shifting cultivation, deforestation and forest fires, and soil mining, among others. Gravity-driven mass movement (also known as landslides), caused by water saturation and water movement, can take many forms: falls, creeps, slumps, earthflows, debris avalanches, debris flows, debris torrents, and bedrock failure. These movements have both on-site and off-site impacts on properties, installations, households, communications, crops, human lives, and the environment. Steeply sloping soils may be stabilized, or, in other words, soil erosion on lands with steep slopes may be minimized through a myriad of mechanical, agronomic, and agroforestry steps.

However, the study showed that 217(67.2%) participants agreed that climate-related pests and diseases have increased and threaten their crops more often. Contrary to those findings, 53(16.5%) respondents disagreed that climate-related pests and diseases have increased and threaten their crops more often. Further, the study results also showed, in terms of mean and standard deviation, that the respondents agreed that climate-related pests and diseases have increased and threaten their crops more often (Mean=3.75, standard deviation=1.14).

County Government Officials [4] said that:

> *"Warmer temperatures and altered rainfall patterns have created favorable breeding conditions for pests such as fall armyworm and stalk borer, as well as fungal diseases like maize smut."*

Additionally, 231 (71.5%) participants agreed that extreme weather events (for example, floods and heatwaves) have become more common and damaging. Contrary to those findings, 44 (13.6%) respondents disagreed that extreme weather events (for example, floods and heatwaves) have become more common and damaging. Further, the study results showed, in terms of mean and standard deviation, that the respondents agreed that extreme weather events (e.g., floods, heatwaves) have become more common and damaging (Mean=3.94, standard deviation=1.10). The study findings agreed with Clarke, Otto, Stuart-Smith, and Harrington (2022), who found influences of climate change on five different extreme weather hazards (extreme temperatures, heavy rainfall, drought, wildfire, tropical cyclones), the impacts of recent extreme weather events of each type, and thus the degree to which various impacts are attributable to climate change.

County Government Officials [9] said that:

> *"Flash floods damage crops and infrastructure, while prolonged heatwaves lead to moisture stress."*

The study further revealed that 236 (72.0%) of the participants agreed that they lacked sufficient resources to cope with the effects of climate change on their farms. On the contrary, 45 (13.9%) of the respondents disagreed that they lacked sufficient resources to cope with the effects of climate change on their farms. Further, the study results showed, in terms of mean and standard deviation, that the respondents agreed they lack sufficient resources to cope with the effects of climate change on their farms. (Mean=3.89, standard deviation=1.18).

County Government Officials [7] said that:

> *"Many farmers lack access to affordable credit, quality inputs, and irrigation infrastructure. Without targeted financial and technical support, farmers will remain vulnerable to even minor climate shocks."*

Mwamakamba et al. (2017) show that the government's objective of securing domestic supplies of staple foods from irrigation schemes conflicts with poverty reduction. While commercial and private irrigation schemes may be profitable in Africa, this review of six publicly owned smallholder irrigation schemes in Mozambique, Tanzania, and Zimbabwe found that these schemes are currently unproductive and do not improve the livelihoods of poor farmers.

However, the study showed that 233(72.1%) participants agreed that climate change has negatively impacted the quality and quantity of their harvests. Contrary to those findings, 46(14.3%) respondents disagreed that climate change has negatively impacted the quality and quantity of their harvests. Further, the study results also showed, in terms of mean and standard deviation, that the respondents agreed that climate change has negatively impacted the quality and quantity of their harvests (Mean=3.91, standard deviation=1.17). The study's findings agreed with Srivastava (2019), who found that climate change has a strong impact on the food industry by affecting cultivation, postharvest management (PHM), food loss, food quality, and food security. These climatic factors (temperature, rainfall, and greenhouse gases (GHGs)) have a significant impact on postharvest quality parameters of fresh produce, including organic acids (citric and malic), antioxidant compounds, and firmness.

In addition, 246 (76.1%) of the participants agreed that their farm income is highly unstable due to changing weather conditions. However, 27(8.7%) of the respondents disagreed that their farm income is highly unstable due to changing weather conditions. Further, the study findings indicated, in terms of mean and standard deviation, that the respondents agreed that their farm income is highly unstable due to changing weather conditions (Mean=3.98, standard deviation=0.98). The study's findings, which agree with Harkness et al. (2023), agree that variability in temperature and rainfall reduces the stability of farm income and food production. While variability in climate can be largely outside the farmers' control, our findings indicate that, under current conditions, farm management can have a larger effect on stability than climate.

County Government Officials [6] stated that;

> *“Yield fluctuations, coupled with market price volatility, make income unpredictable.”*

Haile, Kalkuhl, and von Braun (2016) show that own-price supply elasticities range from about 0.05 to 0.40. Output price volatility, however, has negative correlations with crop supply, implying that farmers shift land, other inputs, and yield-improving investments to crops with less volatile prices. Simulating the impact of price dynamics since 2006, we find that price risk has reduced the production response of wheat in particular and, to a lesser extent, rice, thus dampening price incentive effects.

Finally, 250(77.4%) of the participants agreed that changes in rainfall timing have disrupted their traditional planting calendar. On the contrary, 33(10.2%) of the respondents disagreed that changes in rainfall timing have disrupted their traditional planting calendar. Further, the study results also showed, in terms of mean and standard deviation, that the respondents agreed that changes in rainfall timing have disrupted their traditional planting calendar (Mean=4.06, standard deviation=1.06). The study's findings, which concurred with Yang et al. (2019), revealed that the region had been getting warmer and wetter in recent decades, and local perceptions matched climatic records. Local inhabitants have already been practicing earlier crop planting (for example, wheat) in recent years. Climatic indices calculated from recent weather conditions can support earlier crop planting.

County Government Officials [10] stated that;

> *"Delayed rains push planting dates later than usual, shortening the growing season. In other cases, early rains followed by dry spells lead to seedling losses."*

However, Krell, Morgan, Gower, and Caylor (2021) show that storms are becoming more intense and less frequent. We show that maize crops are prone to water deficit in the part of the growing season when crop water requirements are highest. Despite the potential for higher-yielding, late-maturing varieties to improve total harvest, we find that drought-avoidant early-maturing varieties have the lowest likelihood of failure.

4.5 Inferential Analysis

Inferential analysis used in this section was correlation and multiple regression models. Correlation and multiple regression analyses showed the relationships between the independent variables and the dependent variable.

4.5.1 Correlation Analysis

Correlation analysis was done to determine the direction and strength of the correlation between the study variables. The findings are presented in Table 11.

Table 11

Correlation Analysis

		Climate Change Vulnerabilities	EbA strategies implemented	Rate of adoption of the strategies	Effectiveness of of EbA strategies
Climate Change Vulnerabilities	Pearson Correlation	1			
	Sig. (2-tailed)				
EbA strategies implemented	Pearson Correlation	.736**			
	Sig. (2-tailed)	.000			
Rate of adoption of the EbA strategies	Pearson Correlation	.772**	.797**	1	
	Sig. (2-tailed)	.000	.000		
Effectiveness of EbA strategies	Pearson Correlation	.777**	.739**	.817**	1
	Sig. (2-tailed)	.000	.000	.000	
	N	323	323	323	323

**. Correlation is significant at the 0.01 level (2-tailed).

Table 11 showed that the implemented ecosystem-based adaptation strategies were positively and statistically significantly correlated with Climate Change Vulnerabilities ($r=0.736$, $p<0.01$). Furthermore, the study's findings revealed that the rate of adoption of ecosystem-based adaptation strategies was positive and strongly correlated with Climate Change Vulnerabilities ($r=0.772$, $p<0.01$). The effectiveness of ecosystem-based adaptation strategies was positive and strongly correlated with Climate Change Vulnerabilities ($r = 0.777$, $p < 0.01$).

This implied that all the study variables were positively correlated with Climate Change Vulnerabilities. Ecosystem-based adaptation strategies implemented contribute 73.6% to the increase in Climate Change Vulnerabilities. The rate of adoption of ecosystem-based adaptation strategies contributes 77.2% to the increase in Climate Change Vulnerabilities. The effectiveness of ecosystem-based adaptation strategies accounts for 77.7% of the increase in Climate Change Vulnerabilities. 0 and 1.00 are both valid values for the correlation coefficient. A number of -1.00 indicates a perfect negative correlation, whereas a value of +1.00 indicates a perfect positive correlation. Therefore, if the value is 0.00, there is no association between the two variables (Orodho, 2003).

4.5.2 Regression Analysis Results

Multiple regression analysis was used to examine how each variable in the study related to the others. Tables summarizing the findings are provided below.

4.5.3 Model Summary

The correlation coefficient (R) and the coefficient of determination (R2) illustrated the extent to which the independent variable explained the variance in the dependent variable, while the coefficient of determination (R^2) demonstrated the strength of the relationship between the dependent and independent variables. Table 12 presents the regression model summary.

Table 12

Regression Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.825[a]	.680	.677	.58380

Table 12 shows that the R value is 0.825, the R square is 0.680, and the adjusted R square is 0.590. In addition, the results demonstrated that the rate of adoption of ecosystem-based adaptation strategies, the effectiveness of ecosystem-based adaptation strategies, and the implementation of ecosystem-based adaptation strategies account for 68.0 percent of the variation in climate change vulnerabilities.

4.5.4 Model Fitness

Table 13 presents the findings of an analysis of variance conducted to assess the model's fitness.

Table 13

Results of Model Fitness

	Sum of Squares	df	Mean Square	F	Sig.
Regression	230.861	3	76.954	225.791	.000b
Residual	108.721	319	.341		
Total	339.582	322			

Source: Field Data (2025)

The study findings revealed a significant difference between the independent variables and the dependent variable ($F = 225.791$; $p = 0.000 < 0.05$), as shown in Table 14. Since the multiple regression models fit the data well, they were chosen. The implementation, rate of adoption, and effectiveness of ecosystem-based adaptation strategies all play a role in climate change vulnerabilities.

4.5.5 Regression Coefficients

The primary objective of the study was to determine the respective coefficients of the study variables. The study findings are presented in Table 14.

Table 14

Regression Analysis Coefficient

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std.	Beta		
(Constant)	.676	.106		6.396	.000
EbA strategies implemented	.227	.051	.240	4.424	.000
Rate of adoption of the EbA strategies	.265	.062	.272	4.306	.000
Effectiveness of EbA strategies	.359	.054	.377	6.647	.000

The resultant equation becomes:

$Y=0.676 + 0.227X_1 + 0.265X_2 + 0.359X_3$……………………………………Equation 4.1

Where;

Y represents climate change vulnerabilities, which is the independent variable,

X_1 EbA strategies implemented

X_2 Rate of adoption of the EbA strategies

X_3 Effectiveness of EbA strategies

Table 14 presents the regression coefficient results, which revealed a positive and statistically significant relationship between ecosystem-based adaptation strategies implemented and climate change vulnerabilities ($\beta1 = .227$, $p = .001$). This implies that the more smallholder farmers implement EbA strategies such as agroforestry, soil conservation, and rainwater harvesting, the more resilient they become to climate change shocks. These findings are consistent with those of Catacutan et al. (2017) and Gichuki et al. (2019), who reported that agroforestry and land restoration practices enhanced soil fertility and improved water availability, thereby reducing farmers' exposure to climate risks. Similarly, Nhamo et al. (2021) emphasized that ecosystem-based interventions, such as wetland restoration, improved agricultural resilience in Southern Africa, supporting the positive effect observed in this study.

The results further indicated that the rate of adoption of EbA strategies had a statistically significant effect on climate change vulnerabilities ($\beta 2 = .265$, $p = .000$). This finding resonates with Muriuki, Njeru, and Karanja (2021), who observed that higher adoption rates of conservation agriculture practices in Kenya led to notable improvements in maize yields and soil health. However, the current study's adoption effect was slightly stronger than that reported by Nyasimi et al. (2017), who found adoption levels to be low due to resource and knowledge constraints. This difference may be attributed to the fact that farmers in Moiben Sub-County have benefited from stronger extension services and county-level agricultural support compared to the regions covered by Nyasimi et al.

Lastly, the study revealed that the effectiveness of EbA strategies had a positive and significant influence on climate change vulnerabilities ($\beta 3 = .359$, $p = .000$). This is in agreement with the findings of Mwangi et al. (2021), who showed that community-led mangrove restoration projects improved resilience to flooding and coastal erosion in Kenya, demonstrating that well-implemented EbA interventions yield substantial benefits. On the other hand, the current study's results differ from those of Doswald et al. (2019), who cautioned that many EbA initiatives remain in their infancy and may not always yield immediate tangible outcomes. This variation suggests that context matters greatly; where EbA is integrated with farmer participation and institutional support, effectiveness is significantly enhanced.

Overall, the regression results indicate that implementation, adoption rate, and effectiveness of EbA strategies all play a crucial role in reducing climate change vulnerabilities among smallholder farmers. The alignment with several past studies strengthens the credibility of the results, while the differences highlight the importance of localized conditions, resource availability, and policy support in shaping EbA outcomes.

4.6 Hypotheses Testing

For each hypothesis, the regression equation was initially derived using the B coefficients from the best-fit line. The decision criterion was that if the p-value was below the standard threshold of 0.05, the null hypothesis would be rejected; otherwise, if the p-value exceeded 0.05, the null hypothesis would not be rejected. Hypotheses were evaluated at a 5% significance level (alpha = 0.05).

4.6.1 Hypothesis Testing of Ecosystem-Based Adaptation (EbA) Strategies Implementation

Hypothesis H_{01} stated that smallholder maize farmers implement no significant ecosystem-based adaptation strategies to mitigate climate change vulnerabilities in the study area. However, the study's findings revealed a β value of 0.227 for the EbA strategies implemented, indicating a positive effect on mitigating climate change vulnerabilities. The p-value = 0.000 (which is less than 0.05) indicates a statistically significant effect. Since the p-value is less than 0.05, the study rejected the null hypothesis, indicating that the implementation of ecosystem-based adaptation strategies significantly contributes to mitigating climate change vulnerabilities in the study area. This result suggests that smallholder maize farmers who adopt EbA strategies are more effective in reducing climate-related risks, thereby improving their resilience to changing weather patterns. The positive relationship between EbA strategy implementation and reduced vulnerabilities highlights the importance of integrating ecological approaches into farming practices to safeguard against climate impacts.

4.6.2 Hypothesis Testing of Rate of Adoption of EbA Strategies

Hypothesis H_{02} stated that there is no significant adoption of ecosystem-based adaptation strategies among smallholder maize farmers in the study area. However, the study's findings revealed a β value of 0.265 for the rate of adoption of EbA strategies, suggesting a positive relationship between the rate of adoption and the mitigation of climate change vulnerabilities. The p-value of 0.000 (less than 0.05) indicates statistical significance. Since the p-value is less than 0.05, the study rejected the null hypothesis, confirming that the adoption of ecosystem-based adaptation strategies significantly reduces climate change vulnerabilities. This finding implies that the more widely these strategies are adopted among farmers, the greater the overall effectiveness in combating climate change risks. Increased adoption of EbA strategies enhances climate resilience, underscoring the need to scale them for broader agricultural sustainability.

4.6.3 Hypothesis Testing of Effectiveness of EbA Strategies

Hypothesis H_{03} stated that there is no significant effectiveness of ecosystem-based adaptation strategies in reducing climate change vulnerability among smallholder maize farmers in the study area. The study's findings revealed that the β value for the effectiveness of EbA strategies is 0.359, indicating a strong positive relationship between these strategies' effectiveness and reduced climate change vulnerabilities. The p-value of 0.000 (less than 0.05) indicates statistical significance. As the p-value is less than 0.05, the study rejected the null hypothesis, confirming that ecosystem-based adaptation strategies significantly contribute to mitigating climate change vulnerabilities. This result suggests that when these strategies are effectively implemented, they lead to a significant reduction in climate change vulnerabilities, thereby improving resilience and sustainability for smallholder maize farmers in the study area. This reinforces the importance of not only adopting EbA strategies but also ensuring their effective application to achieve the desired outcomes.

Table 15

Summary of Hypotheses Test Results

Hypotheses	β and P values	Decision rule
H_{01}: There are no significant ecosystem-based adaptation strategies implemented by smallholder maize farmers to mitigate climate change vulnerabilities	$\beta_1 = 0.227$, $p = 0.000 < 0.05$	Rejected the null hypothesis
H_{02}: There is no significant adoption of ecosystem-based adaptation strategies among smallholder maize farmers	$\beta_2 = 0.265$, $p = 0.000 < 0.05$	Rejected the null hypothesis
H_{03}: There is no significant effectiveness of ecosystem-based adaptation strategies in reducing climate change vulnerability among smallholder maize farmers	$\beta_3 = 0.359$, $p = 0.000 < 0.05$	Rejected the null hypothesis

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

5.1 Introduction

This segment provides a summary of the study's discoveries, draws conclusions, and offers recommendations. Moreover, it proposes potential avenues for future research within the subsequent subsections.

5.2 Summary of the Study Findings

This section provides a synopsis of the study's results, in accordance with the research goals.

5.2.1 Existing ecosystem-based adaptation strategies implemented.

The respondents were asked about the existing ecosystem-based adaptation strategies implemented among smallholder maize farmers in Moiben Sub-County. The study findings indicate that the majority of respondents agreed that they practice soil conservation techniques (for example, terracing, contour farming) on their farms and that crop diversification is a key strategy they use to increase resilience to climate variability.

Additionally, they agreed that they have integrated agroforestry practices (for example, trees interplanted with crops) on their farm, that water management strategies such as rainwater harvesting or irrigation are in place, and that they implement cover cropping or mulching to improve soil moisture retention. Further, they agreed that their farm benefits from mixed farming, combining crops and livestock as part of EbA, and that they actively participate in community programs promoting soil and water conservation. Finally, the majority of respondents agreed that using organic farming practices is part of their overall strategy to adapt to climate change.

5.2.2 Rate of adoption of the ecosystem-based adaptation strategies

The respondents were also asked to assess the rate of adoption of ecosystem-based adaptation strategies among smallholder maize farmers in Moiben Sub-County. The study findings indicate that the majority of respondents agreed that they are aware of ecosystem-based adaptation (EbA) strategies available to smallholder farmers and that they have adopted EbA strategies such as soil conservation and agroforestry on their farms. Further, the study finding I have been using EbA strategies consistently for more than two seasons.

Further, most of them agreed that they regularly use extension services to learn about new EbA strategies and that the adoption of EbA strategies in their farming practices has increased in the last few years. The majority of the respondents agreed that their knowledge of EbA strategies has improved through training programs or workshops. Also, they agreed that the duration of time they have been using EbA strategies has significantly impacted their farm’s performance. Finally, they agreed that they believe the rate of adoption of EbA strategies among their neighbors is steadily increasing.

5.2.3 Effectiveness of Ecosystem-Based Adaptation Strategies

Finally, the respondents were asked about the effectiveness of ecosystem-based adaptation strategies in reducing climate change vulnerability among smallholder maize farmers in Moiben Sub-County. Findings indicate that the majority of respondents agreed that, since adopting EbA strategies, the water quality on their farm has significantly improved and that soil nutrient levels have increased due to the use of EbA strategies. Further, the study findings indicate that the respondents agreed that their household income has diversified as a result of using EbA strategies.

Also, the respondent agreed that the use of soil conservation practices has increased soil carbon content on their farm, and the study results reveal that EbA strategies have improved crop yields and overall productivity on their farm. The majority of respondents also indicate that adopting EbA strategies has reduced the vulnerability of their farms to extreme weather events. Water and soil management practices have enhanced their farms' resilience to climate change. Finally, they agree that they have observed long-term positive changes in their farms' ecosystems since adopting EbA strategies.

5.3 Conclusion of the Study

Based on the study findings, it can be concluded that the majority of smallholder maize farmers in Moiben Sub-County are already in the process of implementing several ecosystem-based adaptation (EbA) strategies. The strategies include soil conservation (such as terracing and contour farming), crop diversity, agroforestry, rainwater harvesting, cover cropping, and organic farming. The popularity of these strategies indicates that people have a good understanding of the consequences of climate change and are taking the initiative to improve agricultural sustainability by resorting to so-called nature-based solutions.

The analysis also indicates that a high percentage of farmers have embraced the practice of EbA. Most respondents reported applying these strategies throughout most seasons and learning more about such practices through training and extension services. Further, they indicated that EbA is being applied more in their communities, suggesting a gradual shift towards a climate-resilient farming system in the area.

Lastly, the success of such measures can be evident through the reported results. The farmers observed that water quality increased, soil nutrient levels increased, crop yields improved, and household income diversified. These are some of the beneficial changes that have helped shield the farms against extreme weather conditions, while also encouraging long-term ecological stability. To sum up, an implication of the EbA strategy, besides its meaningful adoption, is the attainment of measurable benefits in

Moiben Sub-County, thereby underscoring its relevance to climate change adaptation and sustainable agricultural production.

5.4 Recommendations

The study's findings recommend that county agricultural departments and stakeholders strengthen the adoption and promotion of ecosystem-based adaptation (EbA) strategies among smallholder farmers growing maize. It can be done by reinforcing agricultural extension services to offer frequent training classes and a sample plot that demonstrates the practical usefulness of EbA practices such as agroforestry, mulching, and soil conservation. These contributed to the improvement of farmers' technical skills and to their confidence in implementing and maintaining the strategies.

Secondly, supportive policies that reward EbA practices should be developed and implemented. Give farmers incentives, such as subsidies or access to credit, to invest in sustainable land management by integrating EbA into climate-smart agriculture programs at local and national levels. In addition, community-based organizations and cooperatives are to be empowered to pursue peer learning and collective action, thereby contributing to greater popularity of EbA approaches and the establishment of a resilience culture among farmers.

Finally, the constant monitoring and evaluation of the EbA interventions must be given high priority to assess their long-term effects on agricultural productivity, environmental health, and the livelihoods of households. This involves the formation of a data collection system and the participatory assessment of local farmers. This way, stakeholders will be able to fine-tune methods using evidence, expand effective measures, and ensure that EbA activities are adaptive to changing climate conditions and farmers' needs.

5.5 Recommendation for Future Areas

Research conducted in other sub-counties and counties besides Moiben is intended to determine whether the adoption and effectiveness of ecosystem-based adaptation (EbA) strategies depend on geographical, climatic, and socio-economic conditions. Such a comparative method will help estimate the scalability of the strategies and the likelihood of replicating similar positive results in other regions with different climate-related issues.

Also, researchers need to consider conducting research in regions and zones where farming practices differ, such as pastoral or mixed crop farming systems, and determine to what extent EbA strategies can be scaled to respond to various agricultural environments. Future studies should be better able to understand good practices and constraints across different agro-ecological zones by examining EbA implementation under various conditions.

Finally, this research contributes new knowledge to farming by providing empirical evidence on the role of ecosystem-based adaptation (EbA) strategies in enhancing maize yields and reducing climate-related risks among smallholder farmers. It demonstrates how specific practices such as agroforestry, soil conservation, rainwater harvesting, and crop diversification directly influence productivity and resilience, offering lessons that can be replicated in similar agricultural contexts. The study further highlights the significant impact of climate variability on yields, showing how shifts in rainfall patterns, prolonged droughts, and pest outbreaks reduce productivity and threaten food security when farmers lack appropriate adaptation measures. Future studies should therefore include counties where EbA practices have not been widely adopted to establish the underlying causes of low adoption and to propose possible policy, financial, or technical interventions to promote uptake. Such research will play a crucial role in informing inclusive climate adaptation policies that accommodate the diverse realities of smallholder farmers nationally.

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APPENDICES

Appendix I: Questionnaire for Smallholder Maize Farmers in Moiben Sub-County

Section A: Demographic Information

Please tick (√) the appropriate response.

1. Gender

   ☐ Male

   ☐ Female

2. Age

   ☐ 18–25 years

   ☐ 26–35 years

   ☐ 36–45 years

   ☐ 46–55 years

   ☐ Above 55 years

3. Level of Education

   ☐ No formal education

   ☐ Primary

   ☐ Secondary

   ☐ College/University

4. Farm Size

   ☐ 1– 5 acre

   ☐ 6–10 acres

   ☐ 11–15 acres

   ☐ More than 15 acres

5. Farming Experience (years)

   ☐ Less than 2 years

   ☐ 2–5 years

☐ 5–10 years

☐ More than 10 years

6. Household Income from Farming

☐ Less than 10,000 KES per month

☐ 10,001–20,000 KES per month

☐ 20,001–30,000 KES per month

☐ More than 30,000 KES per month

7. Do you own or rent the farm?

☐ Own

☐ Rent

Section B: Existing Ecosystem-Based Adaptation (EbA) Strategies Implemented

Please indicate your level of agreement with the following statements by ticking (√) the appropriate box.

(1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree)

Statements	**1**	**2**	**3**	**4**	**5**
1. I practice soil conservation techniques (for example terracing, contour farming) on my farm.					
2. Crop diversification is a key strategy I use to increase resilience to climate variability.					
3. I have integrated agroforestry practices (for example trees interplanted with crops) on my farm.					
4. Water management strategies such as rainwater harvesting or irrigation are in place.					
5. I implement cover cropping or mulching to improve soil moisture retention.					
6. My farm benefits from mixed farming, combining crops and livestock as part of EbA.					
7. I actively participate in community programs promoting soil and water conservation.					
8. The use of organic farming practices is part of my overall strategy to adapt to climate change.					

Section C: Adoption Rate of Ecosystem-Based Adaptation (EbA) Strategies

Please indicate your level of agreement with the following statements by ticking (√) the appropriate box.

(1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree)

Statements	**1**	**2**	**3**	**4**	**5**
1. I am aware of ecosystem-based adaptation (EbA) strategies available for smallholder farmers.					
2. I have adopted EbA strategies such as soil conservation and agroforestry on my farm.					
3. I have been using EbA strategies consistently for more than two seasons.					
4. I regularly use extension services to learn about new EbA strategies.					
5. The adoption of EbA strategies in my farming practice has increased in the last few years.					
6. My knowledge of EbA strategies has improved through training programs or workshops.					
7. The duration of time I have been using EbA strategies has significantly impacted my farm's performance.					
8. I believe the rate of adoption of EbA strategies among my neighbors is steadily increasing.					

Section D: Effectiveness of Ecosystem-Based Adaptation (EbA) Strategies

Please indicate your level of agreement with the following statements by ticking (√) the appropriate box.

(1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree)

Statements	**1**	**2**	**3**	**4**	**5**
1. Since adopting EbA strategies, the water quality on my farm has significantly improved.					
2. Soil nutrient levels on my farm have increased due to the use of EbA strategies.					
3. My household income has diversified as a result of using EbA strategies.					
4. The use of soil conservation practices has increased the soil carbon content on my farm.					
5. EbA strategies have improved crop yields and overall productivity on my farm.					
6. Adopting EbA strategies has reduced the vulnerability of my farm to extreme weather events.					
7. Water and soil management practices have enhanced my farm's resilience to climate change.					
8. I have observed long-term positive changes in my farm's ecosystem since adopting EbA strategies.					

Section E: Effectiveness of Ecosystem-Based Adaptation (EbA) Strategies

Please indicate your level of agreement with the following statements by ticking (√) the appropriate box.

(1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree)

Statements	**1**	**2**	**3**	**4**	**5**
1. I frequently experience significant yield losses due to unpredictable rainfall patterns					
2. My farm is highly susceptible to soil erosion during heavy rains					
3. Climate-related pests and diseases have increased and threaten my crops more often					
4.. Extreme weather events (for example floods, heatwaves) have become more common and damaging					
5. I lack sufficient resources to cope with the effects of climate change on my farm					
6. Climate change has negatively impacted the quality and quantity of my harvests					
7. My farm income is highly unstable due to changing weather conditions					
8. Changes in rainfall timing have disrupted my traditional planting calendar					

Appendix II: Interview Guide for County Government Officials

Introduction:

Thank you for taking the time to participate in this interview. The aim of this study is to evaluate the effectiveness of ecosystem-based adaptation (EbA) strategies in mitigating climate change vulnerabilities among smallholder maize farmers in Moiben Sub-County, Kenya. Your insights and responses will be invaluable to this research.

Instructions:

This interview consists of open-ended questions aimed at collecting qualitative data. Please feel free to elaborate on your responses.

Section A: General Information

1. Position:
2. Department:

   ☐ Department of Agriculture

   ☐ Department of Environment and Natural Resources
3. Years of Service in the Department:
4. Educational Background:

Section B: Existing Ecosystem-Based Adaptation (EbA) Strategies

1. What are the key EbA strategies implemented by smallholder maize farmers in Moiben Sub-County, as observed by you?
2. How have you been involved in promoting soil conservation, crop diversification, agroforestry, and water management practices?
3. What challenges have you observed in the adoption of EbA strategies among farmers in the region?
4. Are there any partnerships between your department and local communities to support EbA practices? If so, how effective are these partnerships?

Section C: Rate of Adoption of EbA Strategies

1. How would you assess the level of awareness and knowledge about EbA strategies among farmers in Moiben Sub-County?

   ----

2. Based on your observations, what percentage of smallholder farmers has adopted EbA strategies in the past five years?

   ----

3. What factors contribute to the success or failure of EbA strategy adoption in this region?

   ----

4. Do farmers regularly seek extension services related to EbA practices? How effective have these services been?

Section D: Effectiveness of EbA Strategies

1. In your opinion, how effective are the implemented EbA strategies in reducing climate change vulnerabilities (for example, droughts, floods) among farmers?

   ----

2. Have EbA strategies contributed to improving water quality, soil nutrient levels, and crop yields in the region? Please provide specific examples.

   ----

3. What impact have EbA strategies had on household incomes and farmers' resilience to climate change?

   ----

4. What recommendations would you make to improve the effectiveness and adoption of EbA strategies in Moiben Sub-County?

Appendix III: Focus Group Discussion (Fgd) Guide For Community Leaders And Smallholder Farmers

Introduction:

Thank you for participating in this Focus Group Discussion. The purpose of this discussion is to gather collective views on the effectiveness of ecosystem-based adaptation (EbA) strategies in mitigating climate change vulnerabilities. Your feedback will be vital for this research.

This FGD will be guided by open-ended questions. Feel free to express your opinions, experiences, and observations. The session will be recorded for research purposes, and your responses will remain confidential.

Section A: Introduction of Participants

1. Please introduce yourselves by stating your name and role in the community (for example, village elder, religious leader, maize farmer, etc.)

Section B: Existing Ecosystem-Based Adaptation (EbA) Strategies

1. What ecosystem-based adaptation strategies (for example soil conservation, crop diversification, agroforestry, water management) are you currently using or aware of in your community?

   ----

2. How do you perceive the effectiveness of these strategies in addressing climate change impacts such as droughts, floods, and soil degradation?

   ---

3. Which EbA strategies do you think have been the most effective in improving your farming practices and why?

   ----

4. Are there any strategies that you believe are difficult to implement? If so, what are the challenges?

Section C: Adoption Rate of EbA Strategies

1. How familiar are community members with EbA strategies? Do you think enough farmers in your area are adopting these strategies?

   ----

2. What motivates or prevents farmers from adopting EbA practices? (for example, knowledge, resources, cultural beliefs)

   ----

3. How long have you or other farmers been using EbA strategies, and what changes have you noticed over time?

   ----

4. Do you receive support from extension officers or agricultural programs to help adopt and maintain EbA practices? How effective is this support?

Section D: Effectiveness of EbA Strategies

1. In your experience, have EbA strategies improved water quality or soil nutrient levels on your farm? Please provide examples.

   ----

2. What impact have EbA strategies had on your household income and crop yields?

   ----

3. Do you think EbA strategies have helped reduce your vulnerability to climate change effects (for example, unpredictable weather, pests, or disease outbreaks)?

   ----

4. What improvements or recommendations would you suggest for making EbA strategies more effective for smallholder maize farmers in your area?

5. ---

Section E: Closing Remarks

1. Is there anything else you would like to add that we haven't discussed regarding EbA strategies and climate change?

   ----

2. Do you have any further questions or suggestions for the research team?

Thank you for your time and contribution. Your insights are invaluable to this research.

Appendix III: KUREC Clearance Letter

KABARAK UNIVERSITY RESEARCH ETHICS COMMITTEE

Private Bag - 20157
KABARAK, KENYA
Email: kurec@kabarak.ac.ke

Tel: 254-51-343234/5
Fax: 254-051-343529
www.kabarak.ac.ke

OUR REF: KABU01/KUREC/001/26/08/24

Date: 27th August, 2024

Kangor Yatich Kipkorir
Reg No: GMOD/NE/0472/01/21
Kabarak University,

Dear Yatich,

RE: INFLUENCE OF ORGANIZATIONAL STRUCTURE COMPONENTS ON STRATEGIC PLAN IMPLEMENTATION IN THE COUNTY GOVERNMENT OF NAKURU, KENYA.

This is to inform you that ***KUREC*** has reviewed and approved your above research proposal. Your application approval number is ***KUREC-260824.*** The approval period is 27***/08/2024 – 27/08/ 2025.***

This approval is subject to compliance with the following requirements:

i. All researchers shall obtain an introduction letter to NACOSTI from the relevant head of institutions (Institute of postgraduate, School dean or Directorate of research)

ii. The researcher shall further obtain a RESEARCH PERMIT from NACOSTI before commencement of data collection & submit a copy of the permit to **KUREC.**

iii. Only approved documents including (informed consents, study instruments, MTA Material Transfer Agreement) will be used

iv. All changes including (amendments, deviations, and violations) are submitted for review and approval by ***KUREC***:

v. Death and life-threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to ***KUREC*** within 72 hours of notification;

vi. Any changes, anticipated or otherwise that may increase the risk(s) or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to ***KUREC*** within 72 hours;

vii. Clearance for export of biological specimens must be obtained from relevant institutions and submit a copy of the permit to KUREC;

viii. Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. Attach a comprehensive progress report to support the renewal and;

ix. Submission of an executive summary report within 90 days upon completion of the study to ***KUREC***

Sincerely,

Prof. Jackson Kitetu PhD.
KUREC-Chairman

Cc
Vice Chancellor
DVC-Academic & Research
Registrar-Academic & Research
Director-Research Innovation & Outreach
Institute of Post Graduate Studies

As members of Kabarak University family, we purpose at all times and in all places, to set apart in one's heart, Jesus as Lord.
(1 Peter 3:15)

Kabarak University is ISO 9001:2015 Certified

Appendix IV: NACOSTI Reserach Permit

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **574393**

Date of Issue: **14/July/2025**

RESEARCH LICENSE

This is to Certify that Ms.. ABIGAEL JEPKORIR KIBET of Kabarak University, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Uasin-Gishu on the topic: EVALUATION OF ECOSYSTEM-BASED ADAPTATION STRATEGIES IN MITIGATION OF CLIMATE CHANGE VULNERABILITIES AMONG SMALLHOLDER MAIZE FARMERS IN MOIBEN SUB-COUNTY, UASIN GISHU COUNTY for the period ending : 14/July/2026.

License No: **NACOSTI/P/25/4176672**

574393

Applicant Identification Number

Ag. Director General
NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Verification QR Code

NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.

See overleaf for conditions

Appendix V: Evidence of Conference Participation

KABARAK UNIVERSITY

Certificate of Participation

Awarded to

KIBET ABIGAEL JEPKORIR

For successfully participating in the 15th Annual Kabarak University International Research Conference held from 10th-11th July 2025 and presented a paper entitled ***"Evaluating the existing ecosystem-based adaptation strategies implemented among smallholder maize farmers in Moiben sub-county"***

Conference Theme

Enhancing Environmental Resilience for Food Production and Energy Sustainability.

Prof. Peter Rugiri
Dean, School of Science, Engineering & Technology

Dr. Phillip Nyawere
Director - Research, Innovation and Outreach

Kabarak University Moral Code

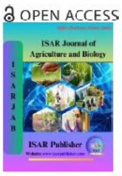
As members of Kabarak University family, we purpose at all times and in all places, to set apart in one's heart, Jesus as Lord.

(1 Peter 3:15)

Kabarak University is ISO 9001:2015 Certified

Appendix VI: List of Publication

OPEN ACCESS



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Volume 3, Issue 8, 2025 | Page: 1-9

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ASSESSING THE EXISTING ECOSYSTEM-BASED ADAPTATION STRATEGIES IMPLEMENTED AMONG SMALLHOLDER MAIZE FARMERS IN MOIBEN SUB-COUNTY

Kibet Abigael Jepkorir[1*], Eliud Garry Michura[2], Danice Otieno Awinda[3]

Kabarak University.

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Abstract: In Moiben Sub-County, climate change poses significant challenges, particularly impacting the agricultural community. The study's main objective is to evaluate existing ecosystem-based adaptation strategies implemented among smallholder maize farmers in Moiben Sub-County. Resilience Theory guided the study. The study used a mixed-methods research design. The target population was 7536 respondents, including Smallholder maize farmers, local government officials and community leaders. The sample size of 390 respondents was determined using the Krejcie and Morgan formulae. The study used systematic random sampling to select smallholder maize farmers (residents) and a purposive sampling technique to select the key informants. This study used a questionnaire for farmers to collect quantitative data and interviews for government officials to collect qualitative data. Quantitative data from filled questionnaires were entered into SPSS version 24 for descriptive statistical analysis. Quantitative data was analyzed using descriptive statistics in the form of means, standard deviation, and percentages and presented in tables and figures. Inferential statistics, including correlation and linear regression, were conducted at a 0.05 significance level to determine the relationships and predictive power of the study variables. The analyzed data was presented in the form of tables and charts. Study findings indicate that there was a positive and statistically significant relationship between ecosystem-based adaptation strategies implemented and climate change vulnerabilities (β_1=.227, p=.001). The study concluded that smallholder maize farmers in Moiben Sub-County have embraced positively a number of ecosystem-based adaptation (EbA) practices that include soil conservation, agroforestry, rainwater harvesting, as well as crop diversification practices, which have led to positive agricultural sustainability and decreased climate change risks. The research suggestd that agricultural stakeholders and county agricultural departments can improve the adoption of EbA by improving extension services, providing helpful training, and creating favourable policies such as subsidies and access to credit to encourage sustainable land management. Bring out the global. Africa and Kenyan feel in the abstract.

Keywords: *ecosystem-based adaptation strategies, smallholder, maize farmers, Moiben Sub-County.*

Cite this article:

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