SMALLHOLDER FARMERS' ADAPTATION TO THE EFFECTS OF CLIMATE CHANGE IN SELECTED PARTS OF MAKUENI COUNTY, KENYA

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Abstract: Climate change is a global challenge that has attracted a lot of attention and debate at all levels. The need for human development has accumulated a buildup of Greenhouse Gases in the atmosphere thus contributing to global warming. Initially, most efforts concerning climate change were focused on mitigation, but in the recent years, more and more applications have been made to adaptation to the effects of climate change, which is currently a major issue in developing countries. The main objective of this study was to examine the adaptation strategies of the small holder farmers against climate change and variability in three agro-ecological sites in Makueni County, Kenya. The study used survey research design. The three agro-ecological sites were selected using stratified sampling, while simple random method was used to select 289 households for interview. Selection of key informants was done through purposive sampling method. Data was collected through administration of semi-structured and open-ended questionnaires to the selected households, and also through interview of key informants, focus group discussions, observation and photography. Findings indicated that there was significant correlation between the climate change and agro-ecological zones studied (X^2=13.3, df=2, $P<0.01$). Results further indicate that there were significance changes in occurrences of emergencies in the three agro-ecological zones ($p<0.05$). There were increased floods (observed by 86.9% of farmers), and water availability decreased (supported by 93.8%). The types of crops varied significantly by the three agro-ecological zones ($p<0.05$), with some crops preferred in some agro-ecological zones to others. Irrigation as an adaptation strategy was statistically significant across the three agro-ecological zones, and more common at Mbooni agro-ecological zone ($p<0.00$). Several adaptive methods of crop production were adopted, and significantly varied across the zones ($p<0.05$). Farmers resorted to using improved planting materials (X^2=20.561, $p< 0.05$) to mitigate effects of climate change and enhance their livelihoods. The study recommends that there is need to embrace more adaptation measures in order to minimize the impacts of climate change at the local level.

Key words: Smallholder farmers, climate change, adaptations, Makueni County.

1.0 Introduction

Climate Change has been studied to be one of the most pressing complex and perplexing global environmental challenge (FAO, 2015), threatening food security, poverty alleviation, and livelihoods for smallholder farmers. Climate change has led to adverse effect to every region across the globe, with many irreversible changes, such as the rise of CO_2 concentrations in the atmosphere, increase of the global surface temperatures and also the rise of the global mean sea levels (IPCC, 2021), therefore, disrupting the global movement towards sustainable development (Harvey *et al.,* 2018). Evidence of experienced climatic changes across the entire globe of extreme events such as heavy precipitation leading to floods, heatwaves, droughts and tropical cyclones has strengthened and are more likely to reach unbearable threshold for agriculture, health and may also lead to adverse effect to natural water cycle (IPCC, 2021).

The Africa's Agenda 2063, which was concluded in 2013, recognized change in climate as a major challenge for the continent's progress and growth. Africa's economy highly depends on agriculture, accounting for the majority of livelihoods, and therefore exposing many smallholder farmers to impacts of climate change and variability. Decreased crop production coupled with increased temperature and drought pressure, increased pest damage and disease damage, flood effects on food system infrastructure, leading to serious consequences for food security and health are major agricultural threats at the regional cascading to local levels. Promotion of socioeconomic growth mostly in the agronomic sector is one of the promising approaches towards reducing climate related risks, poverty and extreme event impacts throughout the continent (UN University, 2020).

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Kenya has been impacted negatively by climate change due to its nascent economic growth trends. Majority of Kenyan agriculture totally relies on rainfall, with only less than 5% under irrigation, and the sector has suffered from increasing variability in rainfall. Floods and drought which constitute some of the climatic extreme events have negative impacts on the socio-economic development, with devastating consequences on the country's economy (G.O.K, 2010; G.O.K, 2019). Agricultural activities are the main sources of economic growth, livelihood, food security, foreign construction and job creation and foreign exchange earnings for the majority of the population of Kenya (KEPSA, 2014; Ochieng *et al.,* 2016). Demand for food, fuel wood and forest products have increased tremendously over the years, leading to unprecedented environmental degradation. An estimation of over 57% of Kenyan population lives below poverty line (FAO, 2015) while, most of smallholder farmers (70%), basically rely on climate-sensitive economic activities including agriculture (Simotwo *et al.,* 2018; Ylva *et al.,* 2020), therefore, increasing farmers' vulnerability and affecting the Sustainable Development Goal (SDG) 13, Target 13.1, aimed at strengthening adaptability and resilience so as to enable farmers respond to risks associated to climate change and natural calamities (GOK, 2018).

It has been proven that effects of change of climate in Kenya have devastating impacts to smallholder farmers in a situation where adaptation and coping mechanisms present a challenge to them when it comes to their vulnerability. Most of these farmers are constrained by poverty and inappropriate coping mechanisms beyond their immediate ability, even when they are aware of the appropriate climate adaptation measures (Muema *et al.,* 2018).

According to the Government of Kenya (GoK, 2013), the County of Makueni is among the 47 counties that form Kenya, and the County lies to the South Eastern part of the country, falling under semi-arid climatic conditions. The County is ecologically categorized as an arid and semi-arid zone, having unreliable and unevenly distributed rainfall over space and time, which is also accompanied by annual long dry weather spells. Between the months of April and March, the county receives long rains, with the short rains coming in the months of November and December. Weather projections show that the two seasons are likely to experience prolonged moisture stress (MoALF, 2016).

Smallholder farmers in Makueni County are the majority, with over eighty percent of her residents depending on rain-fed farming for survival, food security and livelihoods (GOK, 2019). The greatest challenges the County is facing include variabilities associated with climate change, often caused by occurrence of adverse events including droughts and floods with negative effects on farmers and the general economy. Other climate-related challenges include lack of preparedness to mitigate such extreme events, little understanding and lack of information on the susceptibility and the adaptation measures against impacts of climate change by smallholder farmers, and effects on agricultural outputs (Maiju, 2019; Muema *et al.,* 2018; Chaudhury *et al.,* 2020).

The aim of the present study was therefore to determine the adaptation strategies and coping mechanisms against the effects of climate change amongst smallholder farmers in Makueni County, Kenya.

2.0 Methods

General Study Area

Makueni County is among the 47 counties in Kenya, located in the South Eastern region. The neighbourhood include Kitui County to the East, Kajiado County to West, Machakos County to the North and Taita Taveta County to the south. It has an area of 8,008.7 Km2 and is between Latitude 1º 35 ′ and 3 ° 00 ′ South as well as Longitude 37º10 'and 38º 30 ′ East. The County experience frequent droughts as it is in the Arid and Semi-Aid area. It has six sub-counties including Makueni, Kibwezi East, Kaiti, Mbooni, Kilome and Kibwezi West Sub-Counties. The County is then sub-divided in to further 30 wards, containing 60 sub-wards (G.O.K, 2013).

The study was done in selected parts of Makueni County which were classified according to agro-ecological zones (Jaetzold, *et al.,* 2006). The agro-ecological zones were classified as Semi Humid zone (upper part) covering Mbooni Sub County area, Semi-Arid areas (middle part) which covered Makueni Sub County and Arid area (lower part) which covered Kibwezi East Sub County.

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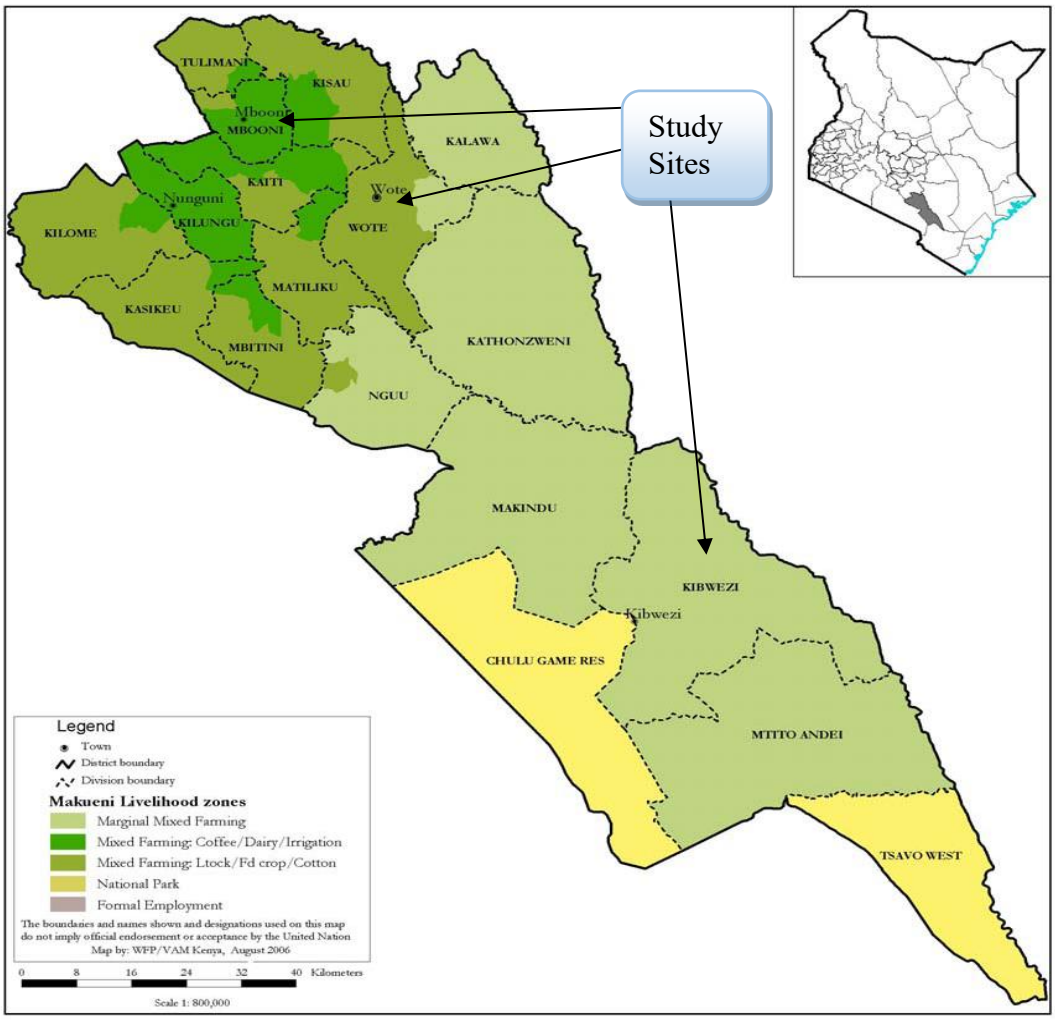

Figure 1: A Map of Makueni Livelihood Zones

Source: Makueni LRA Report, 2013.

Research Design

Descriptive research design was embraced to examine and calculate the susceptibility of smallholder farmers due to changes in climate and variability, including factors that affect their vulnerability. The design was also used to explore their climate change strategies (Asfaw *et al.,* 2021). Mixed methods of both quantitative and qualitative methods were used to collect primary data. Information was collected from family heads regarding socio-economic, biophysical and demographic factors of the study area.

Sample frame and sampling techniques

The sample frame for the study was drawn from farmer beneficiaries from the Kenya Cereals Enhancement Program – Climate Resilient Agricultural Livelihood (KCEP-CRAL). KCEP-CRAL is a national government funded and implemented program in selected counties in Kenya, with Makueni County being a beneficiary. KCEP-CRAL program, which kicked off in 2018 in Makueni, aimed at reducing rural poverty and food insecurity among smallholder farmers in arid and semi-arid lands by developing their economic potential, while improving their natural resource management capacity and resilience to climate change in an increasingly fragile ecosystem. At least 16,000 subsistence farmers benefited from the program through the provision of farm inputs through e-voucher system, financial inclusion, post-production management practices and market linkages for targeted value chains, along with other agricultural resources to enhance their resilience. The current study dwelt on three Sub-Counties selected on the basis of their agro-ecological zone localities and which were beneficiaries of the KCEP-CRAL program.

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Table 1: Sampling Frame of Farmer beneficiaries from KCEP-CRAL program

Area (Sub- County)	KCEP-CRAL Beneficiaries	Percentage
Mbooni Sub- County	140	44.9
Muvau Sub- County	79	25.3
Masongaleni Sub- County	93	29.8
Totals	312	100.0

Source: Ministry of Agriculture Makueni County

The survey research used a randomized multi-stage sampling process to select households (Asfaw *et al.,* 2021).

Sample Size Determination

The following formula was embraced for the study (Asfaw *et al.,* 2021).

$$n = \frac{Z^2 * N * p * q}{e^2(N-1) + Z^2 * p * q} \quad \ldots\ldots\ldots\ldots\ldots \quad \text{(Eqn. 1)}$$

Where; N represents the total targeted population for smallholder farmers, n is the sample size, and Z is the set standard deviation picked at 95% confidence level, which is 1.96. *P* is the alpha levels of 0.5, showing the estimated proportion present while *q* (1-p)(0.5) represents the estimated proportion of the attribute not present in the population, while *e* is the required accuracy level, usually set as 0.05 (5% of acceptable sample error).

Mbooni (Mbooni) - Total Population 140 = Sample Size 103 Households

Makueni (Muvau) - Total Population 79 = Sample Size 66 Households

Kibwezi East (Masongaleni)– Total Population 93 = Sample Size 75 Households

Total Sample Size 244 Households

Research Instruments

The study used the following data collection tools; Household questionnaire, Key Informant Interviews (KIIs) and Focus Group Discussions (FGDs). The tools are explained below:

Household Questionnaire: The questionnaire was the main data collection instrument. It was divided into five sections. The first section captured household demographic information. The second section was capturing household general information, while section three was capturing socioeconomic activities and livelihood options. Section four was on adaptations to climate change and variability. The last section was on institutional support. The questions were distributed across the five sections capturing demographics and socio-economic responses, their livelihoods, outcomes and experiences of climate change in agriculture, land use practices related mitigations to climate actions provided by County Government and other climate actors in the study area.

Focus Group Discussion Guide: The guide had open questions on areas on climate change and variability, and the adaptation strategies embraced by farmers. The FGD tool had questions on farming and livestock rearing activities among farmers, identification and observation of climate change and variability indicators, how climate change has affected crop production, livestock rearing, and livelihood options, and the mitigation measures taken. The guide had also questions on mitigation efforts against climate change and variability in Makueni by governmental, non-governmental and individual households.

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Data Analysis

The data collected was analyzed by both quantitative and qualitative approaches. The study used Statistical Package for Social Sciences (SPSS) software for analyzing data obtained from the questionnaire and the generated results were presented through frequencies, tables, charts, and statistics. Relevant data from key discussions, FGD notes and policy reviews was processed and analyzed to establish leading themes, trends/patterns, relationships or correlations, and conclusions obtained in line with research objectives (Gray, 2004).

Simple linear regression was used to analyze the correlation between a single quantitative effect and a single descriptive quantity indicator. The method was used to determine and detect the long-term trend as well as variation in weather elements like temperature and rainfall on the annual and monthly time scale.

Multinomial logit regression model was used to analyze factors that contribute to the choices of climate change mitigation strategies embraced by smallholder farmers. The model clarified the association between the probability of selecting a particular adaptation strategy and the descriptive variables.

The significance of relationship between independent variables i.e. demographic and socio-economic characteristics, and existing livelihood actions and dependent variable (implementation of adaptation strategies), was analyzed using chi- square contingency (×2) statistical test. This allowed the establishment of assurance on whether there is a correlation between two indicators in the study population. The chi-square (×2) value was interpreted relative to its associated statistical significance levels taken as $p < 0.05$. In interpretation, a *P* value greater than 0.05 denoted lack of association or relationship between the variables in the population.

Ethical Considerations

The study was guided by research ethics. The six elements of research ethics were considered including informed consent, beneficence, confidentiality, anonymity, no harm and the right to withdraw from the exercise. Farmers, who were the main respondent, were first informed of the intentions and objectives of the study, requesting for their informed consent. Once the informed consent was given, then the other ethical considerations were also worked on. Confidentiality was also considered and adhered to, where information collected from farmers was not shared with third parties. The information collected was also kept confidential, as no farmer details were used to expose them to any unauthorized third party.

3.0 Results

3.1 Response rate and demographic characteristics of the respondents

A sample of 289 respondents was reached and the target for each specified study area within the three agro-ecological zones is shown in Table 2 below.

Table 2: Distribution and response rate of the respondents

Constituency (Ward)	Targeted sample size	Reached respondents	Percentage reached
Mbooni (Mbooni)	103	105	102
Makueni (Muvau)	66	79	120
Kibwezi East (Masongaleni)	75	105	140
Totals	**244**	**289**	**120**

The study response rate was 120% as six focus group discussions were reached instead of the initially intended five, which meets the threshold for sample size requirement according to Mugenda and Mugenda (2003).

Summary of demographic characteristics

Most of the respondents were drawn from Kibwezi East and Mbooni (Table 3), both Sub-Counties having a representation of about 36.3%. Makueni had the least representation at 27.4%. In terms of relations to the household head. Majority of the respondents were spouses at 48.1%, while respondents who were the household heads were 38.1%. Further, there were 10.0% and 3.8% of the respondents who identified themselves as children and parents of the household heads. In terms of gender representation, more of the respondents at 64.0% were female, while the other 36% were male. In terms of level of education, majority of the respondents at 56.4% had achieved primary level education, followed by 29.8% who reported to have attained secondary education level. Respondents who had achieved college and university education were 5.5% and 1.4% respectively.

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The distributions of respondents in terms of their age, the majority were aged between 26 to 40 years, representing 34.9% of the population. This category was followed by those aged between 41 to 60 years at 33.6%. The study revealed that 20.1% and 11.4% of the respondents were aged above 61 years and below age 25 years respectively. In terms of occupation, majority of the respondents (66.1%) indicated that they were farmers. Those engaged in small scale business and casual laborers were 10.4% and 10.0% respectively. A further 4.2% of the respondents reported to have been engaged with other different occupational roles, while 3.5% of the respondents indicated that they were not engaged in any form of economic activities.

Majority of the respondents in the study area were married in monogamous union at 78.2%. The study established that 12.5% of the respondents were widowed while 5.2% reported to have had orphans in their households. There was a small percentage of respondents (1.7%) who were in polygamous marriage.

Table 3: Summary of Demographic Characteristics

Variable	Category	Frequency	Percentage
Relations to household head	Household head	110	38.1
	Spouse	139	48.1
	Child	29	10.0
	Parent/guardian	11	3.8
Gender	Female	185	64.0
	Male	104	36.0
Education	College	16	5.5
	None	20	6.9
	Primary	163	56.4
	Secondary	86	29.8
	University	4	1.4
Age of respondent	18-25 years	33	11.4
	26-40 years	101	34.9
	41-60 Years	97	33.6
	Above 61 years	58	20.1
Occupation	Students	8	2.8
	Business	30	10.4
	Casual Labourer	29	10.0
	Farmer	191	66.1
	Teacher	9	3.1
	Not employed	10	3.5
	Other roles	12	4.2
Marital Status	Married (Monogamous)	226	78.2
	Married (Polygamous)	5	1.7
	Separated/Divorced	8	2.8
	Single	14	4.8
	Widowed	36	12.5
Type of Household	Dejure female headed (widow, never married, divorced)	13	4.5
	Female headed	32	11.1
	Male headed	242	83.7
	Polygamous	2	0.7
Presence of an orphan	No	274	94.8
	Yes	15	5.2
Sub-county	Kibwezi East	105	36.3
	Makueni	79	27.4
	Mbooni	105	36.3

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3.2 Farmer's perception on climate change in the study area

Experience of extreme weather conditions

The study established that 76.8% of the farmers experienced extreme weather conditions, with only 23.2% not experiencing extreme weather conditions. In relation to the agro-ecological zones, more farmers in Kibwezi East and Makueni at 88.6% and 70.9% respectively experienced extreme weather conditions, compared to 69.5% in Mbooni (Table 4). There was significant correlation between the climate change and the agro-ecological zones studied (X^2=13.3, df=2, P<0.01). The Pearson correlation portrayed that the agro-ecological zones studied experienced some form of climate change.

Table 4: Experience of extreme weather conditions

	Sub County						
	Kibwezi East	Makueni	Mbooni	Total	Pearson Chi-Square Value	df	Asymptotic Significance (2-sided)
No	12	23	32	67	13.297a	2	0.001
	11.4%	29.1%	30.5%	23.2%			
Yes	93	56	73	222			
	88.6%	70.9%	69.5%	76.8%			
Total	105	79	105	289			

3.3 Frequency of Emergencies for the past 5 years

The study revealed that majority of the respondents (75.8%) did not notice any general changes on weather and climate over the past five years, 4.2% believed that the general changes had decreased with only 2.4% indicating that they had increased while 17.6% were not sure on general changes on climate and weather and other emergencies (Table 5).

Table 5: Frequencies of emergencies in the last five years (n=289)

Change	General changes	Floods	Droughts	Strong winds	Wild fires	Livestock diseases	Community inter-border conflict
No change	75.8	5.2	48.4	79.6	17	73.4	62.3
Decreased	4.2	1	2.1	1.4	3.1	1.7	2.4
Increased	2.4	86.9	38.1	2.1	71.3	11.1	20.4
Not sure	17.6	6.9	11.4	17	8.7	13.8	14.9

Majority of the respondents (86.9%) reported that floods had increased in the last five years (Table 5). Few of them (5.2%) indicated that they had not experience any major change while only 1% of the farmers believed that floods had decreased. On drought, 48.4% of the respondents didn't notice any change, while 38.1% believed that drought had increased over time with only 2.1% reporting a decrease. The impact of storms/strong winds had not been strongly felt as reported by 79.6% of the respondents. The effect of wild fires had been significantly felt with 71.3% of the respondents recording an increase of the trend.

On increase of livestock diseases, majority of the respondents (73.4%) did not notice any change, 11.1% believed that livestock diseases had increased with only 1.7% indicating that there was a decrease. At least 62.3% of the respondents reported that there was no increase in community inter-border conflict while 20.4% believed that there was an increase, and 2.4% believed that the conflicts had decreased over time.

3.4 Trends in water Availability

Generally, the study revealed that most of the farmers (93.8%), believed that the water amounts had decreased over the past five years, 3.8% didn't notice any changes in trends of water amounts and 1.7% believed the water trend had increased. Spring water had the greatest decrease rate (85.5%), followed by boreholes (73%), while river had the least decrease (42.9%). Majority of the respondents (47.4%) indicated that there was no change in terms of water amounts from rivers and streams more than any other water source (Table 6).

Table 6: Trends in water quantity

Change	General Trend	River/Stream	Borehole	Shallow well	Spring	Earth /sand dam
Not sure	0.7	9.3	9	9.3	3.5	12.1
Decreased	93.8	42.9	73	70.6	85.5	68.5
Increased	1.7	0.3	0	0	0.3	0
No change	3.8	47.4	18	20.1	10.7	19.4

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3.5 Farmer's adaptation strategies in crop production

3.5.1 Type of crops grown by farmers

The study established that maize was the most cultivated cereal crop as reported by (89.1%) of the respondents. Sorghum was planted by 6.2% of the farmers. Amongst the legumes, cow peas were the most cultivated crop as reported by 49.4% of the respondents followed by beans (47.1%), green grams (46.3%) and pigeon peas (27.6%). For fruit crops, majority of the farmers planted bananas (16.0%), avocado 15.2%, mangoes 6.6%, oranges 4.7% and pawpaw 0.8% in that order. On vegetables growing (7.0%) of the respondents had planted Sukuma wiki/kales, traditional vegetables such as *mchicha* and *managu* (4.7%), spinach (3.1%) tomatoes (1.9%) and cabbage (1.2%). For cash crops, only coffee and sunflower were cultivated at 6.6% and 0.8% respectively. For tuber crops, 9.7%, of the farmers cultivated cassava, followed by yams (3.5%) and vines (0.8%) (Table 7).

Table 7: Types of crops grown

Category	Crop	Kibwezi East	Makueni	Mbooni	% growing crop	Pearson Chi-Square Value
Cereals	Maize	37.4%	18.7%	33.1%	89.1%	0.21
	Sorghum	4.3%	1.6%	0.4%	6.2%	0.16
Legumes	Beans	0.0%	10.1%	37.0%	47.1%	0.00
	Pigeon peas	15.2%	11.3%	1.2%	27.6%	0.00
	Cow peas	33.1%	14.8%	1.6%	49.4%	0.00
	Green Grams	36.6%	9.3%	0.4%	46.3%	0.00
Fruits	Oranges	0.0%	3.5%	1.2%	4.7%	0.00
	Mangoes	0.4%	5.4%	0.8%	6.6%	0.00
	Avocado	0.0%	0.8%	14.4%	15.2%	0.00
	Bananas	0.0%	1.2%	14.8%	16.0%	0.00
	Pawpaw	0.0%	0.4%	0.4%	0.8%	0.39
	Passion Fruits	0.0%	0.0%	1.6%	1.6%	0.05
Vegetables	Kales	0.0%	0.0%	7.0%	7.0%	0.00
	Spinach	0.0%	0.0%	3.1%	3.1%	0.02
	Cabbage	0.0%	0.0%	1.2%	1.2%	0.10
	Traditional veges	0.0%	0.4%	4.3%	4.7%	0.00
	Tomatoes	0.0%	0.0%	1.9%	1.9%	0.02
	Coffee	0.0%	0.0%	6.6%	6.6%	0.00
Cash Crops	Sunflower	0.0%	0.4%	0.4%	0.8%	0.39
Tubers	Cassava	1.6%	1.6%	6.6%	9.7%	0.01
	Vine	0.0%	0.0%	0.8%	0.8%	0.22
	Yams	0.0%	0.0%	3.5%	3.5%	0.00

3.6 Planting and irrigation of crops

The study revealed that majority of the respondents (94.4%- cumulative of the three agro-ecological zones) had planted crops in the previous rain season. There was overdependence on rain fed agriculture as attested by respondents at 100% in Makueni and Mbooni and 97.1% in Kibwezi.

Only a small percentage of the farmers who irrigated their crops from rivers (riverine) as represented by 9.7%, while another 1.4% used run-off irrigation, 1.0% used shallow wells and another 0.7% used pool water for irrigation. Interestingly, most of the irrigation took place in Mbooni agro-ecological zone and none in the other two zones (Table 8).

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Table 5: Planting of crops and mode of irrigation (n=289)

Category	Kibwezi East (n=105)	Makueni (n=79)	Mbooni (n=105)	% Irrigating	Pearson Chi-Square Value
Planted crops	96 (91.4%)	76 (96.2%)	101 (96.2%)	--------	0.09
Rainfed	102 (97.1%)	79 (100.0%)	105 (100%)	--------	0.43
Irrigated Riverine	12 (11.4%)	2(2.5%)	14 (13.3%)	9.7%	0.00
Pool	0.0%	0.0%	2 (1.9%)	0.7%	0.18
Shallow well	0.0%	0.0%	3(2.9%)	1.0%	0.08
Run-off harvesting	0.0%	0.0%	4(3.8%)	1.4%	0.03

3.7 Adaptive methods of crop production

The study revealed that the majority of farmers used one or another approach in improving crop productivity. An overwhelming majority (85.1%) applied organic manure in their farms to improve productivity. Over half of the farmers (51.9%) practiced early planting as a method for increased crop production, while 30.8% indicated that they used inorganic fertilizers. It was also found that 25.6% of the farmers used mixed cropping to boost their crop production. Very few farmers used crop rotation (5.2%) and irrigation (5.2%), to improve on their crop production. The other methods used by farmers for increased crop production were; drought resistant crops (15.9%), crop protection (14.9%) and use of improved quality seeds (14.9%) (Table 9).

Table 6: Approaches used to increase crop productivity (Methods practiced to increase crop production.

Strategy	Kibwezi East	Makueni	Mbooni	% using strategy	Pearson Chi-Square Value
Early planting	12.8%	12.8%	26.3%	51.9%	0.00
Fertilizer application	0.7%	7.6%	22.5%	30.8%	0.00
Manure application	27.7%	26.0%	31.5%	85.1%	0.00
Mixed cropping	10.7%	9.3%	5.5%	25.6%	0.01
Drought tolerant seed varieties	3.8%	4.8%	7.3%	15.9%	0.13
Irrigation	0.0%	0.7%	4.5%	5.2%	0.00
Quality improved seeds	2.4%	5.2%	7.3%	14.9%	0.01
Crop protection	5.5%	4.5%	4.8%	14.9%	0.85
Crop diversification	5.9%	3.5%	2.8%	12.1%	0.12
Crop rotation	1.4%	1.0%	2.8%	5.2%	0.36
Others (herbicides, harvesting runoff water, proper tilling)	1.7%	0.0%	0.7%	2.4%	0.11

Among the most significant adaptive methods of crop production included early planning ($p<0.00$), fertilizer application ($p<0.00$), manure application ($p<0.00$) mixed cropping ($p<0.01$), irrigation ($p<0.00$), and planting quality improved seeds ($p<0.001$).

3.8 Use of Improved planting materials

It was established that majority of the farmers (63.7%) used improved and quality planting materials (seeds), while a significant percentage of them (36.3%) were not. Majority of those not using improved seeds were from Kibwezi East (50%, n=53), followed by farmers from Makueni (39.2%, n=31) and Mbooni, (20.0%, n=21. Majority of the farmers who used improved and quality planting seeds were from Mbooni sub-county at 45.1% (n=83) followed by Kibwezi East (28.8%, n=53) and Makueni (26.1%, n=48). Analysis derived from the Pearson correlation confirmed that the agro-ecological zone studied was statistically correlated with farmers adopting improved planting seeds ($X^2=20.561$, $p< 0.05$) (Table 10).

Table 7: Use of Improved planting materials (seeds) across three agro-ecological zones

		Sub County			Total
Use improved quality seeds		Kibwezi East	Makueni	Mbooni	
No	Count	53	31	21	105
	% using improved seeds	50.5%	29.5%	20.0%	100.0%
	% of Total	18.3%	10.7%	7.3%	36.3%

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Yes	Count	53	48	83	184
	% use improved seeds	28.8%	26.1%	45.1%	100.0%
	% of Total	18.3%	16.6%	28.7%	63.7%

3.9 Regression and correlation analysis of adaptation strategies on climate change

It was established that climate change was statistically significantly associated with borrowing of money from friends or SACCO ($p<0.042$), and adapting to crop production strategies ($p<0.048$). Climate change was not found to have statistically significant influence on adaptation strategies of provision of information on extreme weather events, government aid to the farmers, and adaptation strategies for livestock production ($p<0.05$). Similarly, farmers not experiencing climate change had 0.834 reduced odds ratio of adapting livestock production strategies (Table 11).

Table 8: Adaptation strategies and climate change

Adaptation strategy	B	S.E.	Wald	df	Sig.	Exp(B)
Borrowed Money from friends/SACCO	-0.802	0.396	4.115	1	0.042	0.448
Information on Extreme weather events	0.308	0.471	0.426	1	0.514	1.36
Government Aid to farmers	0.381	0.861	0.196	1	0.658	1.464
Adapting Crop Production strategies	-0.715	0.362	3.91	1	0.048	0.489
Adapting Livestock production strategies	-0.182	0.332	0.301	1	0.583	0.834
Constant	1.799	0.259	48.118	1	0	6.045

4.0 Discussion

The study established that most of the respondents interviewed were women at 64.0%, whereby 56.4% had primary education level. The findings correlate well with previous studies which established that most rural households in Kenya are farmers and are manned by women (Olsson *et al*., 2014, Mutua *et al.*, 2016).

The finding that 76.8% of the respondents experienced extreme weather conditions was in line with previous related studies who found out that most farmers in the rural areas of many developing countries bear the largest burden of climate change due to extreme weather conditions (Harvey *et al.*, 2018; Minh *et al.,* 2019). As observed in other studies (MoALF, 2016), there was significant correlation between the climate change and the agro-ecological zones studied ($X2=13.3$, $df=2$, $P<0.01$). There was over 93.8% of the respondents who agreed that there was a general decrease in water availability for the past five years. These findings corroborated well with other findings (Kieti *et al.,* 2016) which established that due to climate change, there has been observable reduction in water availability in most rural areas.

The findings on farmer adaptations in crop production were found to significantly change with the ecological zones studied. Consequently, the kind of crops grown including legumes, fruits, vegetables and cash crops were significantly different in the three agro-ecological zones studied ($p<0.005$). These findings were similar to previous studies which revealed that in order to adapt to the climate change, farmers adopted different crops in different agro-ecological zones to mitigate against long-term impacts of climate change (Mbuli *et al*., 2021; Ouya *et al*., 2020).

The fact that farmers in agro-ecological zones with riverine waters tended to adopt irrigation of both cash and food crops (9.7%) was in agreement with previous studies done by Radeny *et al*., (2020). However, only few farmers, (<10%) in the study area had adopted irrigation as a mitigation strategy against climate change, similar to studies done by Simotwo *et al.,* (2018) and Ylva *et.al.*, 2020.

There were several adaptive methods for crop production embraced by farmers, including early planting, fertilizer application, manure application, mixed cropping, irrigation, and use of quality improved seedlings (all statistically significant for the three agro-ecological zones, $p<0.05$). These findings correlated well with other previous studies of Mbuli *et al.,* (2021) who revealed that farmers resulted to use of different approaches in order to adapt to the effects of climate change and maintain their livelihoods.

Analysis derived from the Pearson correlation, confirmed that the agro-ecological zones studied were statistically correlated with farmers adopting improved planting seeds ($X^2=20.561$, $p< 0.05$). Similarly, results from the regression analysis showed that climate

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change adaptation strategies like borrowing of money to support livelihood and adoption of different crop production strategies were statistically significant across the three agro-ecological zones at $p<0.042$ and $p<0.048$ respectively. These findings were similar to those of Mbuli *et al.,* (2021) and Minh *et al.,* (2019) who established that farmers sought different survival mechanisms when faced with climate change conditions.

5. Conclusion

This study examined different adaptation mechanisms employed by local farmers in three agro-ecological zones of Makueni County, Kenya. The study established that farmers in the study area adopted various strategies to mitigate against their vulnerability to impacts of climate change. The main adaptation strategies were crop diversification, use of improved planting material and use of different crop and animal production strategies which were all statistically significant across the three agro-ecological zones studied. The findings showed that there is need to keep farmers informed and engaged on adapting to strategies that enhance their capacity to mitigate the effects of climate change, hence promoting their livelihoods.

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7.0 Declaration of conflict of interest

The authors declare that there is no conflict of interest.

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