ASSESSMENT OF FISH FARMER'S VULNERABILITY TO CLIMATE VARIABILITY AND EXTREME CLIMATE EVENTS IN SELECTED PARTS OF KITUI COUNTY, KENYA

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DECLARATION

I understand that plagiarism is an offense. Therefore, I declare that this thesis is my original work and has not been presented to any other institution for any other award.

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ABBREVIATIONS AND ACRONYMS

ASALs	**:**	Arid and Semi-Arid Lands
IPCC	**:**	Intergovernmental Panel on Climate change
SDGs	**:**	Sustainable Development Goals
SSA	**:**	Sub-Saharan Africa
ESP	**:**	Economic Stimulus Programme
Ksh	**:**	Kenya Shilling
NGOs	**:**	Non-Governmental Organizations
IFAD	**:**	International Fund for Agriculture and Development
ABDP	**:**	Aquaculture Business Development Programme
GDP	**:**	Gross Domestic Product
KCEAP	**:**	Kitui County Environmental Action Plan
UNEP	**:**	United Nations Environment Programme
PCA	**:**	Principal Component Analysis
GIFT	**:**	Genetically Improved Farmed Tilapia
DFID	**:**	Department for International Development- Gov.UK
FFEPP	**:**	Fish Farming Enterprise and Productivity Programme
KCIDP	**:**	Kitui County Integrated Development Plan
ROK	**:**	Republic of Kenya
SPSS	**:**	Statistical Package for Social Sciences
LDI	**:**	Livelihood Diversification index
UNDP	**:**	United Nations Development Programme
HDI	**:**	Human Development Index

ABSTRACT

Fish farmers are a vulnerable group to climate variability and extreme climate events effects as their production heavily relies on precipitation and temperature. However, previous studies on vulnerability of fish farmers to climate variability and extreme events have been done on global, regional and national scales, thus failing to capture the local realities on spatial variability. The current study was carried out to assess the household-level vulnerability of fish farmers to climate variability and extreme climate events in selected parts of Kitui County, Kenya. Purposive sampling technique was used to pick two study sites, namely Kitui Central and Kitui East. Fish farmers' vulnerability to climate variability and extreme climate events was worked out using the integrated vulnerability assessment method. Principal Component Analysis (PCA) was used to assign weights to selected exposure, sensitivity and adaptive capacity indicators. The study employed a descriptive research design. Data on fish farmers' socio-economic status, past experiences with the occurrence of extreme climate events, and adaptation strategies adopted in response to climate variability and extreme events was obtained by using a household survey interview schedule. This data was complemented by rainfall and temperature data for 30 years (1989 - 2019) collected from Kenya Meteorological Department, Kitui County office. A sample size of sixty (60) fish farmers was selected through random sampling from a target population of (200) fish farmers in the study area. Statistical Package for Social Sciences (SPSS) version 22 and Ms Excel were used to analyze the data. In regards to the exposure index of the fish farmers, Kitui Central fish farmers recorded (-0.10) while Kitui East fish farmers recorded (1.02). The sensitivity index of Kitui Central fish farmers was (-0.91) and that of Kitui East fish farmers was (2.67). Further, the adaptive capacity of Kitui Central fish farmers was (1.11) and that of Kitui East fish farmers was (0.74). The results of the study also revealed that Kitui East fish farmers had a vulnerability index of (2.96) and Kitui Central fish farmers recorded (0.31) to climate variability and extreme climate events. The overall vulnerability index and its components were statistically significant ($p<.01$) except for the exposure index. The results also indicated that fish farmers in the study area had adopted multiple adaptation strategies to combat the effects of climate variability and extreme climate events. Consequently, Kitui Central fish farmers registered a higher percentage in adoption of most adaptation strategies compared to Kitui East fish farmers. Therefore, this study recommends that policies on adaptation interventions be put into place to buttress fish farmers' adaptive capacity to cope with vagaries of climate variability and extreme climate events in the study area and beyond.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

Climate models predict negative implications of climate change on agricultural production and food production. Fish farmers however are highly affected as their production heavily relies on precipitation and temperature (Azra *et al.,* 2020). Studies also agree that climate variability and extreme events affect aquatic ecosystems with the damage being projected to the fish farmers hence their vulnerability (Allison *et al*., 2009; Barange *et al*., 2018). Moreover, fish farmers in Arid and Semi-Arid Lands (ASALs) of developing nations are extensively vulnerable to impacts of climate variability and extreme events due to their poor adaptive capacity and overreliance on rainfall (Badjeck *et al*., 2010; Adger, 2006).

Surface temperatures are projected to increase by more than 0.1^0C every decade, as per Intergovernmental Panel on Climate Change (IPCC, 2014). Varying magnitudes and speed of change in the rate of warming are projected across different continents and regions. Rainfall changes have also been reported across the globe. High latitudes and the equator are predicted to experience an increase in rainfall and a decrease is projected in the subtropics and the already arid areas (IPCC, 2014). The frequency in occurrence of extreme events like droughts, heat waves, and changing rainfall amounts is also expected to increase (IPCC, 2007).

The fluctuations in temperature, rainfall amounts, and occurrence of extreme events affect fish farmers differently, increasing their overall vulnerability. For instance, fish require a specific water depth in their culture units for maximum production (Mohammed & Uraguchi, 2013). Therefore, low rainfall and higher temperatures resulting in fast evaporation in culture units will require the fish farmers to manually maintain the water levels, which is an extra cost, increasing their vulnerability. On the other hand, rainfall above the standard threshold can also result in floods, which can destroy culture units leading to fish escapes from the culture units, hence losses to the fish farmers. Consequently, direct impacts of climate variability and extreme events on fish may result in pests and diseases and influence the physiology and behavior of fish affecting their growth, reproduction, distribution, and mortality (Cochrane *et al*., 2009), hence losses to the fish farmers. Additionally, disruption of fish farming operations and land-based infrastructure, are also expected with the occurrence of extreme events further exacerbating the vulnerability of the fish farmers.

Globally, the change in climate is projected to cause severe impacts on fish and fish products trade and accessibility (IPCC, 2007). Such effects can stir up geopolitical and economic consequences. Further, achieving food security, eradicating poverty, and doubling productivity amongst fish farmers as envisioned in the first and the second Sustainable Development Goals (SDGs) will also be affected. Barange *et al.* (2018) highlights that, fish farmers in the Asian continent and particularly in Vietnam, as the most affected and vulnerable to climate change across the globe. This is because Vietnam highly depends on fish farming and her fish farmers, further worsening her vulnerability to climate change. In addition, the fish farmers in the country have negligible diversification into other types of agriculture and income-generating activities, further increasing their overall vulnerability.

Since its introduction in Sub-Saharan Africa (SSA), fish farming has shown limited growth, with the region contributing to only 1% of the world's supply (Hecht, 2006). Water stress is projected to increase in the inland waters of the continents' already drier areas, threatening the well-being of fish farmers. Hulme *et al.* (2010) also predic a rate of warming of 0.05^{0}C per decade in SSA. Implications of climate variability and extreme events have been pointed out to hit hard on African developing countries that depend on climate-sensitive livelihoods and possess weaker economies hence limited adaptive capacity (Medugu *et al.,* 2014). Further, fish farmers in East African Countries, Kenya being one of them have been affected by climate variability and extreme climate events.

In Kenya, the fisheries sector plays a crucial role in the country's social and economic development. The sector has also proven to be vital into the transition into the Blue economy and is among the top priority farming enterprises in the country. It is therefore important for the sector to sustainably grow in order to meet the rising demand in seafood, help in poverty alleviation and solve food security concerns.

Fish farming in Kenya began in early 1900 after being introduced by colonists. The growth trajectory of fish farming in the Country was similar to that of most African countries which was characterized by subsistence production for decades until recently when the government introduced the Economic Stimulus Project (ESP) in 2009 which increased its productivity. Since then, fish farming has progressed and it comprises both Mariculture and freshwater aquaculture, with the country's most overriding fish farming systems being earthen and linen ponds, dams, and tanks. Further, fish farmers in the country have poor knowledge of best fish management practices and nutritional needs, which affect fish productivity and encourage the occurrence of fish diseases (Munguti *et al.,* 2014).

Cinner *et al.* (2012) found Kenya to possess a higher vulnerability to climate change than other nations in the study like Tanzania, Mauritius, Madagascar, and Seychelles. Two-thirds of the country receive less than 500mm in a year, making these parts of the country classified as ASALs and are home to many fish farmers. Twenty-three ASAL Counties in Kenya have been faced with severe droughts, the recent one being the 2014-18 drought, which was declared a national emergency in 2017 and severely affected fish farmers. The frequency of extreme events has been highlighted to possess catastrophic implications for cultured and captured fish productivities in the country, which places the nation further from achieving food security for vulnerable groups as envisioned in vision 2030, Kenya's development programme aiming to transform the nation into a middle income country though improving quality of life for all its citizens by 2030 (Nduku, 2015). Therefore, rural fish farming households should diversify their incomes and fish sources, as this will enable them to manage the adverse implications of climate variability and extreme events (Bell *et al.,* 2008).

The government of Kenya is aware and is serious about the challenges that climate change poses on fish farmers and has therefore come up with several interventions to improve fish farming productivity and adaptation in the country. For instance, after the global economic and financial crisis in 2009, the government injected Ksh 1.12 billion in 2009 and Ksh 2.866 billion in 2010 into fish farming (Nduku, 2015) through the Economic Stimulus Project. The investment was used to purchase fish farming inputs for fish farmers like fingerlings and construction of fishponds in various constituencies and saw an increase in fish productivity. The government has also spearheaded projects with non-governmental organizations (NGOs) and international aid agencies like the Kenya Climate-Smart Agriculture Project in collaboration with the World Bank. One of its main aims is to promote climate-smart aquaculture and research. Further, the Government of Kenya and the International Fund for Agricultural Development (IFAD) have also been funding the Aquaculture Business Development Programme (ABDP) jointly which focuses on strengthening smallholder business-oriented aquaculture organizations, supporting pond construction, and improving existing structures in aquaculture for sustainability of fisheries in fifteen Counties in the country. Additionally, the government has also ensured the enactment of policy frameworks like the Kenya climate change Act of 2016, which addresses climate change vulnerability and adaptation by developing five-year National and County climate change action plans. However, despite the many efforts, fish production in the country still lags compared to other African countries.

Kitui County, which forms the study area for this research, is a semi-arid area (Njoka *et al., 2*016). The livelihoods of most county residents depend on rain-fed agriculture, a practice that makes the fish farmer residents in the county more vulnerable. Fish farming in the County began around the 1980s but was not intensive until 2009 and 2010 when the County benefited from the Economic Stimulus Project. Two hundred households were beneficiaries in Kitui Central Sub County and three hundred in Kitui East Sub County. However, despite the governments' support for aquaculture in the two Sub Counties, adoption was slow as many beneficiary households abandoned their ponds before their first harvest and more are still being abandoned. Further, not all constructed ponds were stocked with Tilapia fingerlings. Nzevu *et al.* (2018) also found out that some fish farmers in the county have completely stopped large-scale fish farming and opted for subsistence fish farming only due to the many challenges they faced. As a result, the sustainability of fish farming in the county has been a challenge.

The most commonly kept fish in the County is Tilapia. Other fish farming households practice polyculture of both catfish and Tilapia. Earthen and linen ponds type of culture units for fish are also very common in the county, and fish farmers rear fish for subsistence use, commercial or both. The county is frequented by erratic rains, changing rainfall onsets, and changing temperature ranges resulting in significant challenges for fish farming households and the county's economy. Therefore, effective adaptation to the implications of climate change will help fish farmers in the study area move towards sustainable fish farming. Climate change adaptation refers to the modification of a system such that it can respond to present or anticipated climate stimuli and implications (Smit and Wandel, 2006). Climate change adaptation is founded on vulnerability reduction and can be achieved by minimizing exposure and sensitivity and strengthening adaptive capacity. Against this background, this research was carried out to assess the vulnerability of fish farmers to climate variability and extreme events in selected parts of Kitui County. Subsequent adaptation strategies taken by fish farmers to combat the implications of climate variability and extreme events were also assessed.

1.2 Statement of the Problem

The fisheries subsector contributes a 0.8% gross domestic product (GDP) to Kenya, provides jobs to more than 500,000 people, and supports the livelihoods of over 2 million people annually either directly or indirectly from exports (KMFRI Aquaculture Division Researchers, 2017). Fish farmers also contribute to food and nutrition security in the country, which has been a challenge (Nduku, 2015). More than 75% of Kenya's population resides in rural areas where poverty affects half of them. Therefore, the fish farming sector has the potential to reduce poverty but has not been fully exploited. Higher productivity in the sector was witnessed after the government ESP investment in fisheries in 2009 and in 2010. However, productivity has stalled as a result of recurring climatic shocks and stresses like floods, fluctuating precipitation and temperatures, and recurrent droughts amid other factors like changing markets, changing technologies, demographic changes, and cultural setbacks (Kabubo and Mariara, 2009).

According to Njoka *et al.* (2016), 89% of the land mass in Kenya is arid and semi-arid, and Kitui County, which forms the study area, is a part. Kitui County is faced with severe water scarcity, recurring drought, and off-season rains, all of which increase the vulnerability of fish farmers. Fish farmers in the study area pointed out water scarcity and droughts as the leading causes of their vulnerability. Other challenges mentioned to cause havoc in the fish farming business were lack of adequate extension services, lack of County government support, and poor knowledge of fish farming management practices. The Kitui County Environmental Action Plan (KCEAP, 2009) recognizes insufficient financial capacity translated as poverty as a developmental setback in the County. Poverty increases the sensitivity of fish farmers to impacts of climate change as they cannot respond fast to eventualities of climate change. Fish farmers in the study area were found to frequently repair the earthen linen ponds destroyed by the scorching sun during drier months of the year. In addition, sharing of fish farming equipment like nets was present in the study area. A significant association between sharing nets has been observed to the transfer of diseases (Mulei et al., 2021). Fish farmers were also observed to prefer growing catfish as this type of fish would survive in mud in periods of water scarcity.

Carrying out vulnerability assessment on fish farmers in the study area will therefore guide fish farming stakeholders in decision making and appropriate adaptation. Hence, this study aimed to empirically assess the vulnerability of fish farmers to climate variability and extreme climate events in selected parts of Kitui County and the adaptation strategies they have adopted to reduce this vulnerability.

1.3 Objectives of the Study

1.3.1 General Objective

To assess the vulnerability of fish farmers to climate variability and extreme climate events in Kitui Central and Kitui East Sub Counties in Kitui County, Kenya.

1.3.2 Specific Objectives

i. To examine the extent of exposure and sensitivity to climate variability and extreme climate events of fish farmers in the study area.

ii. To establish the adaptive capacity of fish farmers in the study area.
iii. To quantify the vulnerability of fish farmers to climate variability and extreme climate events in the study area.
iv. To assess fish farmer's adaptation strategies to climate variability and extreme climate events in the study area.

1.4 Research Questions

i. To what extent have the fish farmers in the study area been exposed and sensitive to climate variability and extreme climate events?
ii. How is the adaptive capacity of the fish farmers in the study area?
iii. How is the degree of vulnerability towards climate variability and extreme climate events of the fish farmers in the study area?
iv. To what extent have the fish farmers adopted adaptation strategies to counter climate variability and extreme climate events in the study area?

1.5 Justification of the Study

Laukkonen *et al.* (2009) observed that carrying out vulnerability assessments on fish farming communities as critical in mounting suitable interventions and coping measures for sustainable fisheries. Several other studies have been done on fish farmers' vulnerability to climate change. However, these studies have solely focused on fish farmers' global, national, or regional vulnerability (Islam *et al.,* 2019; Allison *et al.,* 2009; Cinner *et al.,* 2012; Barange *et al.,* 2018; Azra *et al.,* 2020). These studies have failed to capture vulnerability at local and household levels by generalizing all households whose vulnerability levels depend on their adaptive capacity levels and susceptibility to climate variability and extreme events. To date, just a few studies have been done on the vulnerability of fish farmers to climate variability and extreme events in ASALs and at a household level (Jamir *et al.,* 2013; Luni *et al.,* 2012; Opiyo *et al.,* 2014; Yonus *et al.,* 2018). Understanding fish farmers' vulnerability at the household level is also crucial as significant decisions on climate change adaptation and livelihood choices are made at this level.

In addition, 30% of the population in Kenya resides in ASALs, which portrays the importance of these areas (Opiyo *et al.,* 2014). The number of households vulnerable to climate variability and extreme events particularly in Eastern Africa and Kenya is on the rise. Uncertainty on the levels of vulnerability and incapacity to handle climate change impacts is also present. Additionally, the national government allocation for development in ASALs has always been insufficient (Mwikali & Wafula, 2019). Further, Kitui County, which forms the study area arid and semi-arid area and many livelihoods depend on fish farming. The adaptive capacity in the County is also compromised due to the high poverty levels hence the inability to manage impacts of the changing climate.

1.6 Scope of the Study

The study was carried out in two Sub-Counties in Kitui County, Kitui East and Kitui Central Sub Counties. The two Sub Counties were purposely selected to represent fish farmers in Kenya. The study focused on fish farmers in the two Sub Counties. The vulnerability of the fish farmers in the study area was measured as a function of vulnerability components; Exposure, Sensitivity, and Adaptive capacity.

1.7 Assumptions of the Study

The study was based on the following assumptions;

i. The selected Sub Counties were adequate representatives of fish farmers in Kenya
ii. All the household heads would take part in the household survey interview schedule

1.8 Definition of Terms

Fish farmers' vulnerability- The predisposition of fish farmers to the adverse effects of climate variability and extreme climate events including; droughts, high temperatures, and off-season rains.

Climate variability- The variations in climate variables (precipitation, average annual maximum temperature, and average annual minimum temperature) for a period of thirty years.

Extreme climate events- These are unexpected occurrences of climate variables beyond their historical distribution.

Exposure- This is the nature and degree of stress imposed on fish farmers that significantly affect their fish farming productivity.

Sensitivity- This is the degree to which fish farmers and fisheries system are affected or modified by climate variability and extreme events increasing their risks to any change in the sector.

Adaptive capacity- This is the ability of fish farmers to cope with or adjust to the changing climate (climate variability or extreme climate events).

Potential impact- Refers to the effects of climate variability and extreme events on fish farmers that may occur without considering their present and planned adaptation.

Economic Stimulus Programme- Government program designed to transform weak economic activities with a stimulus in form of tax breaks, subsidies, and improving infrastructure related to these activities.

Fish Farming- The raising of fish for commercial or subsistence use in domestication systems such as ponds, tanks, etc., usually for food.

Fish fatality- The loss of fish in fish stock through death as a result of extreme climate events like high temperatures and drought

Culture unit- An enclosed area that is used to raise fish either for subsistence use, commercial use or both

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 The Exposure and Sensitivity of Fish Farmers to Climate Variability and Extreme Climate Events

In their research, Islam *et al.* (2019) assessed how vulnerable inland and coastal aquaculture was to climate change in a developing country in a study that measured the level of aquaculture vulnerability in 64 districts of Bangladesh. To calculate the exposure of aquaculture in these districts, the authors employed variation in the past temperature and rainfall, projections in the future temperature and precipitation, sea-level rise, and storm surges as the exposure indicators for this particular study. The study results showed that of the 64 districts under study, 13 were highly exposed to climate change. The researchers concluded that the vulnerability of aquaculture varied from region to region depending on specific climatic exposures present in a particular area.

Rijnsdorp *et al.* (2009) observed that an increase in temperature changed the physical environments in water bodies by decreasing dissolved oxygen, encouraging algal blooms, and increasing pests and diseases in these water bodies, often resulting in increased fish mortality rates. Therefore, specific temperature requirements are crucial for maximum productivity in fish farming. A study by Huang *et al.* (2015) confirmed these findings after examining extended reconstructed sea surface temperature. The results revealed that surface water temperature increased by an average of 0.7°C globally every year from 1900 to 2016, and the trend was projected to remain the same or even increase.

Cochrane *et al.* (2009) also noted that regional climate variability affected fish farming. The study indicated that El Niño–Southern Oscillation, increasing temperatures, ground-water and river flows, precipitation, and salinity as the main factors affecting fish farming. The changes in groundwater and river flow were also pointed to undeniably affect fish farming since water is one of the critical requirements for fish to thrive. Further the study highlighted that increase in river flows than their standard threshold would displace fish from their usual habitats. Decreased river water flows would also deny fish adequate water leading to their mortality which would negatively impact fisheries and increase fish farmers' vulnerability.

Ndungu *et al.* (2015) assessed the vulnerability of communities in rural areas to changes in environment at the mid-hills of Himachal Pradesh in India. Exposure in the study was calculated by the use of changes in the historical climate variables for the period between 1984 and 2011 and the patterns of extreme events occurrence within the study area. The researchers used a household survey to capture information on the patterns of extreme events. The assessment showed that droughts, floods, landslides, and hailstorms increased the households' exposure in the study areas while snow decreased their exposure. The finding was hypothesized to result from improved ground-water recharge from increased snow.

Islam *et al.* (2014) also examined the vulnerability of fishery-based livelihoods to climate variability and change in Coastal Bangladesh. The study results showed that floods/storm surges were the leading causes of inland vulnerability, affecting fish farming assets and outputs. At the same time, cyclones and increasing temperatures were found to increase vulnerability in the sea. Similar studies have agreed with the investigation. For instance, a report published by United Nations Environment Program (UNEP) on 22nd December 2008, referred to as "THE DEAD WATERS," cautioned that increasing temperatures threatened three-quarters of the world's fishing grounds.

Adebo and Ayelari (2011) researched on climate change and the vulnerability of fish farmers in Southwestern Nigeria. This study concluded that climate change does undeniably affect fish production. The study revealed that amongst the 120 respondents, 59% of them had experienced flooding periodically, 25.6% had experienced floods occasionally, and 15.4% had experienced floods frequently. Further, out of the 120 respondents, only 15.4% had control measures against floods in the study area. In addition, 8.3% of the total respondents were the only fish farmers that had insured their ponds. Fish farming was also done mainly in the wet seasons of the study area compared to drier seasons due to water scarcity and pilfering, which increased the fish's mortality. Low productivity, low incomes, food insecurity, poor living standards, and poor health were some of the respondents' experiences. The study also pointed out that African fish farming countries were at significant risk of climate variability due to their massive dependence on Coastal and inland fisheries. Consequently, communities on high latitudes or hugely dependent on climate change susceptible systems like the coral reef systems or the coastal upwelling had a higher exposure. A good example was Lake Chad and the people living in its basin. The residents were prone to climate-related perturbations that affected natural resources and their livelihoods. In addition, adverse socio-economic implications on the lake's riparian communities were also evident.

Brander (2007), pointed out that high temperatures directly and indirectly affected global fish production. The direct impacts affected physiology and behavior and altered the fish's growth, development, reproductive capacity, distribution, and mortality. On the other hand, indirect effects were generally noted to affect the ecosystems, which acted as sources of food and shelter for the fish. High temperatures were also pointed out to bleach and kill coral reefs, which are habitats for juvenile fish and also act as a spawning ground for the fish. In addition, increased pest and disease infestation and a rise in the number of invasive species in fish were expected to increase with rising temperatures. Temperature changes have also resulted into fast poleward shifts in distribution of planktons and fish in regions like the North-East Atlantic.

FAO (2018), highlights fish farming as a crucial activity to millions of people. The report indicated that fish farming improves their nutrition and food security, provide them with jobs and wealth creation through incomes from the sale of fish, and fish products. However, climate variability and extreme events have been noted to slow down the global production of fish. The reports' authors noted a decrease in global fish production from cultures and fish captures since the 1980s. The report also pointed out that increased air temperatures, and the global rise in the number of heatwaves affected fish production.

Ngugi and Manyala (2004), while reviewing the Aquaculture Extension Service in Kenya, noted that in East Africa, fish farming had been extensive but less intensive. Ocean warming was pointed to have destroyed significant parts of the coral reef along the Coast where specific species live, reducing fish stocks. In addition, Coastal zone flooding increased coastal populations' vulnerability to rising sea levels in some West African countries. Further, the study alluded that indeed climate variability and extreme events had been experienced in the Country and affected fish farming. For instance, a report from the Lake Victoria Basin Commission (2011) and Obiero *et al.* (2012) noted a significant reduction in water levels in the country's natural water bodies, which affected fish farming. Nzevu *et al.* (2018), noted that fish farming significantly played a key role in the improvement of the social status of many households through the sale and the consumption of the fish in Kitui Central sub-county. However, the authors pointed out that fish farmers lacked the necessary skills for pond management, hence poor production. Fish farming in the County was noted to have been boosted in 2009/2010 through the Economic Stimulus Project (ESP), but the program's limited adoption and non-sustainability were present. The authors also found that 51.9% of the Countys' fish farmers had been affected by water scarcity, while only 48.1% reported having access to water adequate for their fish farming operations. Further, the study showed that fish farming abandonment in Kitui Central Sub-county was at 70.4%, attributed to a lack of water for fish farming operations.

Khisa *et al.* (2014) indicated that rainfall variability in Kitui District was significant in 30 years, but the temperature variability was insignificant. Further, his research discovered that prolonged dry spells, droughts, floods, and strong winds had been severely felt in the County. Despite insignificant temperature variability, its effects were exacerbated by the prolonged droughts and water shortages. All these factors can potentially increase the sensitivity of fish farmers in the County.

Mwangi *et al.* (2020) highlighted that Kitui County eastern parts had the highest exposure to climate change while the Countys' western and central parts had the lowest exposure. This pattern of exposure affected the livelihood systems in these areas. The researchers also noted that the central and west parts of the county with the lowest exposure practiced better-mixed farming than their counterparts in the eastern regions who practiced marginal mixed agriculture. The research also calculated the sensitivity pattern within Kitui County.

The sensitivity was high in the central part of the county and a few areas within the Eastern region, with the western part having low to the lowest sensitivity.

2.2 The Existing Adaptive Capacity of Fish Farmers to Climate Variability and Extreme Climate Events

FAO (2018) projected a substantial change in fish production inland, the seas, and the oceans. The outcome would make fish-dependent economies and communities vulnerable. However, the vulnerability levels depended on the local circumstances and the present adaptive capacity available in a household or a country.

Karienye and Macharia (2020) investigated the adaptive capacity of communities living along the river Tana basin in Kenya in mitigating climate variability and food insecurity. The most common extreme events in the study area were frequent floods and prolonged drought. The floods and the droughts affected agricultural outputs, increased human displacement, caused extreme poverty, food insecurity, and disrupted livelihoods in the study area. The implications had been worsened by low adaptive capacity in the area. However, there was the adoption of measures like diversification of livelihoods, growing drought-resistant crops, planting trees, and sustainable land use. To counter climate change effects, the authors recommended early warning systems and crop insurance avenues to reduce climate change vulnerability in ASALs.

Cinner *et al.* (2015) measured the changes in adaptive capacity among fish farmers in Kenya. The study used nine indicators to quantify adaptive capacity The results showed that the least prepared groups to adapt to change were young people, new immigrants, and non-participators to decision making. The study, which was a comparison over time between 2008 and 2012, showed that adaptive capacity amongst the fish farming communities had increased. The improving adaptive capacity was attributed to improved access to credit, and improved infrastructure.

Smit and Wandel (2006) carried out a general study on adaptation, adaptive capacity, and vulnerability. The authors pointed out that communities could withstand a normal to moderate change in climate conditions. However, they were vulnerable to extreme events beyond their coping ability or those that exceeded their adaptive capacity. This research also showed that exposure levels in individuals or communities were uniform across a single system but the effects were distinctive based on poverty levels, access to resources, gender, lack of political voice, and education levels. Therefore, the study concluded that there was a spatial difference in effects of climate change would vary from household to household based on present adaptive capacity. Adaptive capacity therefore refers to a community's capability to manage or adjust to the changing climate (including climate variability or extreme events), moderating the potential damages, taking advantage, or even coping with the consequences entirely (Luni *et al.,* 2012).

Salick and Byg (2001) and Macchi *et al.* (2008), and Danielsen (2005) agreed that globally, fishing communities adapted to climate variability implications. However, this did not always happen, as the exposures would sometimes surpass the adaptive capacity of the fish farming communities. Nevertheless, the farmers had actively experienced the changing climate and participated in adaptation. Furthermore, the farmers' day-to-day experiences enabled them to develop their local adaptation strategies. The authors further noted that the local knowledge and perception available in a community on climate variability and extreme events was crucial. Therefore, for an adaptation strategy to be successful, the organization imposing it on the community should ensure that the problem at hand is of significant concern to them and should not depend on available models that are rarely accurate across different systems.

Williams and Barton (2008), stressed the importance of local knowledge and perception in communities' ultimate decision on whether or not to take actions that counter climate change. The local knowledge was also pointed out to be vital in deciding whether to go for either long-term or short-term efforts to counter the changing climate on fish farming. Ecosystem-based approaches and precautionary principles were some of the ways fisheries management could be protected against climate change. Therefore, practical initiatives that sufficiently address and improve adaptive social capacity to reduce these farmers' vulnerability were essential.

Mwangi *et al.* (2020) while evaluating the vulnerability of Communities in Kitui County in Kenya by the use of indicator approach noted that existing adaptation strategies were no longer efficient in dealing with the changing climate and the increased extreme weather events. This had intensified the vulnerability of communities in Kenya. The research employed an adaptive capacity index comprised of access to markets, female literacy, and better access to water sources, and distance from the headquarters towns (Mwingi and Kitui). Households in or near towns were found to possess the highest adaptive capacity to climate change compared to households far from urban areas. The finding was attributed to better market access, safe water, and excellent infrastructure within and around these towns.

2.3 Quantifying the Vulnerability of Fish Farmers to Climate Variability and Extreme Climate Events

Letha and Kataktalwareh (2016) carried out a livelihood vulnerability analysis on livestock farmers in Karnataka, India. The study calculated vulnerability using several biophysical and socio-economic indicators. The first step in calculating vulnerability in the study area was combining exposure and sensitivity indicators, which produced potential impact. A comparison was then made between the potential impact and adaptive capacity of the community. The study established a close relationship between a communities' socio-economic status and the adaptive capacity level in Karnataka.

Notenbaert *et al.* (2013) tested the validity of indicators commonly used to measure vulnerability in climate change vulnerability assessments. The authors reiterated that most indicators used in vulnerability assessments are as per experts' judgment rather than employing empirical evidence. Further, these indicators were applied to nations or administrative units whereas management of climate change implications is usually at the household level. The study measured the vulnerability level of agro-pastoralists in Mozambique to climate stresses and majorly focused on their adaptive capacity. The study revealed that 9 out of the 26 indicators of adaptive capacity tested were the only ones that had a statistical significance relationship with vulnerability. The study, therefore, concluded that intensive research was key in coming up with the right vulnerability determinants.

Tesso *et al.* (2012) employed the integrated vulnerability approach to calculate the vulnerability of 452 households to shocks from climate change in North Shewa zone, Ethiopia. Three components of vulnerability were used; exposure, sensitivity, and adaptive capacity. Principal component analysis (PCA) was then applied to provide weights for the vulnerability indicators in the study. The study results showed that farmers living in highlands were more vulnerable to climate-induced shocks than their lowlands counterparts.

Opiyo *et al.* (2014) also measured vulnerability of household to climate change in pastoral rangelands of Kenya. To quantify vulnerability of the households in the study area, the research summed exposure index and the sensitivity index and the result was compared with the adaptive capacity index. PCA was also used to develop weights for vulnerability components. In addition, the probit model and predictor variables were employed to identify the specific determinants of vulnerability in the study area. Results indicated that 27% of the households were highly vulnerable, 44% were moderately susceptible, and 29% being less vulnerable. Further, results showed the determinants of vulnerability in the study area include age, gender, age of the household head, number of dependents, marital status, herd size, herd structure, social linkages, access to early warning systems, income, coping strategies, and access to credit.

2.4 Adaptation Strategies to Climate Variability and Extreme Climate Events Put in Place by Fish Farmers

As per IPCC (2001), adaptation refers to the adjustment of a system in response to actual or anticipated climatic stimuli or their effects, which moderates or averts the harm and exploits its opportunities. The report pointed out that early identification of adaptation strategies can help reduce the effects of climate change on fisheries. However, Brander (2007) noted that the marine ecosystems were complex. Their complexity, regional variability, and responses to climate change implications made it difficult for fish farmers and nations to come up with general and appropriate adaptation strategies that can be applied in all contexts. Nevertheless, this had not deterred fish farmers and scientists from developing appropriate strategies for different areas.

According to Deressa *et al.* (2008), understanding households' vulnerability is critical in developing a system's appropriate mitigation and adaptation programs. Furthermore, this level of assessment gives an accurate picture of vulnerability in an area. This is because susceptibility varies across households, sectors, regions, and social groups, and generalizing all systems fails to capture an area's accurate vulnerability levels. For instance, different households possess different vulnerability levels in a single community, depending on their adaptive capacity and sensitivity relative to their livelihood assets and strategies.

Asiedu *et al.* (2017) highlighted that fish farmers in Ghana had adopted a myriad of adaptation measures to counter climate change. Some of the adaptation strategies included; changing the stocking time, water management, sitting farms close to water bodies, drilling boreholes, and creating barriers around culture units to counter floods. Further, the study results showed significant temperature, rainfall, and relative humidity changes.

Mutunga *et al.* (2020) identified several aspects that influenced the choice of adaptation measure against climate change taken by farmers in Kitui County. The factors included gender, farmers' age, farming experience, memberships in community organizations, farmers' education level, access to extension services and distance to markets from farmers' households. The study concluded that different socio-economic characteristics of a farmer influenced the choices of adaptation strategies. The study lastly recommended that a farmer's socio-economic characteristics should be considered before embarking on climate change adaptation policies, projects, and programs.

Badjeck *et al.* (2010) evaluated how climate change had impacted livelihoods of fish farmers and their subsequent adaptation. The study highlighted that enhancing the livelihood platform for the fish farmers was key in enhancing adaptation. Livelihoods could be enhanced by ensuring full access to and utilization of the five livelihood assets: the physical, social, human, financial, and natural assets and creation of adequate policies that address vulnerability. Two main ways of responding to climate variability and change were present; taking anticipatory measures before climate variability or reactive actions. The study recommended strategies like creating new harvesting techniques and tools suited to any new species brought by climate variability, advancing the education of fish farmers, improving farmers; access to climate information, credit and insurance, livelihood diversification, and improving existing adaptation strategies. The study applauded Peru fish farmers who had responded to new shrimp fish species brought by Elnino in 1997 by modifying existing boat nets from having gill nets to trawl nets that could harvest the new species.

Medugu *et al.* (2014) on a study on the vulnerability of fish farmers to climate change in Nigeria alludes that improving adaptive capacity can improve communities' resilience and reduce vulnerability. The research results however, showed that even though climate change had impacted fish farmers, there was no significant reduction in its productivity. The research also noted variation in temperature and rainfall in the study area, but few adaptation measures were taken to counter the current and expected climate changes. The study suggested adoption of sustainable fish farming and agroforestry by the fish farmers.

Barange *et al.* (2018) highlighted an urgent need to implement effective and progressive adaptation strategies in the fisheries sector to combat climate change impacts as per the 2015 Paris Climate Change agreement requirements. The report suggested several adaptation strategies present globally and nationally that were sufficient. One was the adoption of freshwater aquaculture to substitute the produce from marine captures. This had been practiced in most Pacific island countries and territories and would improve people's food security and cushion them against climate variability and extreme events. In addition, aquaculture was stressed as an adaptation option that would reduce fishing pressure on natural water bodies and coral reefs, reducing their overfishing vulnerability. The authors noted that aquaculture had been practiced in Kenya as an adaptation strategy.

Integrated fish farming was also an adaptation option and was practiced worldwide. It involves the interconnection of agricultural systems with fish farming, creating a design where waste from one agricultural system is ultimately input to another and vice versa. The adaptation strategy resulted in diversified and improved resource use on a farm (Bunting *et al.,* 2010; Shoko *et al.,* 2011). This strategy was pointed out as efficient and highly practiced globally, but its adoption in Kenya is low. Nevertheless, the practice is practiced by many farmers in the Country. For instance, manure from poultry farming and cattle manure is introduced in fishing units for ponds' fertilization, which has recorded outstanding results (Opiyo *et al.,* 2014; Ogello *et al.,* 2013). In addition, new technological options as an adaptation to climate variability and extreme events were present. For instance, there has been an introduction of improved fish species in fish farming where scientists have developed a new genetically improved farmed tilapia (GIFT). As a result, farmers can benefit from early-maturing fish with improved species, enhancing their profits.

Harvey *et al.* (2018) also noted that introducing non-native aquatic germplasm-like species tolerant to warmer temperatures and estuarine species had been done. The new species could withstand increased temperature and the evidence was present globally. In addition, several mitigations like designing deeper ponds at farm levels and risk-based zoning of culture units were present. However, the research noted that most aquaculture sites never underwent risk analysis to reduce their vulnerability to climate change.

2.5 Literature Overview and Gaps

Reviewed literature showed that most studies addressed climate change impacts on fisheries on global and regional scales (FAO, 2015; Luni *et al.,* 2012). Several other pieces of research have been done tackling the vulnerability of fish farming to climate variability and extreme climate events at national levels but mostly fail to capture the reality at local levels (Medugu *et al.,* 2014; Islam *et al.,* 2014; Adebo and Ayelari, 2011). Further, other studies have made significant efforts in carrying out vulnerability studies of fish farmers to climate variability and extreme climate events at local levels but are few (Opiyo *et al.,* 2014; Islam *et al.,* 2019; Dzoga *et al.,* 2018; Laukkonen *et al.,* 2009). These studies have reiterated the importance of understanding the vulnerability of systems at local levels. But unfortunately, not a single study has been done on fish farmers' vulnerability to climate variability and extreme events on the household level in Kitui County.

Regarding the adaptation strategies adopted to counter the effects of climate variability and extreme events by fish farmers, studies revealed that adaptation strategies were crucial in countering climate variability and extreme events. Further, it was noted from the literature that the adaptive capacity present in a system influenced the adaptation strategies that a unit in a system could implement (Mutunga *et al.,* 2020; Opiyo *et al.,* 2014; Marigi, 2017). Therefore, the present study went further ahead and compared the adaptation strategies adopted in the two study sites forming the study area.

2.6 Conceptual Framework

As per IPCC (2012), vulnerability is as a result of three defining factors, namely, adaptive capacity (socio-economic characteristics), sensitivity, and exposure (Biophysical factors). The sum of sensitivity and exposure generate the potential impact. Therefore, the potential impact is subtracted from the system's adaptive capacity to calculate the overall vulnerability.

In the present study, indicators for exposure used in the study included the variation in average annual precipitation and temperature for 30 years (1989-2019) and the frequency of extreme events as perceived by the fish farmers in a period of ten years as illustrated in figure 2.1. Further, the sensitivity of the fish farmers in the study area resulted from extreme events. Therefore, several indicators were used to calculate the fish farmers' sensitivity: fish fatalities, drying of water resources, destruction of culture units, and percentage share of natural resource-based-income and non-natural resource-based-income in the study area. In addition, the adaptive capacity of the fish farmers was derived from the five household assets (human, financial, physical, natural, and social) as per the sustainable livelihoods approach (DFID, 2000).

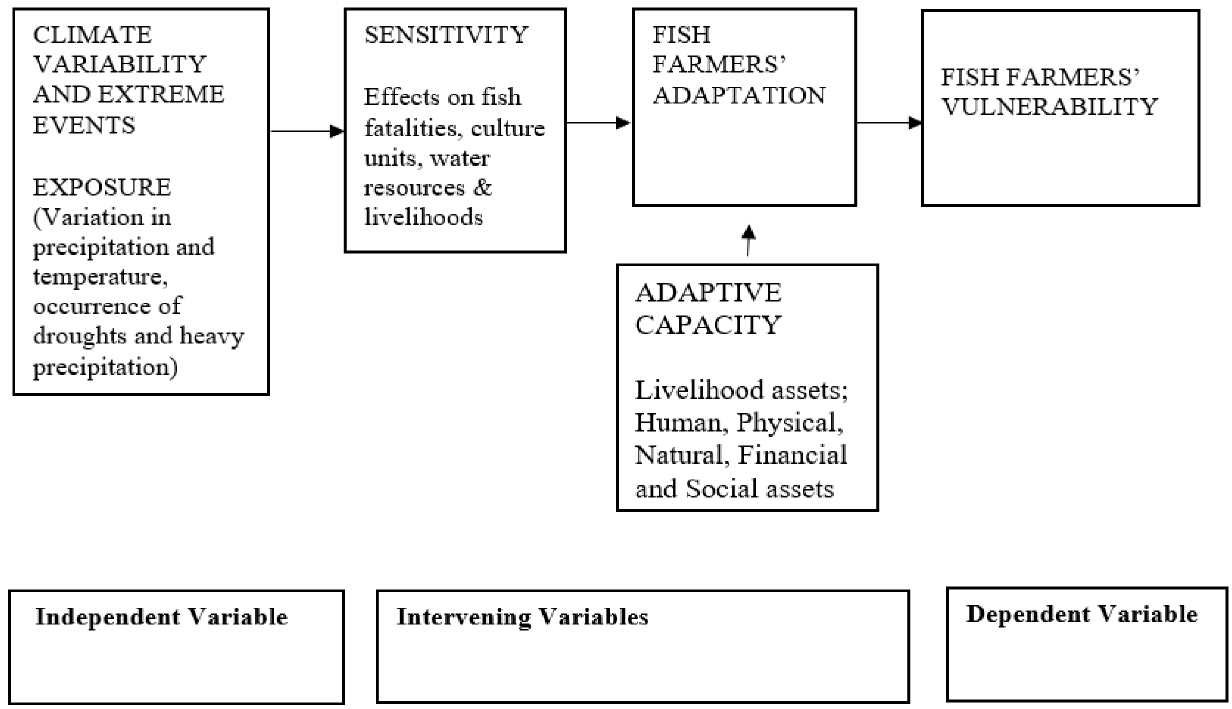

Figure 2. 1: Conceptual Framework

Source: Modified from the Sustainable Livelihood Framework, DFID (2000), IPCC (2007) and Nelson *et al.* (2010).

CHAPTER THREE

3.0 METHODOLOGY

3.1 Study Area

The study was carried out in Kitui Central and Kitui East Sub Counties in Kitui County, Kenya. The study targeted fish farmers who were beneficiaries of the Economic Stimulus Programme(ESP) investment by the government under the Fish Farming Enterprise and Productivity Programme (FFEPP) Phase 1 2009/2010 and Phase 2 2010/2011. The local inhabitants in both Sub Counties are mainly the Kamba community. The study area is as illustrated in figure 3.1 below:

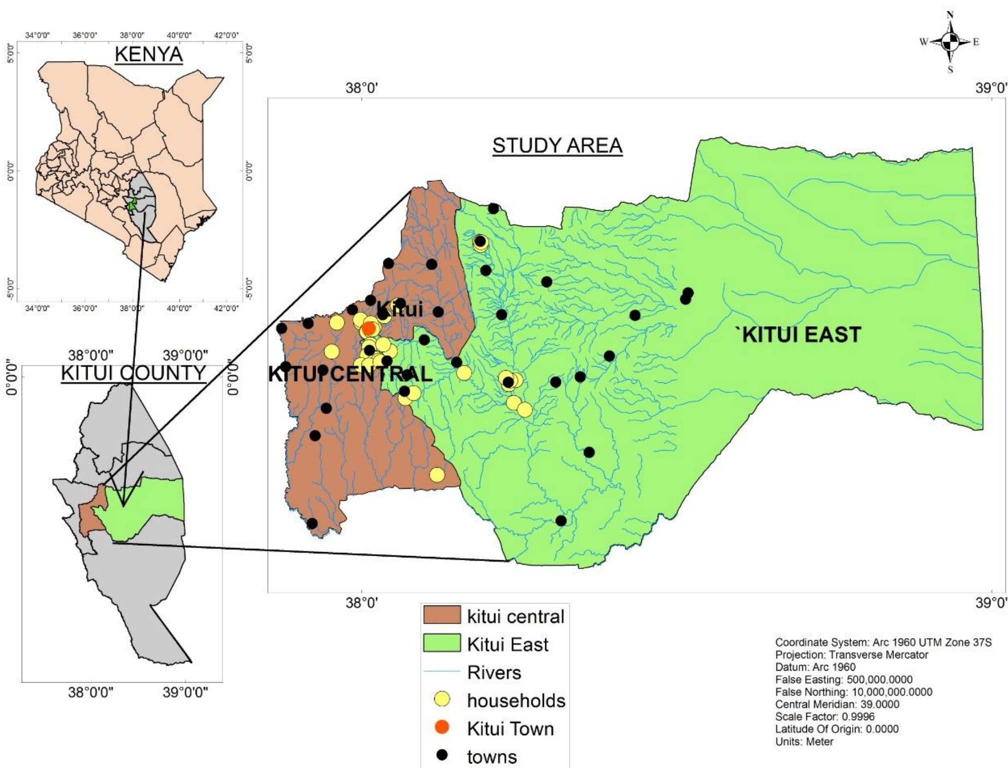

Figure 3. 1: A map showing the study area

(Source, ILRIS GIS Database)

3.1.1 General Topography and Climate of Kitui County

Kitui County is located in the Southern part of Kenya. It covers 30430Km^2 and lies between latitudes 0^0 10 South and 3^0 0 South and longitudes 37^0 50 East and 39^0 0 East. The general landscape of Kitui County is flat but gently rolls down to the East and North East, where altitudes are as low as 400m. The altitude of the County ranges between 400m and 1800m above sea level. Most parts of the County have arid and semi-arid climates with rainfall distribution that is unreliable and erratic (KCIDP, 2018). Fish farming in the County is predominantly done under rain-fed conditions which affects fish farmers. The Countys' lowest annual average temperature is 14^0C, while the highest annual average temperature is 32^0C Republic of Kenya (ROK, 2010), slightly different from the 20^0C to 30^0C requirement for fish to thrive. Agriculture in the County is primarily rain-fed, with the inhabitants practicing; crop farming, livestock keeping, fish farming, beekeeping, and poultry farming.

Kitui Central Sub-County, one of the study sites, exhibits a sub-humid climate and receives more rainfall attributed to its high altitude of 600m to 900m compared to Kitui East Sub County. Further, Kitui Central Sub-county has a temperature range between 19^0C and 35^0C (Nzevu *et al.,* 2018). Most households in the Sub County also have piped water useful in fish farming, unlike fish farmers in Kitui East Sub County. Both study sites have bi-modal rainfall patterns with long rains from March to May. The long rains are mostly erratic and unreliable, increasing fish farmers' vulnerability in the study sites. The short rains run from October to December and are relatively reliable. Most fish farmers in the study area also prefer stocking their culture units during wet seasons when there is enough water for fish farming.

3.1.2 Population and Economy of Kitui County

Kitui County has a population of 1.136M people forming 205,491 households as per the recent census conducted in 2019 (ROK, 2019), resulting in a human growth rate of 1.16% from the previous census in 2009. The rapid human growth rate calls for sustainable food systems to eradicate the county's food insecurity.

Despite its potential in fish farming, the County is classified among ASALs Counties in Kenya, and possesses relatively high poverty level approximated at 47.5%, higher than the state average of 36.1% in 2016. Food insecurity is also prevalent in the County, and half of the population is unable to access upgraded water sources (KCEAP, 2018), which puts fish farmers in the area at risk of fish fatalities due to poor water quality in culture units.

3.2 Study Research Design and Sampling Techniques

3.2.1 The Study Research Design

This study employed the descriptive research design and the individual fish farmers' households formed the unit of analysis. This approach was appropriate for the study as it does not interfere with the research variables or the respondents or arrange for events to happen. The data was collected in February of 2019.

3.2.2 The Sampling Technique

The study used purposive sampling to select the two study sites, Kitui Central Sub-County and Kitui East Sub-County, as ASAL representatives of ASALs in Kenya.

3.2.3 The Sample Size Determination

A target population of (200) fish farmers was used. Further, the fish farmers had to have lived in the study area for ten years before the household survey interview schedule was conducted. As per Mugenda and Mugenda (2003), a precision of between 10% and 30% of the total population is a good representation of the target population when the study population is less than 10,000. The total population of fish farmers was (100) in both study sites. Therefore, this research employed 30% precision for analysis in both study sites and a sample size of sixty (60) fish farmers was selected through random sampling and interviewed for this particular research in the study area.

3.2.4 Operationalization of Variables

Climate variability and extreme events formed the independent variables, while fish farmers' vulnerability to climate variability and extreme events formed the dependent variable. In addition, the fish farmers' sensitivity, adaptive capacity, and adaptation strategies to combat the impacts of climate variability and extreme events formed the explanatory/intervening variables. Table 3.1 below shows how the variables were operationalized.

Table 3.1: Operationalization of variables

Variable	Criteria	Sources/ Tools	Analysis
<u>Independent variable</u>			
Climate variability	Identification of trends in climate variables (Rate of change in average annual maximum and minimum temperature, Rate of change in average annual precipitation	Meteorological data	Independent samples t-test
Extreme events	Identification of the frequency of extreme events in the last ten years	Household survey interview schedule	Independent samples t-test
<u>Intervening/explanatory variable</u>			
Fish farmers’ sensitivity	Identification of fish farmers’ sensitivity to climate variability and extreme events	Household survey interview schedule	Independent samples t-test
Fish farmers’ adaptive capacity	Identification of fish farmers’ adaptive capacity to climate variability and extreme events	Household survey interview schedule	Independent samples t-test
Adaptation strategies adopted by fish farmers	Identification of adaptation strategies adopted by fish farmers to counter the effects of climate variability and extreme events	Household survey interview schedule	Chi-square test of independence
<u>Dependent variables</u>			
Fish farmers’ vulnerability to climate variability and extreme events	Identification of fish farmers’ exposure, sensitivity, and adaptive capacity to climate variability and extreme events	Household survey interview schedule	Independent samples t-test

Source: Nzilu (2022)

3.3 Data Collection Procedure

A household survey interview schedule was used to collect part of the data for this study. The household survey interview schedule used a semi-structured coded interview schedule which was used to target household heads for quantitative and qualitative data. Trained research assistants visited selected household sites and conducted face-to-face interviews with the household heads. The interview schedule was divided into two main sections; demographic and economic characteristics and four other sub-sections defining the fish farmers' vulnerability and adaptation strategies to counter the effects of climate variability and extreme events. Household coordinates were also picked during the survey.

3.4 Data Sources

3.4.1 Primary Data

Primary data was collected using a household survey interview schedule and direct personal observation.

3.4.2 Secondary Data

Secondary data was obtained from relevant institutions and existing literature. Desk research also aided in giving secondary data as well.

3.4.3 Data Analysis

The data was analyzed by the use of Statistical Package for Social Sciences (SPSS) version 22 and Ms Excel.

3.4.4 Data Requirements Per Objectives

Data required for each objective of the study is as shown in Table 3.2 below.

Table 3.2: Data requirements as per objectives

Objective	Required data	Source
To examine the extent of exposure and sensitivity to climate variability and extreme events of fish farmers in the study area	Historical climate data (1989-2019) and occurrence of extreme events in the last ten years Sensitivity indicators (Fish fatalities, destroyed culture units by extreme events, dried up water resources and household income)	Meteorological data and household survey interview schedule
To establish the adaptive capacity of fish farmers in the study area	Adaptive capacity indicators(Physical, financial, human, social, and natural assets)	Household survey interview schedule
To quantify the vulnerability of fish farmers to climate variability and extreme events in the study area	Vulnerability indices	Household survey interview schedule
To assess fish farmers' adaptation strategies to climate variability and extreme events in the study area	Fish farmers' adaptation strategies	Household survey interview schedule

Source: Nzilu (2022)

3.5 Methodology of Measuring Vulnerability

Vulnerability is the degree to which a system is susceptible to or unable to cope with the adverse effects of climate change (including climate variability and extreme events) (Parry *et al.,* 2007). IPCC (2007) notes vulnerability as a component of exposure, sensitivity, and adaptive capacity. Therefore, to assess fish farmers' vulnerability, one needs to understand how the components of vulnerability interact with the fish farmers in question. The fish farmers' vulnerability was therefore calculated using the integrated vulnerability approach, which combines biophysical and socio-economic indicators of a system to calculate its overall vulnerability.

3.5.1 Exposure of the Fish Farmers in the Study Area

Several exposure indicators were used to indicate the exposure levels of the fish farmers to climate variability and extreme events. The indicators included historical changes in climate variables (rate of change in average annual maximum temperature, rate of change in average annual minimum temperature, and rate of change in average annual precipitation) for 30 years (1989-2019). The household survey interview schedule complemented the historical climate data by providing data on the number of extreme events the fish farmers had experienced in the past ten years before the survey exercise was carried out. A higher frequency of extreme events or increasing trends in climate variables portrayed a higher exposure and vice versa. Table 3.3 below shows a summary of the fish farmers' exposure indicators used.

Table 3.3: A summary of the indicators for exposure in the study area

Exposure indicators	Description of indicator	Unit	Relationship with vulnerability
Historical changes in climate variables	Rate of change in average annual maximum temperature (1989 to 2019)	Coefficient of trend	+
	Rate of change in average annual minimum temperature (1989 to 2019)	Coefficient of trend	+
	Rate of change in average annual precipitation (1989 to 2019)	Coefficient of trend	+
Extreme climate events	Frequency of natural climate-related disasters(Floods, Droughts, extreme heat, fish diseases, and fish poisoning over the last ten years)	Number	+

Source: Modified from Piya *et al*. (2012), IPCC (2007), and Luni *et al.* (2012)

3.5.2 Sensitivity of the Fish Farmers in the Study Area

Several indicators were used to show the sensitivity of the fish farmers in the study area. The indicators included fish fatalities resulting from extreme events, destruction of culture units by extreme events, water resources dried up in the last ten years as a result of extreme events, and the household incomes of the fish farmers in the study area. A higher impact of extreme events on the sensitivity indicators would increase the sensitivity of the fish farmers and vice-versa.

Regarding household income, a higher share of non-natural-based-income than the share of natural resources-based-income would reduce the system's sensitivity as non-natural resource-based-income is remunerative and less reliant on climate and vice versa (Luni *et al.,* 2012). Table 3.4 below summarizes the sensitivity indicators used in the study area.

Table 3.4: A summary of the indicators for the sensitivity of the fish farmers in the study area

Sensitivity indicators	Description of the indicators	Unit	Relationship with vulnerability
Fish fatalities	Number of fish stock lost due to extreme climate events and disasters in the last ten years	Number	+
Destruction of culture units	Number of culture units destroyed in the last ten years by extreme climate events	Number	+
The estimated number of times water resources had dried up in the last ten years in the study sites	The estimated number of times water resources have dried in the last ten years	Number	+
Household income structure	Share of natural resource-based incomes(crop farming, sale of forestry products, honey sales, sand harvesting, livestock production, and aquaculture)	%	+
	Share of non-natural resource-based incomes(Remittances, salaried jobs, skilled non-farm jobs, and small business returns)	%	-

Source: Modified from Piya *et al.* (2012), IPCC (2007), and Luni *et al.* (2012)

3.5.3 Adaptive Capacity of the Fish Farmers in the Study Area

The adaptive capacity of the fish farmers was derived from the five livelihood assets (human, financial, physical, natural, and social) as per the sustainable livelihoods approach (DFID, 2000), as indicated in Table 3.4. All the assets can reduce the risks brought by climate shocks by minimizing, pooling and redistributing climate risks.

The Livelihood diversification index (LDI) was used as one of the indicators for financial assets as shown in Table 3.4. The income structure can be from various sources, and usually, a higher number of sources of income reduces the effects of climate variability and extreme events, and vice-versa. Therefore, to capture the income structure aspect of the fish farmers, the LDI was calculated using the Herfindahl-Hirschman index of diversification as applied by (Piya *et al.*, 2012);

$D_k = 1 - \sum_{i=k}^{N} {S_{ik}}^2$ …………… Equation 1

where;

D_k is the diversification index, i is the specific livelihood activity, N is the total number of activities being considered, k is the particular household, and S_{ik} is the share of i^{th} activity to the total household income for k^{th} household.

Table 3.5 below shows a summary of the indicators used.

Table 3.5: A summary of the indicators for adaptive capacity in the study area

Indicator	Description of the indicator	Unit	Relationship with vulnerability
Physical assets	Number of early sources of weather information	Number	+
	Distance to a motorable road	(Km)	-
	Number of fish farming equipment	Number	+
	Number of culture units present in a household	Number	+
	Distance to the nearest permanent water source	(Km)	-
	Total volume in liters of all water storage facilities on the farm	(L)	+
Human assets	Number of fish farming training attended by family members	Number	+
	Number of schooling years of the household head	Number	+
	The number of persons in the household having salaried employment?	Number	+
Natural assets	Number of drought animals in a household	Number	+
	The average number of fish stocked within a cycle	Number	+
	Number of fish species stocked in a household	Number	+
	Total land size devoted to fish farming in a household	In acres	+
	The total size devoted to fish farming in a household	In acres	+
Social assets	The number of CBOs a household head is registered in	Number	+
	Number of credit facilities accessed in the last ten years	Number	+
	Number of times household members have accessed extension services in the last three years	Number	+
Financial Assets	Average gross monthly income within the household from all income-generating activities(Ksh)	In Ksh	+
	Average monthly household savings	In Ksh	+
	Livelihood diversification index		+

Source: Modified from Piya *et al.* (2012), IPCC (2007), and Luni *et al*. (2012)

3.6 Adaptation Strategies Adopted by the Fish Farmers in the Study Area

The adaptation strategies adopted by the fish farmers to reduce their vulnerability to climate variability and extreme events in the study area were collected using a household survey interview schedule.

3.7 Construction of the Vulnerability Index

After selecting the indicators for fish farmers' vulnerability and defining their relationship with vulnerability, the indicators were normalized per the UNDPs' Human Development Index (HDI) (UNDP, 2006). Normalization is usually done for standardization purposes of various indicators with different units such that after normalization all values are between 0 and 1. Normalization was done using the formulae below;

$Normalized\ Value = \frac{Observed\ Value - Mean}{Standard\ Deviation}$…………………Equation 2

Assigning weights to the same indicators followed. Weights were assigned using the Principal Component Analysis (PCA) following Filmer and Pritchett (2001). PCA was run separately on the exposure, sensitivity, and adaptive capacity indicators in SPSS. Loadings from PCA highly correlated to the indicators were used as the weights. Multiplication of the normalized values and the weights then generated the vulnerability indices for each vulnerability component using the formulae below;

$I_j = \sum_{i=1}^{k} b_i [\frac{a_{ji-x_i}}{si}]$…………………. Equation 3

where;

I is the respective index value for the j^{th} household

b is the weighted value for the i^{th} indicator

a is the i^{th} indicator value for j^{th} household

x is the mean value for the i^{th} indicator

and S is the standard deviation for the i^{th} indicator value

The final vulnerability index for the fish farmers was calculated by using the formulae;

$V = E + S - AC$……………………. Equation 4

Where;

V represented the vulnerability index, E represented the Exposure index, S represented the sensitivity index, and AC represented the adaptive capacity index of the fish farmers in the study area.

The final vulnerability index formulae can also be expressed as follows;

$V = PI - AC$…………………. Equation 5

Whereby,

V represented the vulnerability index, PI represented the potential impact (Usually a sum of both exposure and sensitivity), and AC represented the adaptive capacity index of the fish farmers in the study area.

Independent samples t-test was used to compare means for the vulnerability indices of households between the two study sites. The results of the overall vulnerability indices then showed the Sub County with the most vulnerable fish farmers. The Chi-square test of independence was also applied to compare percentages of adoption of various strategies by fish farmers in the two Sub Counties.

3.8 Ethical Considerations

Ethics in research are vital in ensuring that no one is harmed or suffers from adverse consequences from the research activities. Due to the often sensitive nature of relationships between a researcher and respondents, reasonable precautions were built in this study based on ethical considerations and requirements. Therefore, during this study, the fish farmers' information was treated in confidence, and respondents were made aware that all their data would be used only for research purposes. Names of the fish farmers were not used or revealed in this study.

CHAPTER FOUR

4.0 RESULTS

The findings of the study were presented in Tables.

4.1 Fish Farmer's Vulnerability to Climate Variability and Extreme Climate Events in the Study Area

Fish farmers' vulnerability in the study area was calculated using the integrated vulnerability assessment method, which constructed indices from exposure, sensitivity, and adaptive capacity indicators. Principal Component Analysis (PCA) was then used to assign weights to all the chosen exposure, sensitivity, and adaptive capacity indicators, as described earlier in Chapter

4.1.1 Exposure Indicators in the Study Area

Weights and mean values for the indicators for exposure are presented in Table 4.1. All the weights were positive hence, contributed positively to the exposure index. Based on the weights obtained from the indicators, the rate of change in average annual precipitation (0.99) contributed the most to the exposure index while the rate of change in annual minimum temperature (0.00) contributed the least. The results further revealed that the historical climate variables contributed more to the fish farmers' exposure index than the extreme events in the study area.

Further examination of the results indicated that the coefficient of variation in average annual maximum temperature for 30 years (1989-2019) was higher in Kitui Central (1.06) compared to Kitui East (1.05). Regarding the coefficient of variation in average annual minimum temperature for the 30 years, Kitui East registered (2.78), and Kitui Central followed at (1.62). Moreover, the coefficient of variation in the rate of change in annual precipitation for the 30 years was higher in Kitui Central at (31.31) compared to Kitui East at (30.38).

A comparison of the results of the two study sites revealed that the mean values for the rate of change in average annual maximum temperature ($t_{29.00}$=29.000, p=.00), the rate of change in average annual minimum temperature ($t_{-7.57}$=47.746, p=.00), the rate of change in average annual precipitation ($t_{5.22}$=31.025, p=.00) and estimated number of occurrence of heavy precipitation ($t_{57.85}$=-2.445, p=.02) were statistically different between the two study sites. In addition, the mean values for the estimated number of droughts in the last ten years were statistically insignificant at a 95% confidence level.

Table 4.1: Weights and mean values for indicators of exposure in the study area

Indicator	Weight	Sub-County		*P*-Value
		Kitui Central n=30	Kitui East n=30	
Rate of change in average annual maximum temperature (1989-2019)	0.98	1.06(0.00)	1.05(0.00)	.00***
Rate of change in average annual minimum temperature (1989-2019)	0.00	1.62(0.00)	2.78(0.00)	.00***
Rate of change in average annual precipitation (1989-2019)	0.99	31.31(0.00)	30.38(0.00)	.00***
Estimated no. of occurrence of droughts in the last ten years	0.83	6.90(2.12)	6.10(2.52)	.19
Estimated no. of occurrence of heavy precipitation in last ten years	0.63	1.00(1.08)	1.67(1.03)	.02**

Note: Figures in parenthesis indicate standard deviation

***, and **indicate significant at 1% and 5% level of significance, respectively

4.1.2 Sensitivity Indicators in the Study Area

The sensitivity of the fish farmers in the study area was calculated using a 2-step PCA, whereby the first step PCA was run separately on indicators of the components of the overall sensitivity index. In the second step, PCA was run on the sub-composite indices to generate weights for calculating the overall sensitivity index.

4.1.2.1 Fish Fatalities Sub-Composite Index

The first step, PCA, was run on indicators of fish fatalities as presented in Table 4.2. All the indicators had positive weights hence positively impacted the fish fatalities sub-composite index. The number of fish stocks lost to heavy precipitation (0.76) contributed the most to the fish fatalities sub-composite index in the study area while the number of fish stock lost to conflicts with other resource users (0.07) contributed the least. The mean values for the results also showed that the numbers of fish stock lost to droughts, fish diseases, and conflicts with other resource users were higher in Kitui East as compared to Kitui Central. Further examination of the results revealed that the mean values for the numbers of fish stock lost due to droughts ($t_{32.12}$=-2.182, *p*=.04), heavy precipitation ($t_{35.75}$=2.284, *p*=.03), and fish diseases ($t_{41.99}$=-1.941, *p*=.06) were significantly different between the study sites. The mean values for stock lost due to conflicts with other resource users were statistically insignificant at a 95% confidence level.

Table 4.2: Weights and mean values for indicators of fish fatalities due to climate extreme events and disasters in the last ten years in the study areas

Indicator	Weight	Sub-County		*P*-value
		Kitui Central n=30	Kitui East n=30	
The fish stock lost due to drought	0.67	27.67(50.08)	115.93 (215.80)	.04**
The fish stock lost due to high precipitation	0.76	12.17(20.79)	3.00(7.14)	.03**
The fish stock lost due to fish diseases	0.19	1.67(5.31)	5.97(10.91)	.06*
The fish stock lost due to conflict with other resource users	0.07	15.33(41.33)	25.23(61.65)	.47

Note: Figures in parenthesis indicate standard deviation

**and *indicate significant at 5% and 10% level of significance, respectively

4.1.2.2 Water Resources Sub-Composite Index

The estimated number of times nearby water resources had dried up in the last ten years were used as indicators for the sensitivity of water resources as tabulated in Table 4.3. The results showed that the weights for all the water sources sub-composite index indicators were positive, implying a positive influence on the water resources sub-composite index. A close investigation of the results indicated that the estimated number of times shallow wells had dried up in the last ten years (0.80) had the most significant influence on the water resources sub-composite index. The results further revealed that the number of times all water resources had dried up was higher in Kitui East compared to Kitui Central.

Independent-samples t-test performed to compare the two study sites indicated that the mean values for water resources sub-composite index indicators were statistically different ($p < 0.05$) between the two study sites.

Table 4.3: Weights and mean values for indicators of water resources sensitivity to climate extreme events and disasters in the study areas

Indicator	Weight	Sub-County		*P*-value
		Kitui Central	Kitui East	
The estimated number of times rivers/streams had dried up in the last ten years	0.77	0.27(0.69)	3.70(4.00)	.00***
The estimated number of times boreholes had dried up in the last ten years	0.78	0.33(0.84)	3.87(4.02)	.00***
The estimated number of times shallow wells had dried up in the last ten years	0.80	2.03(3.22)	3.77(3.88)	.07*
The estimated number of times sand dams had dried up in the last ten years	0.60	1.17(1.90)	2.43(3.53)	.09*
The estimated number of times water pans had dried up in the last ten years	0.46	3.03(3.36)	5.33(4.44)	.03**
The estimated number of times springs had dried up in the last ten years	0.60	1.47(1.17)	2.47(2.42)	.05**
The estimated number of times other water resources had dried up in the last ten years	0.65	1.83(1.93)	3.80(3.60)	.01**

Note: Figures in parenthesis indicate standard deviation

***, ** and * indicate significant at 1%, 5% and 10% level of significance

4.1.2.3 Weights and Mean Values for Indicators of Overall Sensitivity in the Study Area

Weights and mean values of the indicators of overall sensitivity in the study area are indicated in Table 4.4. The study results showed that all indicators for the overall sensitivity index positively contributed to the overall sensitivity index except for the percentage of non-natural resource-based income, which negatively affected it. The percentage share of natural resources-based income had the highest weight towards the overall sensitivity index (0.98).

A close examination of the mean values for the indicators of the overall sensitivity index revealed that Kitui East had registered a higher number of culture units destroyed by extreme events and higher fish fatalities. Similarly, the mean values of the percentage share of natural resources-based income were higher in Kitui East (0.69) compared to Kitui Central (0.49). On the contrary, the percentage share of non-natural resources-based income was higher in Kitui Central (0.51) compared to Kitui East which registered (0.31). Independent-samples t-test to compare the overall sensitivity in the two study sites indicated that all the indicators were statistically different ($p<0.05$) except for the fish fatalities indicator, which was statistically insignificant at a 95% confidence level.

Table 4.4: Weights and mean values for indicators of overall sensitivity in the study area

Indicator	Weight	Sub-County		*P*-Value
		Kitui Central n=30	Kitui East n=30	
Fish fatalities due to climate extreme events and disasters in last ten years	0.71	-0.02(0.99)	0.02(1.03)	.88
Culture units destroyed by climate extreme events and disasters in last ten years	0.02	-2.29(0.98)	0.23(1.13)	.09*
The estimated number of times water resources have dried up in the last ten years	0.76	-1.62(1.02)	1.62(2.79)	.00***
Percentage share of natural resources based income	0.98	0.49(0.35)	0.69(0.29)	.02**
Percentage share of non-natural resources based income/ Percentage share of remunerative income	-0.98	0.51(0.35)	0.31(0.29)	.02**

Note: Figures in parenthesis indicate standard deviation

***, ** and * indicate significant at 5%, 1% and 10% level of significance respectively

4.1.3 Adaptive Capacity Indicators in the Study Area

Two-step PCA was run to calculate the overall adaptive capacity index. The first step PCA was run separately on each indicator of the five livelihood assets. A second step PCA was then run on all the sub-composite indices of adaptive capacity to generate weights for the overall adaptive capacity index.

4.1.3.1 Indicators of Physical Assets Sub-Composite Index in the Study Area

Results of the indicators of physical assets from the study area are presented in Table 4.5. The results disclosed that all indicators had positive weights hence a positive influence on the physical assets index. The sum of all fish farming equipment (0.88) had the highest contribution towards the physical assets index. Independent-samples t-test performed to compare physical assets in both study sites revealed that the sum of all fish farming equipment ($t_{37.72} = 8.490$, p=.00), the sum of all culture units ($t_{31.49} = 6.578$, p=.00), number of early warning sources of weather information (t47.21 = 5.637, p=.00), and total water storage ($t_{29.84} = 2.369$, p=.02) were statistically different between the two study sites. On the contrary, the mean values of the distance to the nearest motorable road and distance to the nearest permanent water sources were statistically insignificant at a 95% confidence level.

Table 4.5: Weights and mean values for indicators of physical assets in the study area

Indicator	Weight	Sub-County		*P*-Value
		Kitui Central n=30	Kitui East n=30	
Physical assets				
Number of early warning sources of weather information	0.72	3.20(1.45)	1.47(0.86)	.00***
Sum of all culture units in a household	0.76	2.57(1.22)	1.07(0.25)	.00***
Sum of all fish farming equipment	0.88	8.83(3.34)	3.27(1.31)	.00***
Distance to the nearest motorable road	0.61	0.80(0.76)	0.63(0.85)	.43
Distance to the nearest permanent water source	0.78	0.92 (1.05)	1.07(1.05)	.58
Total water storage in a household	0.46	17,202.33(28,701.42)	4,700.00(3453.14)	.02**

Note: Figures in parenthesis indicate standard deviation

*** and ** indicate significant at 1% and 5% level of significance

4.1.3.2 Indicators of Natural Assets in the Study Area

Weights and mean values of various indicators of natural assets are illustrated in Table 4.6. All the weights of the indicators were positive hence a positive relationship with the natural assets index. The results revealed that the total land size in acres owned by a household contributed the most to the natural assets index (0.93). The mean values of the indicators revealed that Kitui East households had a higher natural assets base compared to Kitui Central. Independent-samples t-test performed to compare natural assets in both study sites revealed that all indicators of natural assets were statistically insignificant at a 95% confidence level except for the number of drought animals in a household whereby ($t_{46.94}$=-3.552, p<.01).

Table 4.6: Weights and mean values for indicators of natural assets and in the study area

Indicator	Weight	Sub-County		*P*-Value
		Kitui Central n=30	**Kitui East n=30**	
Natural assets				
Total land size owned by household(acres)	0.93	6.95(11.29)	13.87(25.82)	.19
Total land size devoted to fish farming in the	0.92	1.27(2.03)	2.13(3.66)	.27
household	0.58	0.73(1.72)	2.93(2.92)	.00***
Number of drought animals owned by a	0.63	1.27(0.25)	1.10(0.31)	.14
household Number of fish species cultured in a household The average number of fish stocked within a cycle	0.80	357.67(303.04)	255.67(176.45)	.12

Note: Figures in parenthesis indicate standard deviation

*** indicate significant at 1% level of significance

4.1.3.3 Indicators of Human Assets in the Study Area

Results of the weights and mean values of various indicators of human assets are presented in Table 4.7. All the weights were positive hence a positive relationship with the human assets index. Close examination of the results indicated that the number of fish farming training attended by household members (0.84) contributed the most to the human assets index, followed by the number of schooling years of the household head (0.77) and the least being the number of persons with salaried employment in the household (0.64). Independent-samples t-test performed to compare human assets in both study sites revealed that a fish farmer's number of fish farming training attended was statistically significant ($t_{57.95}=0.795$, $p<.01$). However, this was not the case with the number of schooling years of the household head and the number of persons with salaried employment whose mean values were statistically insignificant at a 95% confidence level.

Table 4.7: Weights and mean values for indicators of human assets in the study area

Indicator	Weight	Sub-County		P-Value
		Kitui Central n=30	**Kitui East n=30**	
Human assets				
Number of schooling years of the household head	0.77	11.53(4.34)	10.63(4.46)	.43
Number of persons with salaried employment in the household	0.64	0.83(0.75)	0.53(0.73)	.12
Number of fish farming training attended by household members	0.84	1.67(1.18)	0.30(0.54)	.00***

Note: Figures in parenthesis indicate standard deviation

*** indicate significant at 1% level of significance

4.1.3.4 Indicators of Social Assets in the Study Area

The weights and mean values of various indicators of social assets are indicated in Table 4.8. All the weights were positive, implying a positive impact on social assets. The results revealed that the number of community-based organizations a household head had a membership in the last ten years (0.85) contributed the most to the social assets index.

Mean values of the indicators revealed that household heads in Kitui Central fish farmers had a higher social assets base compared to Kitui East fish farmers. Independent-samples t-test performed to compare social assets in both study sites revealed that all the indicators were statistically significant ($p<.01$).

Table 4.8: Weights and mean values for indicators of social assets in the study area

Indicator	Weight	Sub-County		*P*-Value
		Kitui Central n=30	Kitui East n=30	
Social assets				
Number Community-based Organizations household head is a member	0.85	1.53(0.57)	0.50(0.63)	.00***
	0.60	1.70(1.51)	0.40 (0.72)	.00***
Number of credit facilities accessed in the last ten (10) years	0.79	1.37(1.10)	0.27(0.52)	.00***
Number of times household members have accessed extension services				

Note: Figures in parenthesis indicate standard deviation

*** indicate significant at 1% level of significance

4.1.3.5 Indicators of Financial Assets in the Study Area

Weights and mean values of various indicators for financial assets are presented in Table 4.9. All the indicators had positive weights hence a positive impact on financial assets. The average monthly savings (Ksh) in households (0.85) had the highest weight towards the financial assets index. Independent-samples t-test performed to compare financial assets in both study sites revealed that gross monthly income within the households from all income-generating activities and average monthly savings were statistically significant ($p<.01$). However, the mean values of the livelihood diversification index were statistically insignificant at a 95% confidence level.

Table 4.9: Weights and mean values for indicators of financial assets in the study area

Indicator	Weight	Sub-County		*P*-Value
		Kitui Central n=30	Kitui East n=30	
Financial assets				
Average gross monthly income within the household from all	0.83	23300.00(20472.27)	8216.67(7488.71)	.00***
income-generating activities(Ksh)	0.85	5183.33(3379.668)	2083.33(1939.09)	.00***
Average monthly savings(Ksh)	0.23	0.38(0.25)	0.47(0.24)	.15
Livelihood diversification index				

Note: Figures in parenthesis indicate standard deviation

*** indicate significant at 1% level of significance

4.1.3.6: Aggregate Adaptive Capacity Index, Composite Sub-Indices, and Component Indicators

Figure 4.1 shows the overall adaptive capacity index, composite sub-indices, and component indicators of various assets that formed the adaptive capacity of the fish farmers in the study area.

Results from the second step PCA showed the significance of the five asset types, as indicated in Figure 4.1. Social assets had the highest contribution to the adaptive capacity of the fish farmers in the study area with a weight of (0.85), followed by both physical (0.79), natural assets (0.79), financial assets (0.73), and lastly the human assets (0.65).

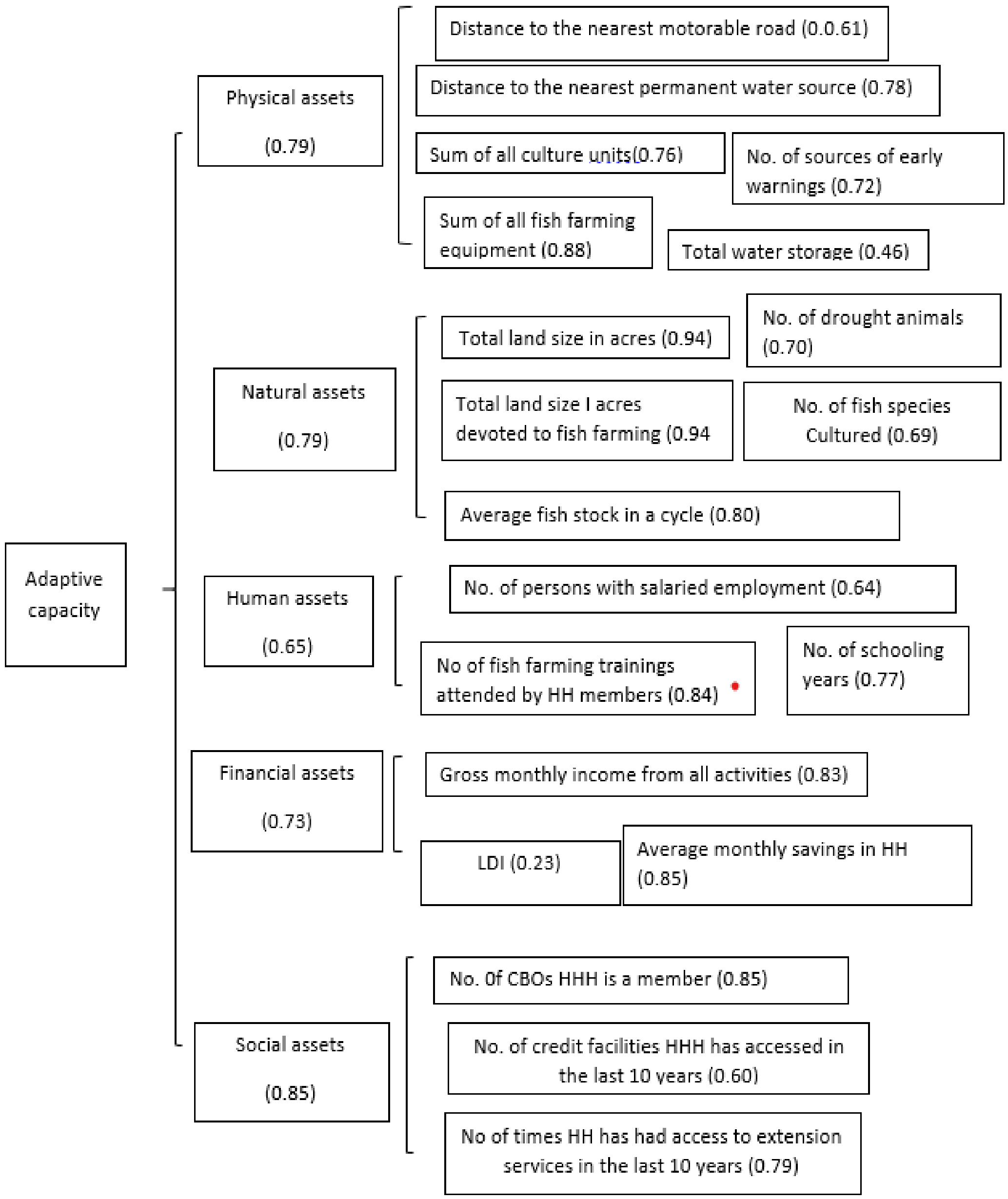

Figure 4.1: Structure of aggregate adaptive capacity index, composite sub-indices, and component indicators

Note: Figures in parenthesis are the loadings obtained from principal component taken as weights for the respective indicators.

4.1.3.7 Weights and Mean Values of Composite Sub-Indices Indicators of Adaptive Capacity in the Study Area

The weights and mean values of various indicators of adaptive capacity are presented in Table 4.10. All the weights of the indicators of overall adaptive capacity were positive, implying a positive contribution to the adaptive capacity index. After the second stepwise PCA, social assets (0.85) had the highest contribution towards the adaptive capacity index in the study area, followed by physical assets (0.79), natural assets (0.79), financial assets (0.73), and lastly, human assets (0.65). Independent-samples t-test performed to compare adaptive capacity in both study sites revealed that physical, social, and financial assets were statistically significant ($p<.01$). However, the mean values for the natural and human assets index were not statistically significant at a 95% confidence level.

Table 4.10: Weights and mean values for overall adaptive capacity indicators in the study area

Indicator	**Weight**	**Sub-County**		***P*-Value**
		Kitui Central n=30	**Kitui East n=30**	
Physical assets index	0.79	1.70(1.97)	-1.71(1.07)	.00***
Natural assets index	0.79	-0.20(1.74)	0.21(2.95)	.52
Human assets index	0.65	0.01(1.18)	-0.01(1.18)	.95
Social assets index	0.85	1.26(1.29)	-1.28(0.94)	.00***
Financial assets index	0.73	1.29(1.73)2	-0.24(0.70)	.00***

Note: Figures in parenthesis indicate standard deviation

*** indicate significant at 1% level of significance

4.1.4 Vulnerability Index

The formula below was adopted to calculate the overall vulnerability of fish farmers in the study area;

$Overall\ Vulnerability = (Exposure + Sensitivity) - Adaptive\ Capacity\ldots\ldots$ Equation 5

The weights and mean values of the indicators of overall vulnerability in the study area are indicated in Table 4.11. Examination of results revealed that the exposure and sensitivity of the fish farmers to climate variability and extreme events were higher in Kitui East at (1.02) and (2.67), respectively, compared to Kitui Central at (-0.10) and (-0.91), respectively. On the contrary, results revealed that mean values of adaptive capacity were higher in Kitui Central (1.11) compared to Kitui East which registered (0.74). Additionally, an independent samples t-test performed to compare the vulnerability of fish farmers in both study sites revealed that; the sensitivity index, potential impact, adaptive capacity index, and overall vulnerability index were statistically significant ($p<.01$). However, the mean values of the exposure index were not statistically significant at a 95% confidence level.

Table 4.11: Vulnerability indices in the study area

Index	**Sub-County**		***P*-Value**
	Kitui Central n=30	**Kitui East n=30**	
Exposure index	-0.10(2.74)	1.02(2.62)	.11
Sensitivity index	-0.91(1.71)	2.67(3.20)	.00***
Potential impact index	-0.80(2.93)	3.70(2.75)	.00***
Adaptive capacity Index	1.11(2.80)	0.74(3.82)	.00***
Vulnerability	0.31(4.35)	2.96(3.39)	.00***

Note: Figures in parenthesis indicate standard deviation

*** indicate significant at 1% level of significance

4.2 Fish Farmer's Adaptation Strategies Taken in Response to Climate Variability and Extreme Climate Events in the Study Area

The study indicated that fish farmers in the study area had adopted different adaptation strategies to counter the effects of climate variability and extreme events, as illustrated in table 4.12. The adaptation strategies were divided into three major categories; adaptation in response to changing precipitations, adaptation in response to changing temperatures, and adaptation to extreme events.

4.2.1 Adaptation in Response to Changing Precipitations

Fish farmers in Kitui Central and Kitui East had adopted multiple strategies to counter changing precipitations, as indicated in Table 4.12. For instance, 60% of fish farmers in Kitui Central and 40% of fish farmers in Kitui East had adopted farming hardy fish tolerant to climate variability and extreme events. Regarding shifting from fish farming to other agricultural activities, 86.7% of the fish farmers in Kitui Central and 33.3% of the fish farmers in Kitui East had shifted from fish farming to other agricultural activities. Practicing agroforestry by households was another popular adaptation strategy. Results revealed that 93.3% of fish farmers in Kitui Central and 60% in Kitui East actively practiced agroforestry.

In addition, shifting from other agricultural activities to fish farming was present, with 76.7% of fish farmers in Kitui Central and 6.7% of fish farmers in Kitui East adopting it. The study area also reported the integration of fish farming into other agricultural activities, whereby 90% of fish farmers in Kitui Central and 73.3% of fish farmers in Kitui East were practicing it. Most fish farmers also practiced fish farming when water was available, and results revealed that 66.7% of fish farmers in Kitui Central and 20% of fish farmers in Kitui East practiced this strategy.

Further, results showed that 90% of Kitui Central and 70% of fish farmers in Kitui East had adopted building water harvesting schemes. In addition, 83.3% of Kitui Central fish farmers and 36.7% of Kitui East fish farmers had begun reusing waste water. Again, it was also noted that 70% of Kitui Central and 23.3% of fish farmers in Kitui East had changed fingerlings stocking time. Further, 90% of Kitui Central and 76% of fish farmers in Kitui East had increased vegetation cover to attract rain. Incorporation of Water conservation techniques in fish farming was also common, and it had been adopted by 90% of fish farmers in Kitui Central and 46.7% of fish farmers in Kitui East. Results also showed that 86.7% of fish farmers in Kitui Central and 36.7% in Kitui East practiced mixed-sex culture. Comparing the adaptation strategies adopted to counter changing temperatures revealed that most strategies' adoption was statistically different between the two study sites ($p<.05$).

Table 4.12: Adaptation strategies (%) used by fish farmers in response to changing precipitations in the study area

Weather element	Adaptation strategy	Sub County		*P*-value
		Kitui Central	**Kitui East**	
Precipitation	Farming hardy fish tolerant to climate variability and extreme events	60%	40%	0.60
	Shifting from fish farming to other agricultural activities	86.7%	33.3%	0.00***
	Shifting from other agricultural activities to fish farming	76.7%	6.7%	0.00***
	Integration of fish farming into other agricultural activities	90%	73.3%	0.10
	Practicing fish farming when water is available	66.7%	20%	0.00***
	Building water harvesting schemes	90%	70%	0.05**
	Reusing waste water	83.3%	36.7%	0.00***
	Changing stocking time	70%	23.3%	0.00***
	Stocking different rearing units at different intervals	33.3%	10%	0.03**
	Increased vegetation cover to attract rain	90%	76.7%	0.17
	Incorporation of Water conservation techniques in fish farming	90%	46.7%	0.00***

Note: ***, ** significant at 1% and 5% level of significance indicates

4.2.2 Adaptation in Response to Changing Temperatures

Fish farmers in the study area adopted several adaptation strategies to counter changing temperatures, as indicated in Table 4.13. For example, 80% of the fish farmers in Kitui Central frequently repaired damaged culture units (earthen linen ponds). In comparison, 56.7% of the fish farmers in Kitui East were also noted to repair slightly damaged culture units. Further, 90% of fish farmers in Kitui Central and 36.7% in Kitui East had adopted stocking juveniles (up to 30g) instead of fry (up to 6g). Reducing stocking fish was also a common practice, with 76.7% of fish farmers in Kitui Central and 46.7% in Kitui East adopting this practice, reportedly due to poor productivity caused by changing temperatures.

Independent Chi-square tests to compare the adoption of adaptation strategies against changing temperatures revealed that all adaptation strategies in this category were statistically different between the two study sites($p<0.05$).

Table 4.13: Adaptation strategies (%) used by fish farmers in response to changing temperatures in the study area

Weather element	**Adaptation strategy**	**Sub-County**		***P*-value**
		Kitui Central (n=30)	**Kitui East (n=30)**	
Temperature	Frequent repairs of slightly damaged culture units (earthen linen ponds)	80%	56.7%	0.05**
	Stocking juveniles (up to 30g) instead of fry(up to 6g)	90%	36.7%	0.00***
	Reducing fish stocking	76.7%	46.7%	0.02**

Note: ***, ** indicates significant at 1% and 5% level of significance

4.2.3 Adaptation in Response to Extreme Events

Fish farmers in Kitui East have adopted several adaptation strategies to counter extreme events, as shown in Table 4.14. For example, 3.3% of fish farmers in Kitui Central had procured insurance for their fish farming business, while (6.7%) in Kitui East adopted the same. Further, 56.7 of fish farmers in Kitui Central sought county government support, while (50%) did the same in Kitui East. Additionally, 30% of fish farmers in Kitui Central procured loans to keep the fish farming business afloat, and (10%) of Kitui East fish farmers reported the same. Lastly, 66.7% of fish farmers in Kitui Central took off-farm jobs, with only 26.7% of fish farmers in Kitui East taking up the strategy.

A comparison of adaptation strategies taken against extreme events between the two study sites revealed that finding off-farm jobs and procuring loans to keep the fish farming business afloat were statistically different ($p<0.05$). On the contrary, procuring insurance for fish farming businesses and seeking county government support were insignificant at a 95% confidence level.

Table 4.14: Adaptation strategies (%) used by fish farmers in response to extreme events in the study area

Weather element	Adaptation strategy	Sub-County		***P*-value**
		Kitui Central	**Kitui East**	
Extreme events	Procuring insurance for the fish farming business	3.3%	6.7%	0.55
	Seeking County government support	56.7%	50%	0.61
	Procuring loans	30%	10%	0.05**
	Finding off-farm jobs	66.7%	26.7%	0.00***

Note: ***, ** indicates significant at 1% and 5% level of significance

CHAPTER FIVE

5.0 DISCUSSION

5.1 Fish Farmer's Vulnerability to Climate Variability and Extreme Climate Events in the Study Area

5.1.1 Exposure Indicators in the Study Area

The present study established that the weights for the rate of change in average annual precipitation, the rate of change in average annual maximum temperature, the rate of change in average annual minimum temperature, the estimated number of droughts in the last ten years, and estimated number of occurrence of high precipitation in the last ten years were positive hence a positive relationship with the exposure index. The possible explanation for this is that fish farming is a climate-sensitive venture, and therefore, any slight variations in the above indicators increase the exposure of fish farmers. The results agree with findings by Islam *et al.* (2019), which indicated that variation in past maximum and minimum temperatures, rainfall variation, storm surges, and past sea-level change contributed positively to fish farmers' exposure index in Bangladesh. Further, Dzoga *et al.* (2018) found that temperature and rainfall indicators positively correlated with the exposure index in a study on vulnerability to climate variability of coastal fishing communities in Ungwana bay and lower Tana estuary in Kenya.

Further, the study results revealed that the rate of change in average annual precipitation had the highest contribution towards the exposure index than the other indicators. The high contribution is attributed to rainfall being a prime input and requirement in fish farming in the study area. Therefore, any changes in precipitation would increase the exposure of fish farmers in the study area. The results corroborate similar studies by Cochrane *et al.* (2009) and Ciseneros *et al.* (2014), which indicated that inland fisheries were highly impacted by changing precipitations and runoff due to climate change. On the contrary, Cochrane *et al.* (2009) noted a likelihood of increased fish production in areas like The Ganges basin in South Asia, which is characterized by high runoff and discharge rates. Similar studies by Allison *et al.* (2005) also point to flooding to increase yields in fish farming in Bangladesh. However, most studies agree that unfavorable impacts of climate change on fisheries outweighed the favorable outcomes, more so in developing countries where adaptive capacity is typically weakest.

Conversely, historical climate variables contributed more to the fish farmers' exposure than the extreme events in the study area. The influence resulted from minimal extreme events in the study area, with droughts and heavy precipitation reportedly being the most experienced events. The results agree with findings by Luni *et al.* (2012) in a study on the vulnerability of rural households to climate change and extremes in Nepal which revealed that the absolute values of weights of historical climate variables had a higher contribution to the exposure index than the occurrence of extreme events in the study area.

In addition, the results also revealed that the coefficient of variation in average annual maximum temperature for 30 years (1989-2019) was slightly higher in Kitui Central compared to Kitui East. The current results trend is attributed to the semi-humid nature of Kitui Central compared to the dry Kitui East Sub County. Higher maximum temperatures result in more significant risks of droughts and water shortages which can affect the productivity of fish farming, increasing the exposure of fish farmers. Usually, higher temperatures increase the evaporation rate from water bodies, leading to faster water loss into the atmosphere and reducing the amounts of water available for fish farming. Inadequate water for fish farming would increase costs in maintaining water levels in fish ponds, affecting the fish farmers. Further, rising temperatures can negatively affect hatchery-based fish seed production, a crucial part of the fish production cycle. Brander (2007) and Azra *et al.* (2020) uphold this finding by noting that higher temperatures affected fish farming directly and indirectly, with other reports having shown rising temperatures across Kenya (Mutunga *et al.,* 2017; Klisch *et al.,* 2015).

Conversely, the results also revealed that the coefficient variation in average annual minimum temperature for 30 years (1989-2019) was higher in Kitui East compared to Kitui Central. Again, the possible explanation is that Kitui East is drier than the semi-humid Kitui Central. The higher minimum temperature may have contributed to the few cases of fish diseases in the study area, which increased veterinary costs to the fish farmers, further increasing their exposure. The results align with Luck *et al*. (2011), who noted that higher minimum temperatures encouraged the proliferation of fish diseases.

The results also revealed that the rate of change in annual precipitation for 30 years (1989-2019) was higher in Kitui Central compared to Kitui East. Therefore, fish farmers in Kitui Central received varying amounts of water compared to Kitui East fish farmers. Water is a critical resource in fish farming; hence, this unpredictability of precipitation increased the fish farmers' exposure in the study area. Any significant variation in precipitations amounts in the study area would affect water levels in fish ponds, affecting water quality and resulting in fish diseases. Other studies have reported unpredictable and irregular rainfall in Kenya (Mutunga *et al.,* 2017; Klisch *et al.,* 2015), affecting fish farmers. Investments in water harvesting technologies and rainwater harvesting for fish farming were higher in Kitui Central, hence better adaptation towards droughts than fish farmers in Kitui East.

Regarding extreme events, droughts were reported to be the most experienced hazard in the study area. The droughts were ascribed to high-temperature variability, which affected the study area's rainfall patterns, increasing the fish farmers' exposures in the study area. Notably, Kitui East Sub County reported higher droughts cases than Kitui Central, which is credited to its dry nature compared to the sub-humid Kitui Central. The finding is in tandem with similar studies conducted in various regions in Kenya (Marigi, 2017; Kisaka *et al.,* 2015; Opiyo *et al.,* 2014), whereby droughts were found to be the most experienced hazard that had resulted in the vulnerability of the communities in their respective study areas.

Moreover, the results indicated that fish farmers in Kitui East Sub County had experienced comparatively higher incidents of droughts and extreme events compared to their counterparts in Kitui Central. The result is similarly attributed to the dryness of Kitui East compared to the sub-humid Kitui Central Sub County. Droughts are likely to increase the exposure and vulnerability of fish farmers since fish farming in the study area is majorly rain-fed. Ndungu *et al.* (2015) corroborated the finding by revealing drought, amongst other extreme events, to have amplified the exposure of mountain people in India.

Independent-samples t-test on mean values for the indicators of exposure revealed a statistically significant difference in the mean values for all the exposure indicators except for the estimated number of occurrences of droughts in both Sub Counties. Therefore, the statistical difference in exposure levels in the study area implied that the two Sub Counties had varying exposure levels to climate variability and extreme events. The difference in exposure levels between the two Sub Counties could be due to variations in rainfall distribution and temperature. The finding is in tandem with studies by Cochrane *et al.* (2009) and Hoque *et al.* (2019), which noted that climate change would affect different geographical areas, nations, social groupings, and individuals differently. Further, the study results revealed that there was indeed climate variation in the study area, which is corroborated by findings by (Mutunga *et al.,* 2017. Khisa *et al.,* 2014), who noted an increase in climate variability in Kenya.

5.1.2 Sensitivity Indicators in the Study Area

5.1.2.1 Fish Fatalities Sub-Composite Index

The first step PCA run on indicators of fish fatalities, revealed that all the indicators had positive weights implying a positive influence on the fish fatalities sub-composite index. Furthermore, the results indicated that fish farmers in Kitui Central experienced more fish fatalities due to heavy precipitation than fish farmers in Kitui East. The possible explanation is that active and large-scale fish farming was reported in Kitui Central compared to Kitui East. Therefore, more fatalities were recorded in Kitui Central in heavy precipitation events. In addition, Nzevu *et al.* (2018) also noted that 66.6% of fish farmers in Kitui Central lacked expertise in management of fish ponds. Therefore, any occurrence of an extreme event would result in many fatalities of fish.

The results further indicated that the weight of fish stock lost due to droughts was the second in regards to the contribution towards the fish fatalities sub-composite index. Droughts translate into a lack of adequate water for fish which is crucial for their growth, increasing fish fatalities. Fish fatalities resulting from droughts were higher in Kitui East compared to Kitui Central, resulting from a lack of adequate water for fish farming and poor water quality due to the severity of droughts in Kitui East compared to Kitui Central.

The finding is corroborated by Adebo and Ayelari (2011), where 80% of fish farmers in their study area had experienced droughts and countered it by stocking culture units only in rainy seasons to reduce fatalities due to lack of adequate water.

In addition, results showed that fish stock lost due to diseases was higher in Kitui East than in Kitui Central. The lack of inadequate water for fish farming in Kitui East could have encouraged poor water quality, hence, the growth of fish diseases. Again, the higher temperatures in Kitui East compared to Kitui Central could have promoted the growth of fish diseases hence the many mortalities. Similar studies by FAO (2018) indicated that freshwater fish species are susceptible to high water temperatures. Further, due to the shallowness of fish ponds, increased air temperatures would exacerbate problems like water quality in areas with increased anthropogenic loading of nutrients like use of fertilizers in crop farming.

Moreover, the fish stock lost to conflicts with other resource users was higher in Kitui East compared to Kitui Central. Fish farmers in the study area reported the destruction of culture units by unknown people, resulting in a total loss of fish stocks after the attacks. The destructions resulted from the scarcity of resources like water, which fueled more conflicts between fish farmers and residents using water for other agricultural activities. Similar findings by Mwikali and Wafula (2019) highlighted water resource based conflicts in Kitui East Sub County.

5.1.2.2 Water Resources Sub-Composite Index

The weights for the water resources indicators had a positive relationship with the water resources sub-composite index, implying that they all increased the sensitivity of water resources in the study area. The results further revealed that the estimated number of times shallow wells, boreholes, and rivers/streams had dried up in the last ten years had the highest contribution towards the water resources sub-composite index. The possible explanation for their high contributions to the water resources sub-composite index is that the study area is part of ASAL. Therefore, these three sources are more resilient to droughts and rainfall variations, more reliable than the rest, and distribute water evenly across the

ASALs. Similar findings were indicated by Marshall (2011), who noted that droughts resulting from climate change affected water resources, thereby interrupting the livelihoods of many in the drylands of Kenya.

In addition, the mean values for water resources sub-composite index indicators were statistically different ($p < 0.05$) between the two study sites. Therefore, the sensitivity levels of the various water resources between the two Sub Counties were different, attributed to the difference in climatic conditions. For example, water resources in Kitui East Sub County, which is drier, are subject to higher evaporation rates, hence likely to dry up compared to water resources in Kitui Central Sub County, which is semi-humid. The current trend of results is concurrent with Obiero *et al.* (2012) and Lake Victoria Basin Commission (2011), which indicated a significant but different drop in water levels of Kenyas' natural water bodies.

Moreover, the results indicated that the number of times all water resources had dried up was higher in Kitui East compared to Kitui Central. This phenomenon was possible due to higher temperatures and frequent droughts in Kitui East compared to Kitui Central, resulting in fast-drying up of surface waters and reduced groundwater. Further, the study area witnessed increased human population growth and development; hence, higher water demand was likely to occur, drying up water resources in dry months. The results are in agreement with FAO (2018), which indicated that high water demand is expected to increase due to the high population growth. Therefore, unless remedial actions are taken, there will be severe impacts on inland fish farming. Similar studies also indicated that Bangladesh's north and north-western districts had been affected by high temperatures and high rainfall variability. This resulted in droughts and hence water stress, making groundwater the only water source for irrigation and insufficient for fish farming (Shahid and Hazarika, 2010; Shahid and Behrawan, 2008; Ramamasy and Baas, 2007).

5.1.2.3 Overall Sensitivity in the Study Area

The sensitivity indicators had a positive relationship with the sensitivity index except non-natural resources-based income, which had a negative relationship. Usually, non-natural resources-based income is remunerative and aids in reducing the sensitivity of an area as it is more consistent and less reliant on the status of the climate. Non-natural resources-based income in the study area ranged from salaried jobs, remittances, skilled non-farm jobs, and small business returns, which are less sensitive to climate variation and extreme events. The finding corroborates similar research that noted that the share of remunerative income helped reduce the overall sensitivity of households (Luni *et al.,* 2012; Opiyo *et al.,* 2014). The results further indicated that the percentage share of natural resources-based income had the highest weight, contributing more to the sensitivity index than the other indicators. A higher share of natural resources-based income of the fish farmers in the study area shows that most households highly depended on natural resources-based income, hence their high sensitivity to climate variability and extreme events. The natural resource-based income in the study area ranged from aquaculture, crop farming, livestock production, honey sales, sale of forestry products, and sand harvesting. The finding is in line with Opiyo *et al.* (2014), that noted that households with over-reliance on natural resources like pastoralism and dryland cropping were at a higher risk of being affected by climate variability and extreme events.

Further, the study results pointed out that the weights of natural and non-natural resources based income (income structure) towards the overall sensitivity index in the study area outweighed the weights of other indicators in the study area. Income structure is crucial in controlling households' sensitivity, which explains its high contribution to the study area's sensitivity index. The finding is in line with Ndungu *et al.* (2015), where the weights of natural resources-based income and non-natural resources-based income contributed more to the overall sensitivity index than the other sensitivity indicators amongst rural communities in Himachal Pradesh, India. In contrast, findings by Luni *et al.* (2012) noted that the weights of all indicators used to measure the sensitivity of households in Chepang, Nepal, livelihood impacts due to natural calamities contributed more to the overall sensitivity index compared to the income structure of the households.

The number of culture units destroyed by climate extreme events and disasters and the number of times water resources dried up in the last ten years was higher in Kitui East compared to Kitui Central. The phenomenon resulted from prolonged droughts and high temperatures during dry seasons in the Kitui East Sub County, which destroyed pond liners used in earthen ponds, the most modern type of culture units used in the study area. The prolonged droughts and varying precipitation rates also contributed to the drying up of water resources due to increased evaporation from water bodies. An increase in the number of culture units destroyed by extreme climate events and the number of water resources drying up increased the overall sensitivity of the fish farmers. The finding is corroborated by the Lake Victoria Basin Commission (2011), which noted declining water levels due to less rainfall and more precipitation, increasing the sensitivity of the ecosystems and communities that derive their livelihoods directly or indirectly from the basin. Further, IPCC (2014) also indicates a change in precipitations that has affected the hydrological cycle reducing the quality and quantity of water in water resources across the globe.

In addition, the percentage share of natural resources-based income was noted to be higher in Kitui East compared to Kitui Central. The high dependence on natural resources increased the sensitivity of the fish farmers in Kitui East since natural resources based-income is climate-sensitive, and any extreme event would render most households vulnerable. Regarding the percentage share of non-natural resources-based income, results revealed that Kitui Central possessed a higher share compared to Kitui East. The observation is attributed to parts of the Kitui Central Sub County being within and near the County headquarters; hence, household members could find off-farm income streams. Therefore, to minimize their sensitivity to climate variability and extreme events, multiple income streams (both natural and non-natural-based) for all fish farmers should be considered.

Similarly, fish fatalities were higher in Kitui East compared to Kitui Central, ascribed to the higher temperatures, more droughts, variation in precipitation, and poor access to extension services in the study site. These factors, directly and indirectly, affected the fish, causing their mortality, which increased the fish farmers' sensitivity. Further, Kitui East fish farmers had extreme dependence on natural resource-based income compared to Kitui Central fish farmers making them more susceptible to fish fatalities.

5.1.3 Adaptive Capacity Indicators in the Study Area

5.1.3.1 Indicators of Physical Livelihood Assets

The results revealed that the sum of fish farming equipment owned by households in the study area significantly influenced the physical assets' sub-composite index compared to the other indicators. The finding is attributed to the importance of fish farming pieces of equipment in extracting outputs in fish farming. Contrary, KCIDP, (2018) recognizes the lack of adequate fish farming equipment in Kitui County. Distance to the nearest permanent water source had the second-highest influence on the physical assets' sub-composite index, attributed to the importance of water as a resource in fish farming. Therefore, a shorter distance from the household to the nearest permanent water source would improve the household's adaptive capacity and vice versa. The average distance from households to the nearest water source is 7Km in Kitui County (KCIDP,2018). Therefore, the results align with Piya *et al.* (2012), who discovered that shorter distances from households to markets, water sources, and motorable roads improved the adaptive capacity of the households.

Further analysis of the results revealed that the number of early warning sources of weather information contributed positively to the physical assets sub-composite index. Sources of weather information are essential to fish farmers. They inform them when to expect rain, hence picking the best stocking time, especially for fish farmers whose water source for ponds is rainfall in the study area. Therefore, more attention should go into the distribution of seasonal warnings in the study area, which will alert fish farmers on occurrences of extreme events and any changes in the climate, hence the appropriate adaptation measures. Ndamani and Watanabe (2015), corroborated these findings by concluding that there was a need to prioritize access to timely weather information for farmers in Ghana to realize increased productivity. Further, studies by (Kluger *et al.,* 2017; Mohanty, 2018) established that reliable early warning systems were a proactive way to respond to climate change.

Total water storage in each household also positively influenced the physical assets index, which implied that total water storage increased the adaptive capacity of the fish farmers. Water storage in the study area was commonly in water tanks. It cushioned fish farmers from droughts by providing additional water to maintain pond water levels during the drier months.

Generally, the results revealed that Kitui Central fish farmers had a higher physical assets base compared to fish farmers in Kitui East. In addition, the sub-composite indicators' mean values for physical assets were significantly different ($p<.05$) except for the distance to the nearest motorable road and the distance to the nearest permanent water source. Therefore, physical livelihood assets varied between both Sub Counties. The possible explanation is that Kitui Central is within and around the County headquarters, allowing its fish farmers to access non-natural resource-based income. Hence, their improved ability to purchase physical assets crucial for fish farming. Deressa *et al.* (2008) support this finding by pointing out that households in remote areas are more susceptible to environmental damage and have low developments than their counterparts near towns.

5.1.3.2 Indicators of Natural Livelihood Assets

The study results showed that all the indicators for natural livelihood assets had positive weights and, hence, positively influenced the natural assets' sub-composite index. As expected, fish farmers in Kitui East registered higher mean values in most of the indicators compared to Kitui Central. The finding is ascribed to the lower population, hence a higher possession of natural assets among Kitui East fish farmers compared to Kitui Central fish farmers. Further, Kitui East was far from the County headquarters, hence its minor exploitation of its natural assets base.

Examination of the results showed that Kitui East Sub County fish farmers owned large tracts of land, and the total land size dedicated to fish farming compared to Kitui Central Sub County fish farmers. The difference in the mean values of the land size is again attributed to the fact that Kitui East households had more extensive land due to less population in the Sub County compared to Kitui Central, which is within and around the County headquarters and densely populated. *Seto et al.* (2000) corroborate this finding by noting that most agricultural land around urban centers had been developed in most developing countries, resulting in the loss of arable lands around urban centers.

Regarding the number of draught animals possessed by a household, Kitui East Sub County registered a higher number of draught animals, including donkeys and ox, compared to Kitui Central. The result is ascribed to the possession of large tracts of land by Kitui East Sub County fish farmers, which could be used to feed the draught animals. Further, the long distances to permanent water sources required the households to have drought animals for fetching water. In addition, draught animals would be used to offset the effects of droughts as they could survive during such periods. The results agree with findings by Speranza (2010), who noted diversification in herd composition in the Makueni district, including draught animals like camels and donkeys, which were highly resistant to droughts and could provide food during dry seasons.

In contrast, the mean values of the results indicated that the average number of fish stocked within a cycle and the average number of fish species cultured in a household were higher in Kitui Central Sub County compared to Kitui East Sub County. Fish farmers in Kitui Central had better incomes than those in Kitui East, which enabled them to stock more fish every cycle and diversify the number of fish species as they could afford multiple culture units. Again, it was noted that fish farmers in Kitui Central also had access to water, markets, extension services, and adequate and quality fingerlings due to their proximity to County headquarters compared to fish farmers in Kitui East.

5.1.3.3 Indicators of Human Livelihood Assets

The study established that all the indicators of human livelihood assets positively impacted the human assets' sub-composite index. The number of fish farming training attended by fish farmers contributed the most to the human assets sub-composite index. The results are in agreement with Ndungu *et al.* (2015), who indicated that education level, number of persons with salaried employment, and number of vocational courses attained within a household improved the adaptive capacity of the households.

This study further showed that fish farmers in Kitui Central had attended more fish farming training compared to their counterparts in Kitui East, which is explained by their proximity to the County headquarters and institutions dealing with fish farming. For instance, the

County has only one agricultural training center (ATC) and agricultural mechanization station (AMS) located within Kitui Central Sub County. Therefore, fish farming training and extension services are vital to fish farmers as it educates them on how best to carry out their fish farming activities for maximum productivity. The result agrees with findings by Simotwo *et al.* (2018), who noted training as critical for success in fish farming.

The mean values also revealed that household heads in Kitui Central had more schooling years compared to household heads in Kitui East. Education is crucial in understanding concepts and working principles of technologies present in fish farming. Therefore, a household with a head or members who have acquired more education has a better chance of understanding and appreciating new technologies and basic concepts in fish farming. The findings are corroborated by Nzevu *et al.* (2018), who found a positive but insignificant relationship between the education level/number of schooling years and the adoption of modern technologies in fish farming in Kitui Central Sub County.

In addition, the results revealed that the number of persons with salaried employment in a household was higher in Kitui Central households than in Kitui East households. The numbers were ascribed to the proximity of Kitui Central household members to County headquarters, improving their chances of finding salaried jobs. Further, it was also evident that household members in Kitui Central were more educated as they had enough income to aid them in accessing education. Salaried employment can help enhance the adoption of multiple adaptation strategies, averting households' vulnerability. Similar observations by Agnes *et al.* (2017) indicated that low financial capacity of farmers in Busia County, Kenya, contributed to limited adaptive capacity to climate change.

5.1.3.4 Indicators of Social Livelihood Assets

The study results showed that all the indicators of social livelihood assets were positive and contributed positively to the social assets' sub-composite index. The mean values for the results further indicated that Kitui Central had a higher social assets base compared to Kitui East. Additionally, the mean values for all the indicators were statistically significant at ($p<.00$), meaning that the indicators varied between the two study sites. For example, the number of CBOs a household head belonged to and the mean values revealed that Kitui Central fish farmers had more membership into CBOS compared to Kitui East fish farmers. This observation can be attributed to better incomes amongst fish farmers in Kitui Central, who could have diversified sources of income compared to Kitui East fish farmers.

In addition, the number of times a household could access credit facilities to boost their fish farming business was higher amongst Kitui Central fish farmers compared to Kitui East. The possible explanation was high possession of many assets that could be used as collateral by credit facilities before issuing loans to the fish farmers in Kitui Central compared to Kitui East fish farmers. Credit is vital to fish farmers as it enables them to invest in capital-intensive fish farming. Therefore, fish farmers who could not access credit were likely to face financial constraints, limiting the growth of their fish farming business. The findings are corroborated by Musyoka and Mutia (2016), where access to credit had a positive correlation on adoption and productivity in fish farming ventures in Makueni County.

5.1.3.5 Indicators of Financial Livelihood Assets

Scrutiny of the results revealed that all the indicators of financial livelihood assets had a positive weightage, hence contributing positively to the financial assets' sub-composite index. Further, it was noted that the average monthly savings had the highest contribution to the financial assets compared to other indicators. The possible explanation is that savings can help a household respond quickly to climate variability and extreme events. The trend in the results has been supported by (Fagariba *et al.,* 2018, Chepkoech *et al.,* 2020), who noted household income, savings, and diversification in income streams to increase the adaptive capacity of households.

The examination of the results further revealed that the mean values of average income from all income-generating activities were higher in Kitui Central compared to Kitui East. The difference is attributed to the proximity of Kitui Central to the County headquarters; hence the fish farmers in the Sub County had access to multiple off-farm jobs. In addition, regarding the average monthly savings, Kitui Central fish farmers registered a higher monthly savings amount compared to Kitui East fish farmers. The observation is supported by Egyir *et al.* (2015), who pointed out that off-farm income is crucial in adopting many adaptation strategies, hence improving the adaptive capacity of households.

Further, the study results revealed that Kitui East fish farmers had diversified their income streams compared to fish farmers in Kitui Central, as depicted by the livelihood diversification index. The possible explanation for the finding is the presence of a vast array of natural resources-based activities ranging from aquaculture, crop farming, livestock keeping, beekeeping, and sand harvesting to selling forestry products. The natural resource based-income was accessible in Kitui East due to its remoteness and possession of large tracts of land, which enabled taking part in these activities compared to Kitui Central. The finding is in line with Fagariba *et al.* (2018), who found a positive correlation between livelihood diversification and the adaptive capacity of households.

5.1.3.6 Overall Adaptive Capacity

The second step PCA performed on various asset categories indicated that all their weights were positive hence a positive implication on the overall adaptive capacity of fish farmers in the study area. It was also evident that social assets substantially influenced the overall adaptive capacity, followed closely by natural, physical, financial, and human assets. Social networks are crucial in enhancing the adaptive capacity to climate variability and extreme events.

A higher physical assets sub-composite index was recorded amongst fish farmers in Kitui Central compared to Kitui East due to their higher possession of culture units, early warning sources of weather information, fish farming equipment, total water storage, and a shorter distance to the nearest permanent water source compared to fish farmers in Kitui East. Physical assets, in general, have been known to be crucial in extracting natural assets. The finding, therefore, meant that Kitui Central fish farmers were better off in terms of productivity as compared to Kitui East fish farmers.

Further, concerning the natural assets sub composite index, it was noted that Kitui East fish farmers possessed more land size owned by a fish farming household, more land dedicated to fish farming only, and more drought animals as compared to Kitui Central fish farmers. On the other hand, Kitui Central fish farmers were noted to excel in the average number of fish stocked per cycle and the number of fish species cultured in a household. The high natural assets possessions in Kitui East can be ascribed to its remoteness and lower population density than Kitui Central.

As for the human assets, the sub-composite index revealed that Kitui Central had a higher human assets base than Kitui East. Improving human assets in terms of quality education, more fish farming training, and the number of people within a household with a constant income is vital in increasing the adaptive capacity of fish farmers within the study area. Therefore, efforts should be made to reinforce the human asset base in the study area. The findings of the current study are corroborated by Simotwo *et al.* (2018), who noted that the dependency ratio in a household and the level of education had a significant association with the adaptive capacity of farmers in Transmara East Sub County in Kenya. Further, the level of education has also been revealed to have an association with adaptation to adverse environmental challenges (Maina *et al.,* 2014; Perez *et al.,* 2015; Kassie *et al.,* 2014).

Similarly, Kitui Central registered a higher social assets base compared to Kitui East under the social assets sub-composite index. Therefore, social networks like CBOs, merry-go-rounds and local institutions conducting extension services and offering credit facilities are essential. Therefore, more efforts should be directed to improving the fish farmers' social assets base in the study area. The observation concurs with Kimathi (2013), which noted that fish farming training upgraded the fish farmers' technical understanding of fish farming, enabling them to solve any challenges in their fish farming business. Further, similar studies by Munguti *et al.* (2014) indicated a positive correlation between productivity and adoption of fish farming in Kenya with access to credit.

Additionally, the financial assets sub-composite index revealed that Kitui Central had higher financial assets than Kitui East. The observation can be ascribed to its proximity to the County headquarters; hence fish farmers in Kitui Central could find off-farm jobs leading to increased incomes and savings compared to fish farmers in Kitui East. The fish farmers in Kitui Central could purchase quality fish farming inputs and invest in quality education. The results are in line with Ndungu *et al.* (2015), which pointed out that households near district headquarters had a higher adaptive capacity than households far away. Further, financial assets can easily be transformed into other assets or indirectly aid in improving different asset categories. Therefore, one of the primary focuses in Kitui East should be improving their financial assets base, which would enhance other asset categories like social, physical, human, and natural assets and maintain their households' economies. Further, independent samples t-test on mean values of the asset categories revealed that physical assets sub composite index, social assets sub composite index, and financial assets sub composite index were statistically significant at ($p<.01$) in the two Sub Counties. Therefore, these asset categories were different in the two Sub Counties and had contributed differently to the adaptive capacity of the fish farmers. The finding is corroborated by (Aswani *et al.,* 2018; Williams and Rota, 2011), who pointed out that the ability of households to adapt better was determined by an array of factors, including their extent of dependence on an activity, the assets they own, their location, education levels, wealth and other factors.

5.1.4 Overall Vulnerability

The study results revealed a statistical significance in the overall vulnerability index and its components' indices ($p<.01$) except for the exposure component in the two sub Counties. Therefore, the finding implied that both sub-counties sensitivity, potential impact, adaptive capacity, and overall vulnerability levels differed. Similar studies by (Cochrane *et al.,* 2009; Smit and Wandel, 2006) corroborate the finding by noting that vulnerability levels to climate change effects were different across different regions based on poverty levels, lack of access to resources, gender, lack of political voice, and education levels of an individual or the community in question.

Kitui East registered a higher exposure index compared to Kitui Central. The observation can be ascribed to the higher occurrences of extreme events coupled with the high rate of change in both maximum and minimum temperatures and low precipitation amounts in the Sub County compared to Kitui Central. The results are in consonance with Mwangi *et al.* (2020), who reported that the Eastern parts of Kitui County experienced comparatively higher exposure to climate change vulnerability than the western and central parts of the County.

Further, the results revealed that the sensitivity index was higher in Kitui East compared to Kitui Central. The finding can be attributed to the higher fish fatalities, the higher rate at which water resources dried up, and the higher number in which culture units got destroyed by extreme events. In addition, Kitui East fish farmers over-relied on natural resources-based income more than non-natural resources-based income compared to fish farmers in Kitui Central, which further increased their sensitivity.

The results also indicated that the adaptive capacity index was higher in Kitui Central compared to Kitui East. The high adaptive capacity in Kitui Central was brought forth by the high possession of assets (financial, social, human, and physical) by the fish farmers in Kitui Central compared to fish farmers in Kitui East. The finding portrayed Kitui East Sub County fish farmers as marginalized, and therefore efforts should be directed to fish farmers in the Sub County to build their adaptive capacity. The results are supported by Cochrane *et al.* (2009), who noted that Kenyan fish farmers from marginalized households were more likely to be stuck in the declining fish industry. Regardless, Kitui Central fish farmers, whose adaptive capacity was comparatively high, also need more improvement since the present adaptive capacity may not be sufficient in the face of higher exposure and sensitivity than what is present.

Regarding the overall vulnerability index of the fish farmers, results indicated that fish farmers in Kitui East were more vulnerable to climate variability and extreme events as compared to the fish farmers in Kitui Central. The results are ascribed to the high exposure levels of the fish farmers in Kitui East, coupled with their high sensitivity levels; hence a higher potential impact and less adaptive capacity towards climate variability and extreme events compared to Kitui Central fish farmers. The observation agrees with (IPCC, 2007;

Luni *et al.,* 2012), who pointed out that poor and marginalized households with the least adaptive capacity, high exposure, and high sensitivity had the most heightened vulnerability. Therefore, lots of effort into improving the adaptive capacity of the fish farmers in the study area is needed, which will, in return, reduce the sensitivity of the fish farmers hence reducing their vulnerability.

5.2 Fish Farmer's Adaptation Strategies Taken in Response to Climate Variability and Extreme Climate Events in the Study Area

The study results indicated that fish farmers in the study area had adopted various strategies as a precautionary response to climate variability and extreme events. The observation concurs with findings by Coulthard (2009), who noted that fish farming households and their communities were actively adapting against changes affecting the fish farming sectors. Similarly, a study by Fagariba *et al.* (2018) concluded that farmers had adopted multiple adaptation strategies to counter climate variability in Sissala west district, northern Ghana.

The adaptation strategies in response to climate variability and extreme events in the study area were divided into three major categories; adaptation in response to changing precipitations, adaptation in response to changing temperatures, and adaptation in response to extreme events.

5.2.1 Adaptation in Response to Changing Precipitations

Regarding the changing precipitations, fish farmers in the study area had adopted various strategies, including farming hardy fish like catfish, which were tolerant to reducing precipitations. However, it was noted that the adoption of this strategy was higher in Kitui Central Sub County compared to Kitui East Sub County, which is attributed to the large-scale fish farming in Kitui Central compared to Kitui East. The results are in line with Lebel *et al.* (2015), who indicated that fish farmers in Thailand had switched from Tilapia to more tolerant catfish fish species in response to climate-related risks like reduced dissolved oxygen.

Further, the fish farmers also reported practicing mixed-sex culture to increase the output from each production cycle. Most fish farmers in the study area were also reported to have shifted from fish farming to other agricultural activities and vice versa. These strategies were commonly adopted in Kitui Central compared to Kitui East. The fish farmers reported this to result in recurrent losses from the fish farming business hence the need for an alternative source of income. Similar findings were reported by Boonstra and Hahn (2015). They noted that fish farmers in Vietnam had resulted to rice cultivation as an adaptation strategy when there were floods due to huge precipitations and then reverted to fish farming when precipitation decreased.

Integration of fish farming with other agricultural activities was another common practice and was also highly adopted amongst fish farmers in Kitui Central compared to Kitui East. The possible explanation for adopting this strategy is that Kitui Central fish farmers had higher assets possession and could afford to integrate different forms of agriculture simultaneously. Again, total land size ownership in Kitui Central was lower compared to Kitui East, forcing farmers to incorporate various agricultural forms into the same piece of land. The practice was reportedly done to cushion fish farmers from either failure. The results are in line with findings by Kumar *et al.* (2017), which indicated that farmers in Coastal India adopted traditional integrated farming systems; whereby fish was grown on the same piece of land as crops and livestock, and outputs from either could be used as inputs for the others. Further, they applauded the strategy for improving biodiversity conservation and providing livelihood services to the communities around.

Water is crucial in fish farming enterprises, and fish farmers in the study area had adopted various strategies to ensure adequate water for the fish farming activities. One, fish farmers in the study area practiced fish farming when water was available, commonly during wet seasons. The practice was adopted because fish farmers in the study area were highly dependent on rainfall as the source of water and wetter seasons also had lower temperatures, hence less water loss from the culture units. In addition, the fish farmers in the study area had also built water harvesting schemes. Furthermore, they reused water, helping them increase the amount of water available in a household to supplement water trapped from rain by the culture units. In addition, it was noted that fish farmers had changed stocking time to when water was available. They also reported incorporating water conservation techniques in their fish farming and stocking different rearing units at different intervals to avoid huge losses in case of eventualities.

Results also revealed that agroforestry and a general increase in the number of vegetation cover to protect culture units were standard practices by the fish farming households in the study area. However, it was noted that Kitui Central fish farmers had a slightly higher agroforestry adoption than Kitui East fish farmers. The semi-humid nature of Kitui Central might have increased planted trees' survival rates, motivating fish farmers to adopt this strategy more than fish farmers in Kitui East. However, the latter had to irrigate their planted trees hence poor survival rates and adoption of the strategy. The adoption of this strategy has been reported in many studies like Fagariba *et al.* (2018), who reported the adoption of agroforestry in the Sissala West district, and Dubey *et al.* (2017), who noted that fish farmers planted trees around pond dykes to reinforce the dykes in India.

In addition, the study results showed that all adaptation strategies against changing precipitation were statistically significant except for farming hardy fish tolerant to climate change, integrating fish farming into other agricultural activities, and increasing vegetation cover to attract rain. The finding implied a variation in adopting adaptation strategies in this category between the two Sub Counties. Therefore, the difference in adaptive capacity in the two Sub Counties likely contributed to the outcome. The finding is similar to (Mutunga *et al.,* 2017; Ndamani and Watanabe, 2015), who noted a correlation between the adoption of adaptation strategies by different households and communities in their study areas with levels of education, income, awareness, sensitivity, and vulnerability.

5.2.2 Adaptation in Response to Changing Temperatures

In response to changing temperatures, fish farmers in the study area had opted to repair slightly damaged culture units (earthen linen ponds) instead of purchasing new ones. High temperatures were reportedly the primary cause of damaging culture units in the study area. The results revealed that Kitui East fish farmers experienced more significant damage to their culture units due to higher temperatures compared to fish farmers in Kitui Central. This observation is attributed to the higher temperatures in Kitui East compared to Kitui Central.

In addition, the results revealed that fish farmers in the study area preferred stocking juvenile fish (up to 30g) instead of fry (up to 6g), which had better survival percentages, outputs, and potential to survive the high temperature. The current trend of results is in agreement with (Navy *et al.,* 2017; Islam *et al.,* 2019) in Vietnam and Bangladesh, respectively, which revealed that fish farmers responded to warmer temperatures by early harvesting undersized shrimps and stocking fish seed tolerant to warmer temperatures.

Interestingly, fish farmers in the study area had also reduced stocking, with others abandoning fish farming due to the many challenges the fish farmers faced. The observation was reported to be a result of increased temperatures coupled with lesser rainfall which increased the cost of maintaining water levels in culture units, increased fish losses, and damage to the culture units. The results are corroborated by (Lebel *et al.,* 2015; Navy *et al.,* 2015; Pelletier *et al.,* 2014), who noted that fish farming communities had reduced their overall stocking densities as an adaptation strategy.

Further, the study results showed that all adaptation strategies in this category were statistically significant. But, again, the outcome implied a difference in adoption levels of these strategies amongst fish farmers in the two Sub Counties, which was also ascribed to different adaptive capacity levels. Similar findings by Smit and Pilifosova (2003) indicated a variation in adaptation strategies in different households based on adaptive capacity.

5.2.3 Adaptation in Response to Extreme Events

In response to extreme events (droughts, fish diseases, and high precipitation), a handful of fish farmers had procured insurance for their fish farming business, with most fish farmers opting to be self-insured due to the high costs of fish farming insurance. However, it was also noted that fish farmers that procured insurance were the ones that stocked the most fish in the study area. Therefore, the government should consider providing the right educational, legal, and other support frameworks to improve the operating standards of small-scale fish farmers. This would bring the fish farmers to stock levels that can allow them to be insured, if not independently, as coordinated groups or cooperatives in the study area. The findings are in agreement with Olayinka *et al.* (2018), who, in their study in Ondo State, Nigeria, concluded that most fish farmers did not procure insurance due to the small-scale status of their fish farming business. Therefore, the study recommended that the government empower the respondents to increase their production scale, thereby improving their attitudes towards and adoption of insurance. Similarly, Mahul and Stutley (2010) encouraged government support for agricultural insurance in developing countries, and Mohanty (2018) reported adopting aquaculture insurance as an adaptation strategy amongst shrimp farmers in India.

A number of the fish farmers in the study area had procured loans to keep their fish farming business afloat. However, a higher number still could not access loans due to the small-scale nature of their fish farming business. This, therefore, calls for government support to ease the procedures of accessing credit to fish farmers in the study area. Further, the fish farmers could also consider forming groups /associations to enhance access to loans and resources. Ahmed *et al.* (2014) supported the results of the present study by noting that community-based adaptation strategies had improved the socio-ecological resilience to climate change of fish farmers in Bangladesh.

The study results also pointed out that fish farmers in the study area sought county government support. Kitui Central fish farmers reported a higher county government support compared to fish farmers in Kitui East. The difference in adoption of the strategy is attributed to proximity to the County headquarters by Kitui Central fish farmers compared to Kitui East fish farmers. Government agencies can help fish farmers by creating and sustaining markets for fish farming outputs and also offer monetary assistance. The results are supported by Azra *et al.* (2020), who noted seeking government support as one of the many adaptation strategies adopted by aquaculture communities to counter the effects of climate change.

Finding off-farm jobs was also common in supplementing the income from the fish farming business. This adaptation strategy was mainly present amongst fish farmers in Kitui Central compared to fish farmers in Kitui East Sub County. The possible explanation for this was the proximity of Kitui Central fish farmers to County headquarters compared to Kitui East fish farmers, whose significant diversification had to be in natural resources. These results are in agreement with findings by Ogallo (2014), where households had adapted to climate change by finding off-farm jobs in Soroti district, Eastern Uganda. Further, Boonstra and Hahn (2015) reported fish farmers in Vietnam to have diversified their income sources by finding employment in cities and coffee plantations during flooding periods.

In addition, the study results revealed that all adaptation strategies to counter extreme events in the two study sites were statistically different except for procurement of insurance for fish farming business and seeking county government support. Kitui East fish farmers had less adoption of these strategies compared to Kitui Central fish farmers. The observation was again attributed to differences in adaptive capacity and possession of different income streams in the two study sites. The study results are in line with Nielsen and Reenberg (2010), who concluded that diversity in income streams and adaptive capacity was closely associated with better adaptation and response towards climate variability and change, hence reducing the sensitivity of households.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The study confirmed that fish farmers in the study area have experienced the effects of climate variability and extreme climate events. Therefore, fish farmers should adequately adapt to these effects to survive in the future. Regarding the exposure of fish farmers, the study results revealed that biophysical elements used as indicators for exposure in the study were crucial determinants of the overall vulnerability of the fish farmers. It is noteworthy that policymakers have no control over the exposure elements and therefore, the only way to protect the fish farmers from the effects of climate variability and extreme events would be to enhance their adaptive capacity. For instance, improving water harvesting schemes, creating irrigation projects, creating more income streams, establishing early warning systems, and creating awareness of water conservation techniques would shield the fish farmers from climate variables and extreme climate events.

Regarding the sensitivity of fish farmers, the results revealed that it was present but varied between the two study sites. Kitui East fish farmers were more sensitive to climate variability and extreme events compared to their Kitui Central counterparts. The high sensitivity of the fish farmers in Kitui East was ascribed to the low adaptive capacity and a higher exposure amongst its fish farmers compared to Kitui Central fish farmers. Additionally, there was overreliance on natural resources based-incomes. Overreliance on natural resources-based income increases the sensitivity of a system due to its dependence on climate variables beyond human control. Therefore, response efforts should be more focused on Kitui East. Still, Kitui central fish farmers should not be left behind, as exposure to higher magnitudes of extreme climate events would render most fish farmers in the study area vulnerable.

The adaptive capacity in the study area varied between the two study sites, with Kitui Central fish farmers possessing a higher adaptive capacity compared to Kitui East fish farmers. Emphasis should therefore be made on improving the financial livelihood assets component since it can be transformed into other assets, hence improving them.

Fish farmers in the study area had also adopted various adaptation strategies to counter climate variability and extreme climate events. However, from the findings, Kitui East fish farmers recorded lower adoption percentages in all adaptation strategies compared to Kitui Central. The finding was attributed to the lower adaptive capacity amongst Kitui East fish farmers' which could have restricted their ability to invest in various adaptation strategies.

6.2 Recommendations

The following interventions are useful in reducing the vulnerability of fish farmers to climate variability and extreme climate events in the study area by improving their overall adaptive capacity, reducing their sensitivity, and strengthening their resilience.

i. In regards to exposure of the fish farmers, investment in sustainable water harvesting technologies to provide a long-term solution to water shortages and accessibility caused by droughts can be adopted. This can reduce the exposure of fish and, consequently, the fish farmers in the study area.
ii. Establishment of early warning systems can also reduce the level of exposure of the fish farmers in the study area. The strategy would provide timely warnings to the fish farmers on any projected occurrences of extreme events or rainfall failure hence appropriate adaptation.
iii. To improve the adaptive capacity of the fish farmers, creation of more off-farm income opportunities to fish farmers can resolve the overreliance on natural resources based-income, hence reducing the overall vulnerability of the fish farmers to climate variability and extreme climate events
iv. Community-based adaptation strategies can also be adopted by the fish farmers in the study area. This can be through formation of fish farmers' CBOs, associations, and groups. These strategies would strengthen socio-ecological resilience to climate variability and extreme climate events by improving fish farmers' access to loans, resources, government support, and extension services.
v. Fish farmers in the study area should also proactively look for extension services, climate-related information, and new technologies in fish farming to improve their overall resilience to climate variability and extreme climate events

vi. Active support for adaptation in the fish farming industry from national, regional, and local levels of governance should also adopted, with more emphasis being made on the contribution of fish farmers to poverty reduction, the food security in ASALs, and the country's economy.

6.3 Suggestions for Further Studies

The study recommends further studies in the following areas

i. There is a need for an assessment of water retention by water resources in the study area and its subsequent effects on fish farming productivity. The assessment would be crucial to the fish farmers by informing them on the most reliable water resources for their fish farming activities.
ii. An evaluation of institutional responses to the implications of climate variability and extreme climate events in the fish farming sector can also be done. This kind of study can inform relevant fish farming stake holders whether the sector is receiving enough attention from relevant institutions.
iii. There is also a need for a research analyzing the seasonal rainfall and distribution in the study area and its effects on fish farming in the study area which is yet to be done.

REFERENCES

Adebo, G. M., & Ayelari, T. A. (2011). Climate change and the vulnerability of fish farmers in Southwestern Nigeria. *African Journal of Agricultural Research*, *6*(18), 4230-4238.

Adger, W. N. (2006). Vulnerability. *Global Environmental Change*, *16*(3), 268-281.

Agnes, M. S., Alice, K., Richard, M.B. (2017). Adaptive Capacity to Climate Change among Smallholder Farmers in Busia County, Kenya. *OSR Journal of Agriculture and Veterinary Science (IOSR-JAVS)*, *10*(11), 2319-2372.

Ahmed, N., Bunting, S. W., Rahman, S., Garforth, C. J. (2014). Community-based climate change adaptation strategies for integrated prawn–fish–rice farming in Bangladesh to promote social-ecological resilience. *Reviews in Aquaculture*, *6*(1), 20-35.

Allison, E. H., Perry, A. L., Badjeck, M. C., Neil Adger, W., Brown, K., Conway, D., Dulvy, N. K. (2009). The vulnerability of national economies to the impacts of climate change on fisheries. *Fish and Fisheries*, *10*(2), 173-196.

Asiedu, B., Adetola, J. O., Odame Kissi, I. (2017). Aquaculture in troubled climate: Farmers' perception of climate change and their adaptation. *Cogent Food & Agriculture*, *3*(1), 1-16.

Aswani, S., Howard, J. E., Gasalla, M. A., Jennings, S., Malherbe, W., Martins, I. M., Watmough, G. R. (2019). An integrated framework for assessing coastal community vulnerability across cultures, oceans, and scales. *Climate and Development*, *11*(4), 365-382.

Azra, M. N., Aaqillah-Amr, M. A., Ikhwanuddin, M. H., Waiho, K., Ostrensky, A., Abol-Munafi, A. B. (2020). Effects of climate-induced water temperature changes on the life history of brachyuran crabs. *Reviews in Aquaculture*, *12*(2), 1211-1216.

Badjeck, M. C., Allison, E. H., Halls, A. S., Dulvy, N. K. (2010). Impacts of climate variability and change on fishery-based livelihoods. *Marine Policy*, *34*(3), 375-383.

Barange, M., Bahri, T., Beveridge, M. C., Cochrane, K. L., Funge-Smith, S., Poulain, F. (2018). *Impacts of climate change on fisheries and aquaculture: synthesis of current knowledge, adaptation and mitigation options*. FAO.

Bell, J. D., Kronen, M., Vunisea, A., Nash, W. J., Keeble, G., Demmke, A., Andréfouët, S. (2009). Planning the use of fish for food security in the Pacific. *Marine Policy*, *33*(1), 64-76.

Boonstra, W. J., & Hanh, T. T. H. (2015). Adaptation to climate change as social-ecological trap: a case study of fishing and aquaculture in the Tam Giang Lagoon, Vietnam. *Environment, Development, and Sustainability*, *17*(6), 1527-1544.

Brander, K. M. (2007). Global fish production and climate change. *Proceedings of the National Academy of Sciences*, *104*(50), 19709-19714.

Bunting, S. W., Pretty, J., & Edwards, P. (2010). Wastewater-fed aquaculture in the East Kolkata Wetlands, India: anachronism or archetype for resilient eco cultures? *Reviews in Aquaculture*, *2*(3), 138-153.

Chepkoech, W., Mungai, N. W., Stöber, S., Lotze-Campen, H. (2020). Understanding adaptive capacity of smallholder African indigenous vegetable farmers to climate change in Kenya. *Climate Risk Management*, *27*, 100204.

Cinner, J. E., Huchery, C., Hicks, C. C., Daw, T. M., Marshall, N., Wamukota, A., Allison, E. H. (2015). Changes in adaptive capacity of Kenyan fishing communities. *Nature Climate Change*, *5*(9), 872-876.

Cinner, J. E., McClanahan, T. R., Graham, N. A., Daw, T. M., Maina, J., Stead, S. M., & Bodin, Ö. (2012). Vulnerability of coastal communities to key impacts of climate change on coral reef fisheries. *Global Environmental Change*, *22*(1), 12-20.

Cisneros, B. E., Oki, T., Arnell, N. W., Benito, G., Cogley, J. G., Doll, P., Jiang, T. and Mwakalila, S. S. (2014). *Freshwater resources.* In: Field, C. B., Barros, V. R., Dokken, D. J., Mach, K. J., Mastrandrea, M. D., Bilir, T. E., Chatterjee, M., Ebi, K. L., Estrada, Y. O., Genova, R. C., Gimma, B., Kissel, E. S., Levy, A. N., MacCracken, S., Mastrandrea, P. R. and White, L. L. (eds.) Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. *Cambridge University Press, Cambridge*, 229-269.

Cochrane, K., De Young, C., Soto, D., & Bahri, T. (2009). Climate change implications for fisheries and aquaculture. *FAO Fisheries and aquaculture technical paper*, *530*, 1-212.

Coulthard, S. (2009). Adaptation and conflict within fisheries: insights for living with climate change. *Adapting to Climate Change: Thresholds, Values and Governance (eds. WN Adger, I. Lorenzoni and KL O'Brien)*, 255-268.

Danielsen, F., Burgess, N. D., & Balmford, A. (2005). Monitoring matters: examining the potential of locally-based approaches. *Biodiversity & Conservation*, *14*(11), 2507-2542.

Department for International Development (DFID). (2000). Sustainable livelihoods guidance sheets, Section 2. *Framework*. 1-26.

Deressa, T., Hassan, R. M., & Ringler, C. (2008). *Measuring Ethiopian farmers' vulnerability to climate change across regional states*. Intl Food Policy Res Inst.

Dubey, S. K., Trivedi, R. K., Chand, B. K., Mandal, B., & Rout, S. K. (2017). Farmers' perceptions of climate change, impacts on freshwater aquaculture and adaptation strategies in climatic change hotspots: A case of the Indian Sundarban delta. *Environmental Development*, *21*, 38-51.

Dzoga, M., Simatele, D., & Munga, C. (2018). Assessment of ecological vulnerability to climate variability on coastal fishing communities: A study of Ungwana Bay and Lower Tana Estuary, Kenya. *Ocean & Coastal Management*, *163*, 437-444.

Egyir, I. S., Ofori, K., Antwi, G., & Ntiamoa-Baidu, Y. (2015). Adaptive capacity and coping strategies in the face of climate change: a comparative study of communities around two protected areas in the coastal savanna and transitional zones of Ghana. Journal of Sustainable Development, *8(*1), 1-15.

Fagariba, C. J., Song, S., & Soule Baoro, S. K. G. (2018). Climate change adaptation strategies and constraints in Northern Ghana: Evidence of farmers in Sissala West District. *Sustainability*, *10*(5), 1-18.

Filmer, D., & Pritchett, L. H. (2001). Estimating wealth effects without expenditure data—or tears: an application to educational enrollments in states of India. *Demography*, *38*(1), 115-132.

Food and Agriculture Organization of the United Nations (FAO). (2007). *Aquaculture production, 2006. Yearbook of Fishery Statistics, 96*(2).

Food and Agriculture Organization of the United Nations (FAO). (2009). *The state of the world fisheries and aquaculture 2008*. Rome, Italy: FAO Fisheries and Aquaculture Dept.

Food and Agriculture Organization of the United Nations (FAO). (2010). Securing Small-Scale Sustainable Fisheries: Bringing Together Responsible Fisheries and Social Development. *RAP Publication*.

Food and Agriculture Organization of the United Nations (FAO). (2012). *The State of World Fisheries and Aquaculture 2012.* FAO.

Food and Agriculture Organization of the United Nations (FAO). (2018). *The State of World Fisheries and Aquaculture 2018–Meeting the sustainable development goals.* FAO.

Government of Kenya (G.O.K). (2019). *National Census Report*. Kenya National Bureau of Statistics (KNBS), Nairobi, Kenya.

Harvey, B., Soto, D., Carolsfeld, J., Beveridge, M., & Bartley, D. M. (2016, June). Planning for aquaculture diversification: the importance of climate change and other drivers. In *FAO Technical Workshop* (pp. 23-25).

Hecht, T. (2006). Regional review on aquaculture development for Sub-Saharan Africa-2005.

Hoque, M. Z., Cui, S., Xu, L., Islam, I., Tang, J., Ding, S. (2019). Assessing agricultural livelihood vulnerability to climate change in coastal Bangladesh. *International Journal of Environmental Research and Public Health*, *16*(22), 1-21.

Huang, B., Banzon, V. F., Freeman, E., Lawrimore, J., Liu, W., Peterson, T. C., Zhang, H. M. (2015). Extended reconstructed sea surface temperature version 4 (ERSST. v4). Part I: Upgrades and intercomparisons. *Journal of Climate*, *28*(3), 911-930.

Hulme, M., Doherty, R.M., Ngara, T., New, M.G. and Lister, D. (2010). African climate change: 1900–2100. Climate Research,Vol. 17 No. 2, pp. 145-168.

Ifejika Speranza, C. (2010). Drought coping and adaptation strategies: Understanding adaptations to climate change in agro-pastoral livestock production in Makueni District, Kenya. *The European Journal of Development Research*, *22*(5), 623-642.

Intergovernmental Panel on Climate Change (IPCC). (2001). *Third Assessment Report: Climate Change 2001, Intergovernmental Panel on Climate Change,* Cambridge University Press, Cambridge.

Intergovernmental Panel on Climate Change (IPCC). (2007). *Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change.* Cambridge University Press, Cambridge.

Intergovernmental Panel on Climate Change (IPCC). (2012). *Managing the risks of extreme events and disasters to advance climate change adaptation*. Cambridge: Cambridge University Press.

Intergovernmental Panel on Climate Change (IPCC). (2014): *Climate change: Impacts, Adaptation, and Vulnerability. Working Group II contribution to the IPCC 5th Assessment Report.* Cambridge University Press, Cambridge.

Islam, M. M., Barman, A., Kundu, G. K., Kabir, M. A., & Paul, B. (2019). Vulnerability of inland and coastal aquaculture to climate change: Evidence from a developing country. *Aquaculture and Fisheries*, *4*(5), 183-189.

Islam, M. M., Sallu, S., Hubacek, K., Paavola, J. (2014). Vulnerability of fishery-based livelihoods to the impacts of climate variability and change: insights from coastal Bangladesh. *Regional Environmental Change*, *14*(1), 281-294.

Jamir, C., Sharma, N., Sengupta, A., Ravindranath, N. H. (2013). Farmers' vulnerability to climate variability in Dimapur district of Nagaland, India. *Regional Environmental Change*, *13*(1), 153-164.

Kabubo-Mariara, J. (2009). Global warming and livestock husbandry in Kenya: Impacts and adaptations. *Ecological Economics*, *68*(7), 1915-1924.

Karienye, D., & Macharia, J. (2020). Adaptive Capacity to Mitigate Climate Variability and Food Insecurity of Rural Communities Along River Tana Basin, Kenya. *African Handbook of Climate Change Adaptation*, 1-12.

Kassie, M., Ndiritu, S. W., & Stage, J. (2014). What determines gender inequality in household food security in Kenya? Application of exogenous switching treatment regression. *World Development*, *56*, 153-171.

Khisa, G. V., Oteng'i, S. B., & Mikalitsa, S. M. (2014). Effect of climate change on small-scale agricultural production and food security in Kitui District, Kenya. *The Journal of Agriculture and Natural Resources Sciences, 1*(1), 34-44.

Kimani, N. C., Bhardwaj, S. K., Sharma, D. P., Sharma, R., Gupta, R. K., Sharma, B. (2015). Vulnerability Assessment of Rural Communities to Environmental Changes in Mid-Hills of Himachal Pradesh in India. *Universal Journal of Environmental Research & Technology*, *5*(1).

Kimathi, A. N., Ibuathu, C. N., & Guyo, H. (2013). Factors Affecting Profitability of Fish under the Economic Stimulus Program in Tigania East District. *Journal of Business and Management, 16*(3).

Kisaka, M. O., Mucheru-Muna, M., Ngetich, F. K., Mugwe, J. N., Mugendi, D., Mairura, F. (2015). Rainfall variability, drought characterization, and efficacy of rainfall data reconstruction: case of Eastern Kenya. *Advances in Meteorology*, 1-17.

Kitui County Environmental Action Plan (KCEAP). (2009). *Population dynamics, environment, and sustainable development in Kitui county.* County Government of Kitui.

Kitui County Integrated Development Plan (KCIDP). (2018). *County Integrated Development Plan 2018-2022.* County Government of Kitui.

Klisch, A., Atzberger, C., & Luminari, L. (2015). Satellite-Based Drought Monitoring In Kenya In An Operational Setting. *International Archives of the Photogrammetry, Remote Sensing & Spatial Information Sciences*. XL-7/W3.

Kluger, L. C., Kochalski, S., Aguirre-Velarde, A., Vivar, I., Wolff, M. (2019). Coping with abrupt environmental change: the impact of the coastal El Niño 2017 on artisanal fisheries and mariculture in North Peru. *ICES Journal of Marine Science*, *76*(4), 1122-1130.

KMFRI Aquaculture Division Researchers. (2017). *Kenya's aquaculture brief 2017: status, trends, challenges, and future outlook.* Kenya Marine and Fisheries Research Institute (KMFRI).

Kumar, A., Bhagyalekshmi, V., Riyas, A. (2017). Climate change, fisheries, and coastal ecosystems in India. *Journal of Aquatic Biology & Fisheries 5*, 7-17.

Lake Victoria Basin Commission (LVBC). (2011). *A Study on aquatic biodiversity in the Lake Victoria basin.* Lake Victoria Basin Commission.

Laukkonen, J., Blanco, P. K., Lenhart, J., Keiner, M., Cavric, B., Kinuthia-Njenga, C. (2009). Combining climate change adaptation and mitigation measures at the local level. *Habitat International*, *33*(3), 287-292.

Lebel, P., Whangchai, N., Chitmanat, C., Lebel, L. (2015). Climate risk management in river-based Tilapia cage culture in northern Thailand. *International Journal of Climate Change Strategies and Management*, 476-498.

Letha Devi, G., Varma, D., & Kataktalware, M. A. (2016). The Livelihood Vulnerability Analysis: A Pragmatic Approach to Assessing Risks from Climate Variability and Change—a Case Study of Livestock Farming In Karnataka, India. *Journal of Agriculture and Veterinary Science*, *9*(2), 15-19.

Luck, J., Spackman, M., & Freeman, A. (2011). Tre bicki. *P., Griffiths, W., Finlay, K., & Chakraborty, S*, 113-121.

Luni P, Maharjan K, Joshi N (2012) Perceptions and realities of climate change among the Chepang Communities in rural mid-hills of Nepal. J. Contemp. India Stud. Space Soc. 2(5): 35-50

Macchi, M., Oviedo, G., Gotheil, S., Cross, K., Boedhihartono, A., Wolfangel, C., & Howell, M. (2008). Indigenous and traditional peoples and climate change. *IUCN Issues Paper, International Union for Conservation of Nature (IUCN), Gland, Switzerland*.

Mahul, O., & Stutley, C. J. (2010). *Government support to agricultural insurance: challenges and options for developing countries*. World Bank Publications.

Maina, J. G., Mbuthia, P. G., Ngugi, J., Omolo, B., Orina, P., Wangia, S. M., & Owiti, G. O. (2014). 1. Influence of social-economic factors, gender, and the Fish Farming Enterprise and Productivity Project on fish farming practices in Kenya. *Development*, *26*(2).

Marigi, S. N. (2017). Climate change vulnerability and impacts analysis in Kenya. *American Journal of Climate Change*, *6*(01), 52.

Marshall, S. (2011). The water crisis in Kenya: Causes, effects, and solutions. *Global Majority E-Journal*, *2*(1), 31-45.

Medugu, I. N., Majid, M. R., & Leal Filho, W. (2014). Assessing the vulnerability of farmers, fishermen, and herdsmen to climate change: A case study from Nigeria. *International Journal of Global Warming*, *6*(1), 1-14.

Mohammed, E. Y., & Uraguchi, Z. B. (2013). Impacts of climate change on fisheries: implications for food security in Sub-Saharan Africa. *Global Food Security, Nova Science Publishers, Inc*, 114-135.

Mohanty, A. K. (2018). Impact of climate change: A curse to the shrimp farming in India. *Int. J. Adv. Res. Technol.*, 1151-1158.

Mugenda, A., & Mugenda, O. (2003). Research Methods: Quantitative and Qualitative approaches NAIROBI: African Center for Technology Studies (ACTS).

Mulei, I. R., Mbuthia, P. G., Waruiru, R. M., Nyaga, P. N., Mutoloki, S., Evensen, Ø. (2021). Management Practices, Farmers' Knowledge of Diseased Fish, and Their Occurrence in Fish Farms in Nyeri County, Kenya. *Veterinary medicine international*, *2021*.

Munguti, J. M., Kim, J. D., & Ogello, E. O. (2014). An overview of Kenyan aquaculture: Current status, challenges, and opportunities for future development. *Fisheries and Aquatic Sciences*, *17*(1), 1-11.

Musyoka, S. N., & Mutia, G. M. (2016). The status of fish farming development in arid and semi-arid counties of Kenya: case study of Makueni County. *European Journal of physical and agricultural sciences, 4*(3), 28-40.

Mutunga, E. J., Ndungu, C. K., Mwangi, M., Kariuki, P. C. (2020). Modeling Determinants of Farmers' Choice of Adaptation Strategies to Climate Variability and Extreme Events in Kitui County, Kenya. *International Journal of Environment, Agriculture and Biotechnology*, 5(6), 1596-1608.

Mutunga, E., Ndungu, C. & Muendo, P. (2017) Smallholder Farmers Perceptions and Adaptations to Climate Change and Variability in Kitui County, Kenya. J Earth Sci Clim Change, 8(3).

Mwangi, M., Kituyi, E., Ouma, G., & Macharia, D. (2020). Indicator approach to assessing climate change vulnerability of communities in Kenya: a case study of Kitui county. American Journal of Climate Change, *9*, 53-67.

Mwikali, W., & Wafula, D. (2019) Historical Causes of Farmer-Herder Conflict in Kitui East Sub County, Kenya. *International Journal of Humanities Social Sciences and Education,* 6(12). 55-64.

Navy, H., Minh, T. H., & Pomeroy, R. (2017). Impacts of climate change on snakehead fish value chains in the Lower Mekong Basin of Cambodia and Vietnam. *Aquaculture Economics & Management*, *21*(2), 261-282.

Ndamani, F., & Watanabe, T. (2015). Farmers' perceptions about adaptation practices to climate change and barriers to adaptation: A micro-level study in Ghana. *Water*, *7*(9), 4593-4604.

Nduku, T. (2015). *Efficiency of Fish Farming under Economic Stimulus Programme in Kenya*. Kenya Institute of Public Policy Research and Analysis.

Ndungu, K. C., Bhardwaj, S. K., Sharma, D. P., Sharma, R., Gupta, R. K., Sharma, B. (2015). Vulnerability Assessment of Rural Communities to Environmental Changes in Mid-Hills of Himachal Pradesh in India. *Universal Journal of Environmental Research & Technology*, *5*(1).

Nelson, R., Kokic, P., Crimp, S., Martin, P., Meinke, H., Howden, S. M., Nidumolu, U. (2010). The vulnerability of Australian rural communities to climate variability and change: Part II—Integrating impacts with adaptive capacity. *Environmental Science & Policy*, *13*(1), 18-27.

Ngugi, C. C., & Manyala, J. O. (2004). Review of aquaculture extension service in Kenya. *Aquaculture extension in sub-Saharan Africa, FAO Fisheries Circular*, (1002).

Nielsen, J. Ø., & Reenberg, A. (2010). Temporality and the problem with singling out climate as a current driver of change in a small West African village. *Journal of Arid Environments*, *74*(4), 464-474.

Njoka, J. T., Yanda, P., Maganga, F., Liwenga, E., Kateka, A., Henku, A., Bavo, C. (2016). Kenya: Country situation assessment. *Pathways to Resilience in Semi-arid Economies (PRISE)*. IDRC-CRDI.

Notenbaert, A., Karanja, S. N., Herrero, M., Felisberto, M., Moyo, S. (2013). Derivation of a household-level vulnerability index for empirically testing measures of adaptive capacity and vulnerability. *Regional Environmental Change*, *13*(2), 459-470.

Nzevu, J. M., Amwata, D. A., & Mutua, A. K. (2018). Status of socio-economic parameters of fish farmers in Kitui Central Sub-County, Kitui County. *Journal of Research in Agriculture and Animal Science, 5*(1). 28-41.

Obiero, K. O., Raburu, P. O., Okeyo-Owuor, J. B., & Raburu, E. A. (2012). Community perceptions on the impact of the recession of Lake Victoria waters on Nyando Wetlands. *Scientific Research and Essays*, *7*(16), 1647-1661.

Ogallo, E. A. (2014). *Household vulnerability and adaptive capacity to impacts of climate change and variability in Soroti district, Eastern Uganda* (Doctoral dissertation, University of Nairobi).

Ogello, E. O., Mlingi, F. T., Nyonje, B. M., Charo-Karisa, H., & Munguti, J. M. (2013). Can integrated livestock-fish culture be a solution to East Africa's food insecurity? A Review. *African journal of food, agriculture, nutrition and development*, *13*(4), 8058-8078.

Olayinka, O. F., Olayode, O. O., Adesoji, S. A., & Daudu, A. K. (2018). Fish farmers' attitude toward agricultural insurance scheme in Ondo State Nigeria. *Journal of Agricultural Extension*, *22*(3), 97-108.

Opiyo, F. E., Wasonga, O. V., & Nyangito, M. M. (2014). Measuring household vulnerability to climate-induced stresses in pastoral rangelands of Kenya: Implications for resilience programming. *Pastoralism*, *4*(1), 10.

Parry, M. L., Canziani, O. F., Palutikof, J. P., Van Der Linden, P. J., Hanson, C. E. (2007). IPCC, 2007: climate change 2007: impacts, adaptation, and vulnerability. Contribution of working group II to the fourth assessment report of the intergovernmental panel on climate change. *Cambridge University Press, Cambridge, UK*.

Pelletier, N., André, J., Charef, A., Damalas, D., Green, B., Parker, R., Watson, R. (2014). Energy prices and seafood security. *Global Environmental Change*, *24*, 30-41.

Perez, C., Jones, E. M., Kristjanson, P., Cramer, L., Thornton, P. K., Förch, W., Barahona, C. A. (2015). How resilient are farming households and communities to a changing climate in Africa? A gender-based perspective. *Global Environmental Change*, *34*, 95-107.

Piya, L., Maharjan, K. L., & Joshi, N. P. (2012). Perceptions and realities of climate change among the Chepang communities in rural mid-hills of Nepal. *Journal of Contemporary India Studies: Space and Society, Hiroshima University*, *2*(5), 35-50.

Piya, L., Maharjan, K. L., & Joshi, N. P. (2012). *Vulnerability of rural households to climate change and extremes: Analysis of Chepang households in the Mid-Hills of Nepal* (No. 1007-2016-79495).

Ramamasy, S., & Baas, S. (2007). *Climate variability and change: adaptation to drought in Bangladesh. A resource book and training guide*. Food and Agriculture Organization (FAO).

Republic of Kenya (ROK). (2010). Agricultural Sector Development Strategy. *Ministry of Agriculture.* Government Press.

Ridler, N. B., & Hishamunda, N. (2001). *Promotion of sustainable commercial aquaculture in sub-Saharan Africa* (No. 408). Food & Agriculture Org.

Rijnsdorp, A. D., Peck, M. A., Engelhard, G. H., Möllmann, C., & Pinnegar, J. K. (2009). Resolving the effect of climate change on fish populations. *ICES journal of marine science*, *66*(7), 1570-1583.

Salick, J., & Byg, A. (2007). Indigenous peoples and climate change. Tyndall center for climate change research. *University of Oxford,* Oxford.

Seneviratne, S., Nicholls, N., Easterling, D., Goodess, C., Kanae, S., Kossin, J., & Zwiers, F. W. (2012). *Changes in climate extremes and their impacts on the natural physical environment.* Cambridge University Press.

Seto, K. C., Kaufmann, R. K., & Woodcock, C. E. (2000). Landsat reveals China's farmland reserves, but they're vanishing fast. *Nature*, *406*(6792), 121-121.

Shahid, S., & Behrawan, H. (2008). Drought risk assessment in the western part of Bangladesh. *Natural hazards*, *46*(3), 391-413.

Shahid, S., & Hazarika, M. K. (2010). Groundwater drought in the north-western districts of Bangladesh. *Water resources management*, *24*(10), 1989-2006.

Shoko, A. P., Getabu, A., & Mwayuli, G. (2011). Growth performance, yields, and economic benefits of Nile tilapia Oreochromis niloticus and Kales Brassica oleracea cultured under vegetable-fish culture integration. *Tanzania Journal of Science*, 37.

Simotwo, H. K., Mikalitsa, S. M., & Wambua, B. N. (2018). Climate change adaptive capacity and smallholder farming in Trans-Mara East sub-County, Kenya. *Geoenvironmental Disasters*, *5*(1), 1-14.

Smit, B., & Pilifosova, O. (2003). From adaptation to adaptive capacity and vulnerability reduction. In *Climate change, adaptive capacity and development* (pp. 9-28).

Smit, B., & Wandel, J. (2006). Adaptation, adaptive capacity, and vulnerability. *Global environmental change*, *16*(3), 282-292.

Tesso, G., Emana, B., & Ketema, M. (2012). Analysis of vulnerability and resilience to climate change-induced shocks in North Shewa, Ethiopia. *Agricultural Sciences*, *3*(06), 871.

United Nations Development Programme (UNDP). (2006). Human development report, United Nations Development Program.

Williams, L., & Rota, A. (2011). Impact of climate change on fisheries and aquaculture in the developing world and opportunities for adaptation. IFAD Fisheries Thematic Paper: Tool for Project Design.

Williams, P., & Barton, M. (2008). Perception of change in freshwater in remote resource-dependent Arctic communities. *Global Environmental Change*, *1*(18), 153-164.

APPENDICES

Appendix 1: QUESTIONNAIRE

SECTION A: GENERAL INFORMATION

1. Name of the Respondent:..
2. Gender of the respondent:..
3. Age of the respondent (*Years*)...
4. Relationship with the household head (*Tick one that is appropriate*)

    Household head

    Spouse of the household head

    Grown-up child

    Relative

    Others (*Specify*)...

5. Name of household head (*If the respondent is not the household head*):...
6. Gender of the Household head:..
7. Age of household head (*Years*):.................
8. Marital status of the household head (*Tick one that is appropriate*):

    Single

    Monogamously married

    Polygamously married,

    Divorced/ separated

    Widowed

9. Type of household (*Tick one that is appropriate*)

    Male headed

    Female-headed

    De jure female-headed (widow, never married, divorced),

    De facto female-headed (husband absent)

    Not yet married

    Polygamous

10. Education level of household head (*Give the number of years of formal schooling*).....................

11. The main occupation of the household head (*Tick one that is appropriate*)

Full-time fish farmer

Business

Casual laborer

Formal employment

Others (*Specify*)..

12. What is the main occupation of the Spouse? (*Tick one that is appropriate*)

Full-time fish farmer

Business

Casual laborer

Formal employment

Others (*Specify*)..

13. Number of members of the household:...................Males ....Females

SECTION B: VULNERABILITY TO CLIMATE CHANGE

EXPOSURE

14. What is your view on occurrences of the following climate extreme events and disasters in the last ten years?

Event/Disaster	**Increased**	**Decreased**	**Constant**	**Not sure**
Prolonged drought				
Heavy precipitation				
Floods				
Extreme heat				
Higher wind speed				
Fish diseases				
Fish poisoning				

15. What is your perception of the frequency and number of occurrences of the following disasters in the last ten years?

	Frequency			**Estimated number of incidents in the last ten years**
Event/Disaster	**Increased**	**No change**	**Decreased**	
Prolonged drought				
Heavy precipitation				
Floods				
Extreme heat				
Higher wind speed				
Fish diseases				
Fish poisoning				
Conflict with other resource users				

SENSITIVITY

16. How many fish stocks have you lost (*either through escape or mortality*) due to extreme events and disasters in the last ten years?

Event/Disaster	**Number of fish lost**
Prolonged drought	
Heavy precipitation	
Floods	
Extreme heat	
Higher wind speed	
Fish diseases	
Fish poisoning	
Conflict with other resource users	
Total	

17. How many culture units have been damaged due to extreme events and disasters in the last ten years?

Event/Disaster	**Number of damaged units**	**Number repairable**	**Number not repairable**
Prolonged drought			
Heavy precipitation			
Floods			
Extreme heat			
Higher wind speed			
Fish diseases			
Fish poisoning			
Conflict with other resource users			
Total			

18. What is your perception of the trend of the quantity of water in following water resources in the last ten years?

Water Resource	**The trend in Water Quantity**			**The estimated Number of Times it has dried up in the last ten years**
	Increased	**No change**	**Decreased**	
River/stream				
Borehole				
Shallow Well				
Spring				
Sand dam				
Earth Dam				
Rock Catchment				
Water Pan				
Other (*Specify*)				

19. What is the average harvesting weight of fish (*g*) recorded in the last three incidences of the various extreme events and disasters?

Event/Disaster	**W1**	**W2**	**W3**
Prolonged drought			
Heavy precipitation			
Floods			
Extreme heat			
Higher wind speed			
Fish diseases			
Fish poisoning			

20. Give an estimate of your monthly household income (*KSh.*) in the following:

Income structure	**Tick**	**Estimate per month (Kshs.)**
Natural Resource-Based Income		
Aquaculture		
Crop farming		
Livestock production		
Honey Sales		
Forestry products		
Sand harvesting		
Others (*Specify*)		
Total		
Non-natural based income		
Salaried jobs		
Remittances		
Skilled non-farm jobs, e.g., masonry, carpentry, handcraft, mechanic, brick making		
Small business returns		
Others (*Specify*)		
Total		

21. Type of land ownership (*Tick one that applies*):

Own

Rented

Family land/Inherited

Community

22. What is the nature of your diversification of species in terms of the number of species cultured in the fish farm? (*Tick one that applies*):

Single species culture

Mixed species culture

23. Give the number of the following culture units present on your fish farm.

Culture units	**Number**
Earthen pond	
Concrete pond	
Liner pond	
Glass tanks	
Plastic tanks	
Others (*Specify*)	
Total	

ADAPTIVE CAPACITY

24.

<table>
<tr><th>Component Indicators</th><th>Guiding Questions</th><th>Quantity</th></tr>
<tr><td rowspan="10">Physical Assets</td><td>Indicate the number of gadgets owned and used in accessing information</td><td></td></tr>
<tr><td>Indicate the number of times you accessed extension services in the last year</td><td></td></tr>
<tr><td>Indicate the number of sources of timely early warning weather information</td><td></td></tr>
<tr><td>Distance in Km to the nearest motorable road</td><td></td></tr>
<tr><td>Distance in Km to the nearest market for fish</td><td></td></tr>
<tr><td>Distance in Km to the nearest permanent water source</td><td></td></tr>
<tr><td>Distance in Km to the nearest hatchery</td><td></td></tr>
<tr><td>Distance in Km to the nearest input shop (e.g., agro vet)</td><td></td></tr>
<tr><td>Total volume in liters of all water storage facilities on the farm</td><td></td></tr>
<tr><td colspan="2">Number of fish farming equipment
<table>
<tr><th></th><th>Number</th></tr>
<tr><td>Secchi disc</td><td></td></tr>
<tr><td>Water quality test kit</td><td></td></tr>
<tr><td>Pond liner</td><td></td></tr>
<tr><td>Weighing scale</td><td></td></tr>
<tr><td>Thermometer</td><td></td></tr>
<tr><td>Harvesting net</td><td></td></tr>
<tr><td>Scoop net</td><td></td></tr>
<tr><td>Aerator</td><td></td></tr>
<tr><td>Packaging bag</td><td></td></tr>
<tr><td>Oxygen cylinder</td><td></td></tr>
<tr><td>Rearing units</td><td></td></tr>
<tr><td>Others (Specify)
....
....
............................</td><td></td></tr>
<tr><td>Total</td><td></td></tr>
</table>
</td></tr>
</table>

<table>
<tr><td rowspan="4">Human Assets</td><td rowspan="2">Highest level of education or qualification in the family</td><td>Level</td><td>Number of schooling years</td></tr>
<tr><td>None
Primary
High School
College Graduate
Post Graduate
Total</td><td></td></tr>
<tr><td>The number of persons in the household having salaried employment?</td><td colspan="2">Indicate the number</td></tr>
<tr><td>Number of fish farming training attended by family members</td><td colspan="2">Indicate the number</td></tr>
<tr><td rowspan="7">Natural Assets</td><td>The total size of your land?</td><td colspan="2">(In acres)</td></tr>
<tr><td>Size of land devoted to fish farming</td><td colspan="2">(In acres)</td></tr>
<tr><td>Size of land devoted to other farming activities</td><td colspan="2">(In acres)</td></tr>
<tr><td>Size of land devoted to settlement</td><td colspan="2">(In acres)</td></tr>
<tr><td>The average number of fish stocked in one production cycle</td><td colspan="2"></td></tr>
<tr><td>Number of fish species cultured</td><td colspan="2"></td></tr>
<tr><td>Number of drought animals owned</td><td colspan="2"></td></tr>
<tr><td rowspan="6">Social Assets</td><td>Are you a member of any community-based organization?
Yes[ ] No[ ]</td><td colspan="2">Indicate number</td></tr>
<tr><td>Are you a member of any cooperative society?
Yes[ ] No[ ]</td><td colspan="2"></td></tr>
<tr><td>Indicate the number of credit facilities accessed in the last ten years</td><td colspan="2"></td></tr>
<tr><td>Indicate the highest amount of credit (Ksh.) accessed in the last ten years</td><td colspan="2"></td></tr>
<tr><td>Indicate your average monthly income (Ksh.) from all income-generating activities.</td><td colspan="2"></td></tr>
<tr><td>Indicate your average monthly savings (Ksh.)</td><td colspan="2"></td></tr>
</table>

SECTION C: FISH FARMER'S ADAPTATION TO CLIMATE CHANGE

25. Which adaptation strategies have you adopted in your fish farming business in response to the changing climate?

Adaptation Options	**Adopted? Yes or No**
Farming hardy fish species that are tolerant to extreme climatic conditions	
Shift from fish farming to different agricultural activities	
Shift from other agricultural activities to fish farming	
Integrating fish farming with other agricultural activities	
Practice fish farming during seasons when water is available in sufficient quantities only	
Build a water-harvesting scheme	
Practice reuse of water	
Changing stocking time	
Stocking different rearing units at different intervals	
Stocking of juveniles (*up to 30g*) instead of fry(*up to 6g*)	
Implement water conservation techniques in fish farming	
Frequent repair of slight damages in culture units	
Procure insurance for fish farming business	
Increasing vegetation cover to attract rain	
Reduce stocking	
Practice mixed-sex culture	
Find off-farm job	
Lease your land	
Agro-forestry	
Regular vaccination of fish	
Seeking support from the county government	
Procure loan to keep the business afloat	
No adaptation	
Others (*Specify*)	