PERCEPTION OF ADAPTATION STRATEGIES TO CLIMATE VARIABILITY IN MACHAKOS COUNTY, KENYA

Abstract: Thestudy was designed to assess climate variability trends on rainfall and temperature data between 1990 and 2020, analyse community perception to climate variability, evaluate adaptation strategies and their effectiveness and examined the challenges of adaptation to climate variability. Farmers were randomly selected and questionnaires administered, while focused group discussions were conducted to obtain farmer's perceptions of climate variability. Rainfall and temperature data was statistically analysed using Mann Kendall test and Sen's slope estimator ($p<0.05$. The study found out there was a significant variation in the amount of annual rainfall received of ($p< 0.004$) ($S= -53$) which showed a decreasing trend, while temperature showed a warming trend of ($p>0.099$) ($S=29$). Also, farmers perceived that climate variability events were real with (71.1%) and (68.0%) noticing a change in rainfall and temperature respectively over the same period.

The study established that community perceptions on rainfall and temperature trends agreed with meteorological data on observed climatic trends. Planting of drought resistant crops was most popular with (89.8%) ($n=255$) agreeing, while (79.2%) said it was the most effective strategy. The study found that although some farmers have adopted some adaptation strategies, they were constrained with (82.4%) agreeing that age was a great challenge to adaptation and had a moderate negative correlation with adaptation of (0.097) with labour and (25.5%) saying it was not a challenge.

The study recommends farmers use the study findings on rainfall and temperature trends anddata recordings on local agricultural performances to enhance their ability to adapt. To researchersand academic community the study recommends the intensification of research on ecosystem-based adaptation and the use of the results in mainstreaming policy making, planning and implementation of climate related decisions. The results reveal important knowledge that if effectively applied will inform the county government in climate management decisions and reduce farmer's vulnerability.

Keywords: Perception of adaptation strategies, adaptation, vulnerability, impacts, and adaptive capacity, precipitation and Temperature Variability, Matungulu Sub-County.

1. Introduction: Climate variability refers to the point at which temperature and rainfall amounts of an area vary over a specified period of time across an area. When rainfall or temperature is recorded in one given location over a specific period of time it is referred to as temporal variability (Masinde, 2017). In this study, temporal variability was considered since the area of study was one location in Machakos County. Temporal dispersion is the monthly, seasonal, and yearly rainfall variation from the long-term mean. Climate variability causes human ill health, causes floods or drought, crop failure reducing yields, extreme

weather conditions and, animal deaths (U.S. Department of Agriculture, 2020) while Subsistence crop production becomes uncertain in agricultural area (Oxfarm, 2018).

In Africa, the rapid expansion of Sahara Desert is attributed to rainfall variability. Desert conditions are said to be expanding into African steppes lands and savannah to date (IPCC, 2020). Most African countries are vulnerable to climate variability because they rely on rainfall for Agriculture (Alberto, 2022). Study done in West Africa by United Nations disaster Risk Reduction (UNDRR, 2021), indicate that the area has experienced prolonged drought leading to decline in agricultural produce. In East Africa, inter annual rainfall differences being experienced in equatorial regions are clearly linked to Elnino Southern Oscillations (ENSO), which has led to heavy rainfall, flooding and prolonged droughts during Lanina period (Caminade, 2019),which has greatly impacted on food security and human livelihoods. Sometimes most areas in east Africa receives excessive rainfall, while others receive very little or no rainfall for prolonged period (Nicholson *et al.,* 2017).

In Kenya, the problem of climate variability has and is being experienced over time now. According to a United Nations environmental programme report released in 2000, (UNEP, 2000), Kenya experienced an extra ordinarily heavy rainfall between 1997 and 1998 due to EL-Nino weather Phenomenon. The 10 months of heavy rainfall caused widespread landslides and ranging floods touching almost all the provinces in the country. A study done by Ovuka (2016) analyzing rainfall trends in the Kenyan central highlands between 1972 and 2012 showed extreme fluctuations in rainfall amounts received over 40 years of study which greatly impacted on people's livelihoods. Similarly, a research done by Sisanya *et al.,* (2016) in semi-Arid lands in Kenya showed that these areas faced great climate variability which affected crop production and vegetation cover.

A study done by Voss (2014) indicated that farmer populations around the world is aging rapidly and the average farmer's age is now at 60 years especially in developing countries making them immobile. This increases their risks to especially when an extreme weather occurs. The use of some medication and aging body can change the ability of the body to respond to either cold or hot weather, putting them at more risks to illness, heat or even death as climate warms up. Aging farmers, especially women are poorly educated and less likely to adopt to new and transformative production techniques. This affect food production especially now, with changing climate and with new adaptation techniques which are constantly emerging. In developing countries, most of the elderly live in rural areas, and mostly depend on agricultural activities, which is adversely affected by climate variability.

For this reason, the study sought to examine rainfall data on annual, seasonal and monthly scales on a time series basis and community perception of adaptation strategies (Musyoka, 2018). On climate variability, the study looked at how people adapted to the effects changing climate and the effectiveness of the adaptation strategies (Gebre *et al.,* 2023), it also examined the challenges of adaptation. Further, the study analysed variability patterns using meteorological data of Drought intensity (DI) which was to determine the ratio of rainfall deficiency to the long term mean, precipitation concentration index (PCI) to determine the annual and seasonal rainfall patterns and concentration, coefficient of variability (CV) was used to measure the rainfall variability, while standard deviation (SD) was used to measure departure of the total amount of rainfall from the mean. Relative variability (RI) was used to measure the variability while anomaly was used to show the departure of the annual total rainfall from the long term mean.

2. METHODOLOGY:

2.1 Study area.

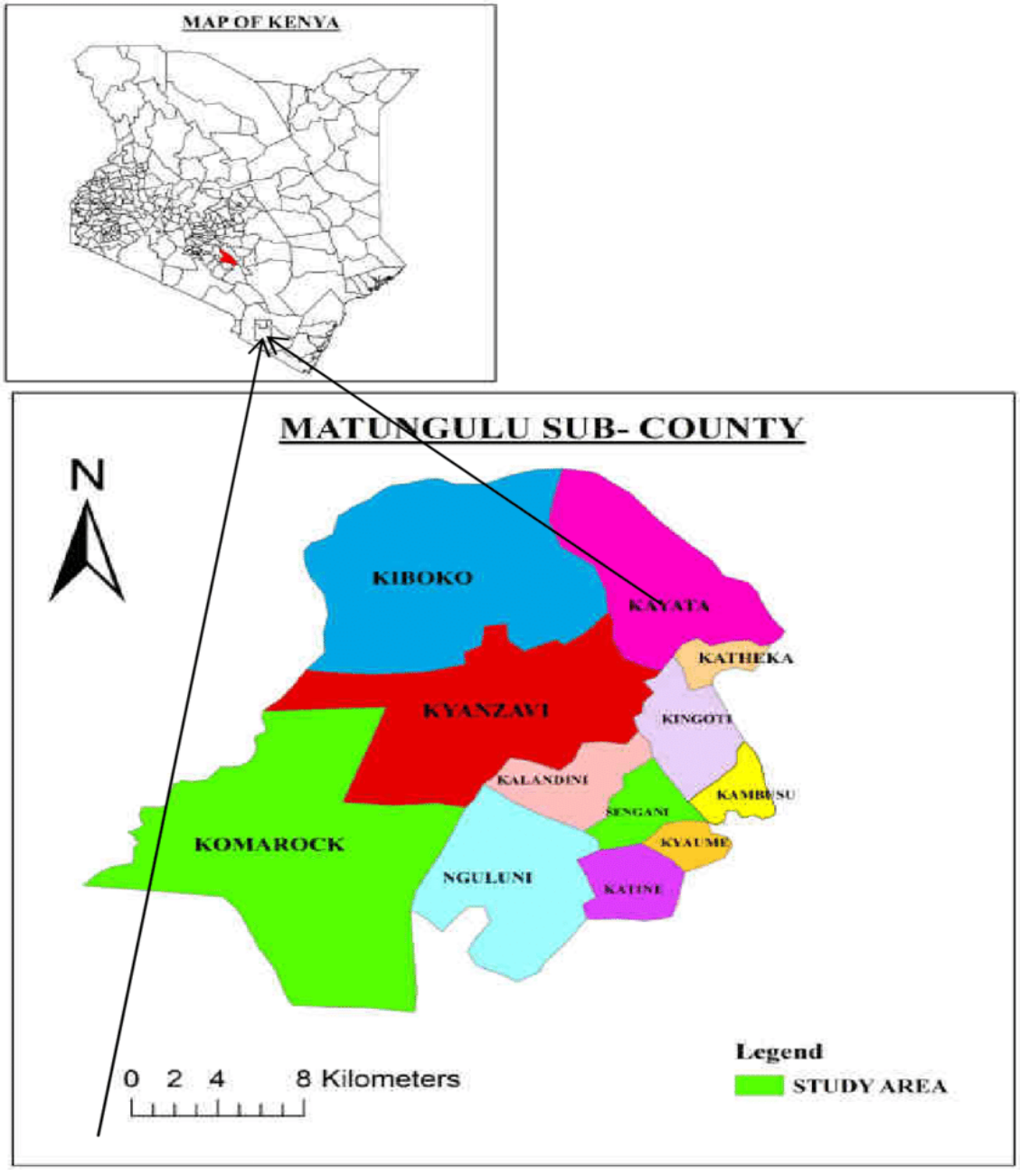

Figure 1: Map showing study location:Source: (Kungu &Mutuku,2018)

2.1.1. Location:

Matungulu Sub- County is one of 8 sub counties of Machakos County. It borders Nairobi and Mavoko to the east and Kiambu to the north Yatta to the west and Kangundo and Kathiani to the south. It stretches from longitudes 36° 45' East to 37° 45' East and latitudes 0º 45' South to 1º 31' South, an altitude of 1000 – 1600 meters above sea level and covers an area of 577.5 sq. km.

2.2 Study Design:

An exploratory research design was chosen for the study. This was because of the limited time required to cover the whole county and sub county and the nature and spread of the targeted population. The design guided the selection of the type of information and the sources. The use of this method ensured that the overall strength of the study is greater than either quantitative or qualitative research.

2.3. Target population

The study covered Tala, Sengani, Nguluni, Komarock, Kyaume, Katine, Kayata, Katheka, Kingoti, Kalandini, Kyanzavi, Kiboko, and Kalandini wards. The study targeted household farmers in the Sub-County. Population is 124,736 and has 46,645 Households (KBNS, 2019).

2.4Sample size and sampling Procedure:

The study targeted, 386 household heads as the baseline unit for the administration of the questionnaires and 10 Key informants. Simple and Stratified random sampling techniques, were employed given fact that area is heterogeneous with different experiences of the farmers to select a subset of the population. Random sampling ensured that all elements in the sample population had an equal chance of being selected within each of the locations. Stratified random Sampling enabled the researcher to divide the sample size into five clusters of households from each of the five-location based on the sex, age bracket.

2.5Instruments:

Questionnaires consisting of open ended and closed Items was administered to the household heads. Four sections were used to deploy the household questionnaires, where participants were chosen using a simple random sampling. A total of (2) FGDs were conducted one male one female each group comprising of 10 Participants, while interviews were used for the Key informants

2.6 Data Collection Methods:

2.6.1 Ethical consideration

The researcher followed the guidelines as recommended by Kenyatta University research ethics. This included a careful research ethics review process before engaging the respondents for fairness and to avoid biasness. Secrecy of the respondents was maintained, while the research assistants were briefed on issues of professionalism and voluntary response of the respondents was sought.

2.6.2Secondary data:

Secondary data sources included; a review of reliable rainfall and temperature data from the Machakos county government offices and the Kenya metrological department in Katumani and Thika weather stations.

2.6.3Primary data:

The primary data obtained by administering semi-structured questionnaires to selected households and oral interviews with the participating groups. Questionnaire instruments were designed to collect data on most if not all the respondents. Interviews, were also used to provide in-depth information and to explain the results of quantitative analysis. The information was then collected and correlated, recorded and interpreted.

2.6.4 Climatological trend:

Data was collected from Kenya meteorological department (KMD) on monthly basis by averaging the totals of 10 years groups. To obtain a visual data on the climate trends, on yearly and monthly trends, the R (Gangwar, 2022) software plotting command was used.

2.6.5 QuestionnaireData:

A pretested structured questionnaire including closed and open- ended questionswere administered to the respondents. This incorporated direct questions on the socio-economic factors of the households such as age, gender, education family size and land tenure. The questionnaires were divided into different sections each section seeking particular kind of data as per the objectives. Pretesting the questionnaires was done before the data collection carried out. This helped in determining the respondents understanding of the questions to find out whether they have the information being sought by the study and whether they can perform the task required by the study. Pre-testing is also necessary because it provides the most direct proof for the consistency and validity of the questionnaire needed for most items. The questionnaires were numbered in each pile and the answers recorded in a chart. A coded book was made, which had provisions like name of location which is the variable and the description of that variable ordinal or nominal.

2.6.7 Key informants interviews

Purposive sampling was applied to select 10 key informants. These included meteorological officers, chiefs, agricultural extension officers in Sengani, Matuu and Koma locations, women and church leaders, village headmen, elected representatives, NGO Representatives, School Principals and heads and other community leaders. They were then interviewed or served with structured questionnaire to fill to obtain an in-depth information. This is a qualitative method used to collect information on people's perception on climate variability, adaptation strategies, their effectiveness and challenges. This method targeted range of people including. The data was obtained by booking appointments and structured, Semi and un-structured interview depending on the respondent then used a tape recorder or wrote their responses on a note book.

2.6.8 Focused group Discussions

Convenience or purposive sampling employed to select respondents who will give best information. The study used 2 focus group consisting of ten people in each of the 5 locations identified. Each of the focus group consisted of male, female and the youth of all age cadre. Meeting venues and time was set and then a moderator of the sessions was

identified to control the plenary sessions. The topics of discussion and questions were formulated and served early enough to avoid time wasting.

The purpose of this group discussion was to obtain qualitative and quantitative data on adaptation strategies, their effectiveness and challenges.it allows the participants a chance to ask more thought challenging questions in relation to the research topic and others provide possible solutions to the asked questions. It gave a more insightful opinion/ views, bridges the research gap and practices on the topic and was used to explore the survey results which could not be captured statistically like indigenous knowledge on perception of adaptation strategies and climate variability and old and current adaptation strategies being used by the people. It was also used to collect data on a wide variety of knowledge and terminologies used in a topic of interest and enables a process to be managed more smoothly (Nyumba, 2018).

2.7Data Analysis:

The data obtained from the field was scrutinized for completeness, consistency and clarity of the response. The questionnaires were numbered, responses indexed and coded. A code book was therefore made which had specifications of variables names, description of variables types like ordinal, nominal, Discrete or Continuous. Data was captured as categorical, Numeric or as themes and subjected to data cleaning using data cleaning tools and analysed. On climate variability between 1990 and 2020, the key variables were rainfall and temperature patterns over the last 30 years, while the source of data was Kenya meteorological department and analysed using Mann Kendall and Sen's Slope and the analysis was on climate parameters, decadal changes, descriptive statistics and comparative analysis. Trend analysiswas done using a non-parametric method called the Sen's estimator (Sen's, 1968). To guess the true slope of a current trend like the amount of change obtained annually, the Sen's non-parametric method was applied and test was done using XLSTAT, 2017 Software. Therefore, a positive value of the Sen's slope shows an increasing or upward trend while a negative value shows a decreasing or downward trend in the time series.

Community perception, a Likert scale of five-point perception continuums of 'Response continuum. Positive of strongly agree to strongly disagree and which were coded 1 to 5 was used as response categories to measure their perception on climate variability statement. On the adaptation strategies and their effectiveness, the key variables were adaptation strategies found in the area of study and their effectiveness. Expert Judgment,

Historical or Geographic Analogs, is a qualitative tool which was used to evaluate the effectiveness of existing and potential adaptation strategies. This was done by comparing observed existing adaptations with past climate extreme events in different time periods and geographic locations. This method looked at events that had the same effect in the recent past and could most likely impact on future events related with climate variability. It assumed that lessons learnt from past experience such as on drought, floods and pest invasion be applied to future situations. Climate variability conditions can commonly share many important characteristics like time scale, intensity, reversibility, impacted sector and severity. one adaptation strategy being applied in one place at a particular time may not always be applicable to a future adaptation at another place (UNFCCC, 1999).

To examine the challenges of adaptation to climate variability. Key variables were adaptation strategies and perceived challenges. The adaptation tool used was the Tool for

Environmental Assessment and Management (TEAM) which was developed adopted by (UNFCCC, 1999). Likert scale questionnaire consisting of Yes and No choices was used to collect data. The data was obtained, then coded as Excellent=1, good=2, fair=3 and poor=4) similar answers grouped into themes, then entered into Excel, TEAM and Spss for analysis.

3.0 RESULTS AND DISCUSSIONS:

3.1 Ability to Adapt:

Results show that majority of the respondents (74.6%) agreed that land use affected their ability to adapt. This could be attributed to the high population in the area, leading to farmers holding small pieces of land, which cannot sustain their livelihoods. Long periods of drought leading to drying up of crops and unpredictable weather patterns leading to low yields and poverty could have compounded the situation. Furtherwhen data analysis was conducted in Spss (Pearson's correlation, the study found a very weak positive correlation of (.011) (p=0.01) between grazing and adaptation. This was due to the type of grazing animals kept in the farm. The study found out that goats and sheep can survive harsh climatic conditions because of their ability to eat many kinds of plants, while cattle require a lot of feeds and tends to finish their feed earlier than goats and sheep because they feed on large volumes of feed.

3.2 Climate variability between 1980 and 2020 in Matungulu Sub-Machakos County

To measure climate variability, Drought intensity (DI) was used to determine the ratio of rainfall deficiency to the long term mean, precipitation concentration index (PCI) to determine the annual and seasonal rainfall concentration, coefficient of variability (CV) was used to measure the rainfall variability, while standard deviation (SD) was used to measure departure of the total amount of rainfall from the mean. Relative variability (RI) was used to measure the variability while anomaly was used to show the departure of the annual total rainfall from the long term mean. Mann Kendall Trend and Sen's slope analysis was done and patterns of weather in the county were presented using average yearly and monthly means whereas temperature was presented using Maximum, Minimum and mean statistics to understand the trends in variability between 2009 and 2022 (13 years period) Results demonstrated a strong negative relationship of (-707) between annual average rainfall and years. Further, results showed that as years increase, there was a decrease in the rainfall received as shown in figure.1 below. The probable reason for this result is that warmer temperatures increases evaporation, which in turn reduces surface water leading drying out of vegetation and soils. This makes episodes with low precipitation which are drier than expected in cooler conditions. Further, climate change is also changing the timing of water availability.

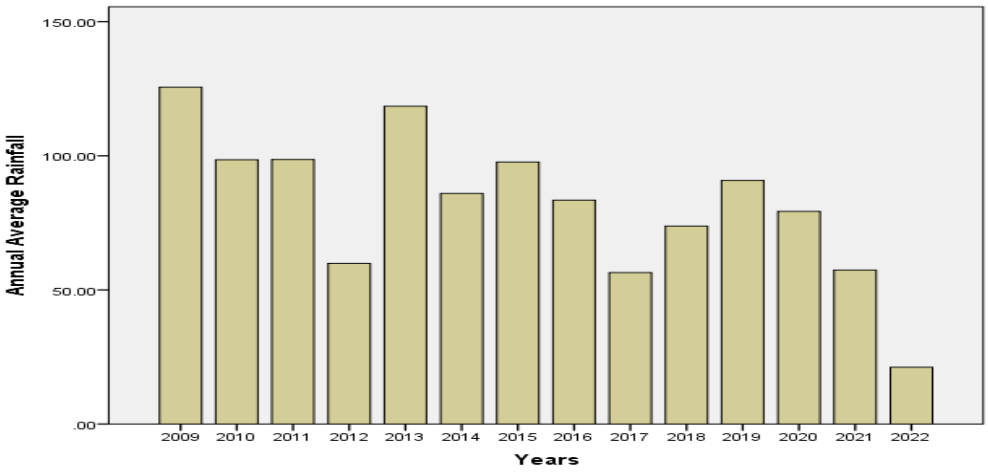

Figure 3.1: Rainfall Variation 2009-2022 Source: (Field data, 2023)

According to a report by Ongoma (2019) cyclone Idai hindered the northward movement of the rain-bearing low-pressure zone, popularly known as the Inter-Tropical Convergence Zone. An event which reduced the moisture flow from reaching Kenya, resulting to an observed delay in seasonal rainfall strengthening irregular dryness from early March till the onset of rainfall in April. A combination of apparent high temperature will most likely adversely affect agricultural activities in most parts of the country.

3.3 Seasonal Variation in rainfall patterns

Seasonal rainfall variation is the variation in a given time series recorded annually and that which is repeated more or less regularly. Seasonal variation is triggered by the rainfall, temperature and cycles of seasons. For this study, variation was observed for three seasons March, April, May (MAM) June July and August (JJA), which is generally the cold season and October, November December (OND). Results were obtained and presented as in figure 2 below.

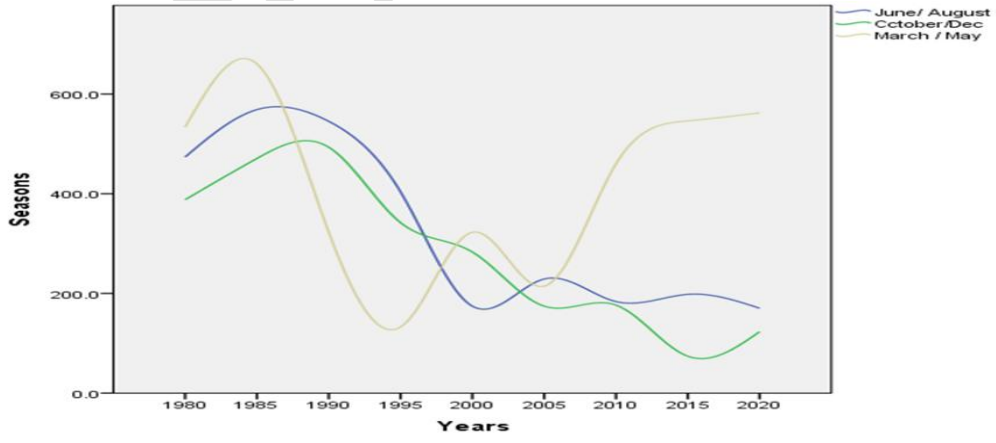

Figure.3.2: Annual Rainfall and Annual Temperature Source: (Field data, 2023)

Results showed a general decline in short rains OND and in JJA. However, long rains showed a great variation in the amount received over the three months with the lowest rainfall experienced between 1995 and 2007. It is important to note that from 2017 to 2022,

there has been a steady increase in the amount of rainfall received during long rains season. This is as a result of global warming which is increasing sea and ocean warming, increase sing the volume of moisture in the atmosphere. When warm and moisture laden air moves over land, it can converge into a storm, causing heavy downpour or snow storms (intense precipitation).

Rainfall/ precipitation Data from 2009 -2022

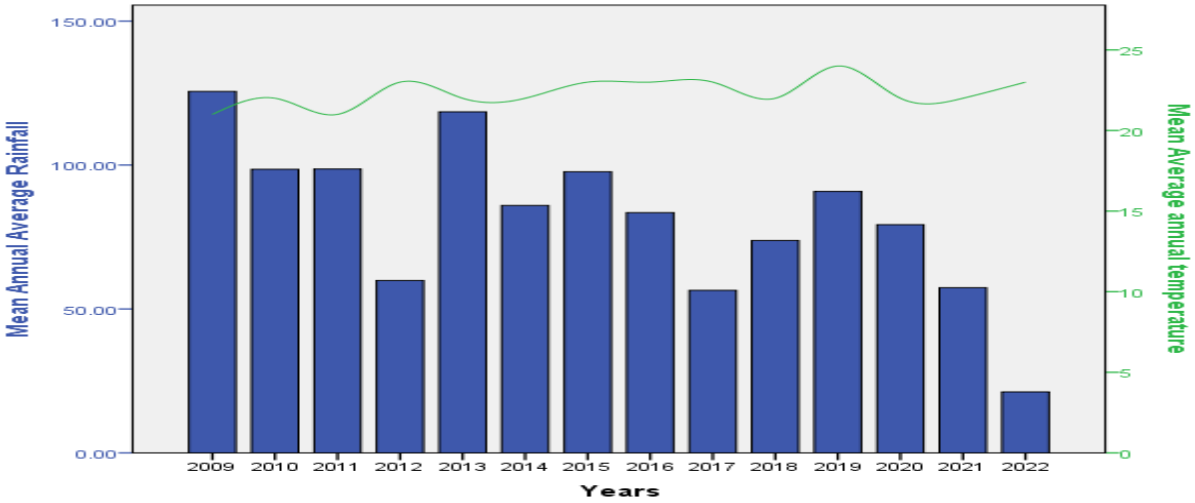

Figure 3.3: Annual Rainfall and Annual Temperature Source: (Field data, 2023)

Results from the above figure 3 show a general decline in the mean annual rainfall amount received over the 14 years period (2009- 2022) the highest received in 2009 (125.59 mm) and 2013(118.47mm) respectively, while the lowest was 2012 (59.9 mm) and 2022 (21.17 mm) respectively. The general trend over the years is that rainfall has shown a great variation. To find out whether there was a correlation between mean annual amount of rainfall and temperature. A comparison was done between rainfall and temperature. The line plot in figure 4above shows annual temperature anomalies from 2009 to 2020. Results shows minor annual temperature variations and a gradual increase warming in all 14-year period, with 2012 and 2019 (24^0C) being the warmest. This is because the temperatures experienced locally and in short periods do fluctuate significantly as a result of cyclical and predictable events. This includes winter and summer, night and day, precipitation patterns and hard-to-predict wind Nonetheless, global temperature depends largely on solar radiation,

Table 1: Mann–Kendall trend analysis of seasonal maximum and minimum temperature from 2009 to 2020.

Mann-Kendall trend test / Two-tailed test (Annual Average Rainfall

Kendall's tau	-0.582
S	-53
Var(S)	333.667
p-value (Two-tailed)	0.004
alpha	0.05

Source: (Field data, 2023)

An approximation has been used to compute the p-value.Test interpretation:H0: There is no trend in the seriesHa: There is a trend in the series

As the computed p-value is lower than the significance level alpha=0.05, one should reject the null hypothesis H0, and accept the alternative hypothesis Ha.

Further analysis done using the Sen's slope showed a decrease in the rainfall in Machakos county a negative value of (-4.208) meaning the rainfall has been decreasing as years increased. When exploring various methods of weather forecasting that is predicting of the next value(s) in a time series. Which is a sequence of observations y1… yn. Usually the subscripts represent equally spaced time intervals in years, seasons, months, and minutes and in seconds.When a trend test line was drawn across the years, results shows a decrease in rainfall amounts as the trend line shows a decreasing trend as shown in figure 5 below. This analysis confirms a significant evidence of a decrease in rainfall recorded in the years and the claim that particular data has a trend based on a two-sided test. Actually, if the study had done a one-sided test, then we would clearly reject the null hypothesis that there is either an upward trend or no trend and could have conclude that there is a downward trend (the p-value for this test is half of the value shown the figure 4. below.

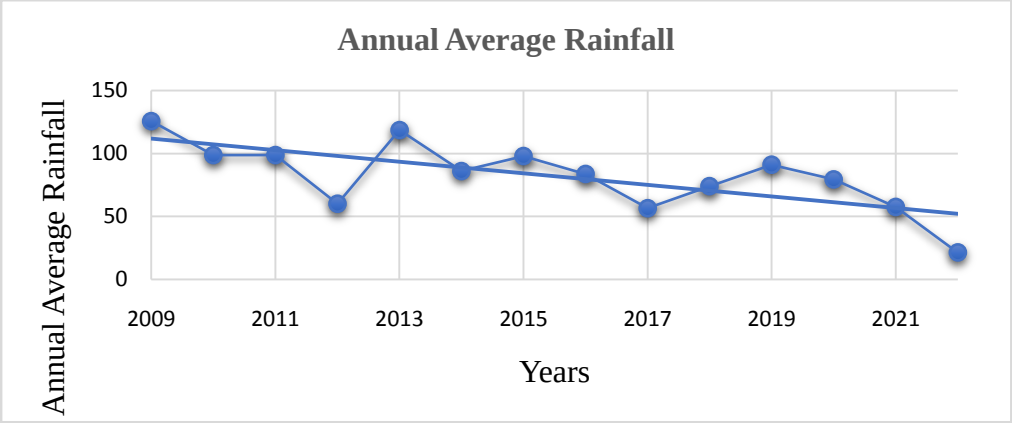

Figure 3.4: annual average Temperature for Machakos County (2009-2021)Temperature Source: (Field data, 2023).

List 1 : Mann-Kendall trend test / Two-tailed test (Average annual temperature

Kendall's tau	0.377
S	29
Var(S)	287.667
p-value (Two-tailed)	0.099
alpha	0.05

Source: (Field data, 2023)

An approximation has been used to compute the p-value.

Test interpretation:H0: There is no trend in the seriesHa: There is a trend in the series

As the computed p-value is greater than the significance level alpha=0.05, one cannot reject the null hypothesis H0.

List 2 : Test interpretation result

Sen's slope:			
	Value	Lower bound (95%)	Upper bound (95%)
Slope	0.083	0.000	0.250
Intercept	-145.625	-313.375	-61.750

Source: (Field data, 2023)

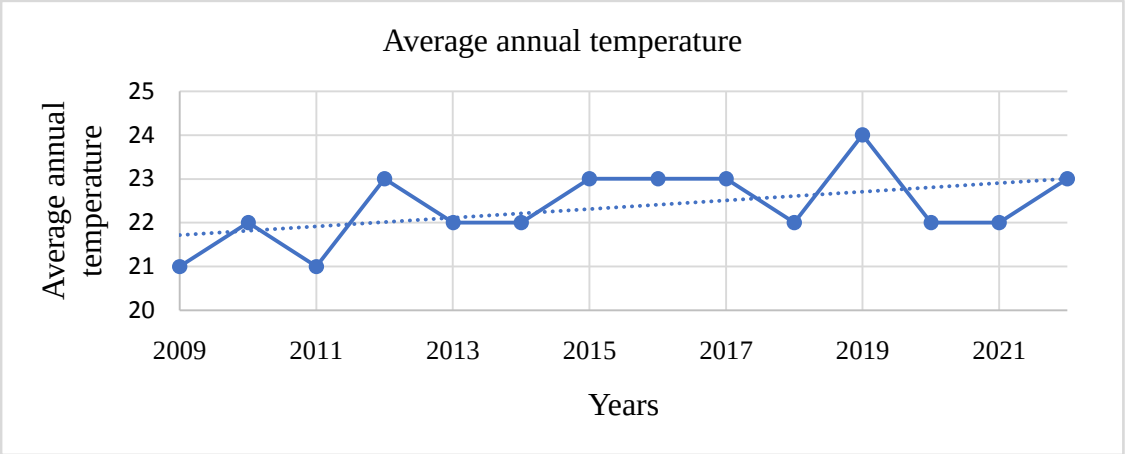

Figure3.5: annual Temperature for Machakos County (2009-2021). Source: (Field data, 2023).

Table 2: Seasonal Rainfall and maximum and minimum temperature

	Seasonal rainfall	Seasonal Min Temp	Seasonal Max Temp
Kendall Tau	0.466	0.235	-0.046
Sen's Slope	3.036	0.26	-0.008
S	340	130	-18
P-Value	0.001	0.030	0.238
Significance	Significant	Significant	Not-Significant

Source: (Field data, 2023).

The nonparametric test, was used to find out if there was a monotonic downward or upward trend of the variables over time. Result shows a trend in seasonal rainfall pattern in the two stations and that the results were statistically significant at 95% confidence limit in the period 2009–2020. The 95% confidence limit was decided based on "z" score value. Rainfall shows a decreasing trend (Sen's slope = 3.036) rain season. Generally, maximum temperature showed a slight increasing trend (Sen's slope = 0.26) in the observed period while minimum temperature showed a slight a cooling trend (Sen's slope = −0.008). Maximum temperature showed a statistically significant trend at 95% confidence limit, contrary result of minimum temperature was not statistically significant.

3.4 Temperature Variation between 2009 and 2020

Results showed that temperature was the highest (31.5°C) and lowest (15.04°C) recorded in 2022 and 2012, respectively. The lowest annual minimum temperature were at (21.0°C) in 2011 and highest (24.1°C) recorded in 2022 respectively. The average mean annual

temperature was (23.34°C) for the period 2009–2020. However, in 2022, the average annual temperature was the highest at 24.2°C.

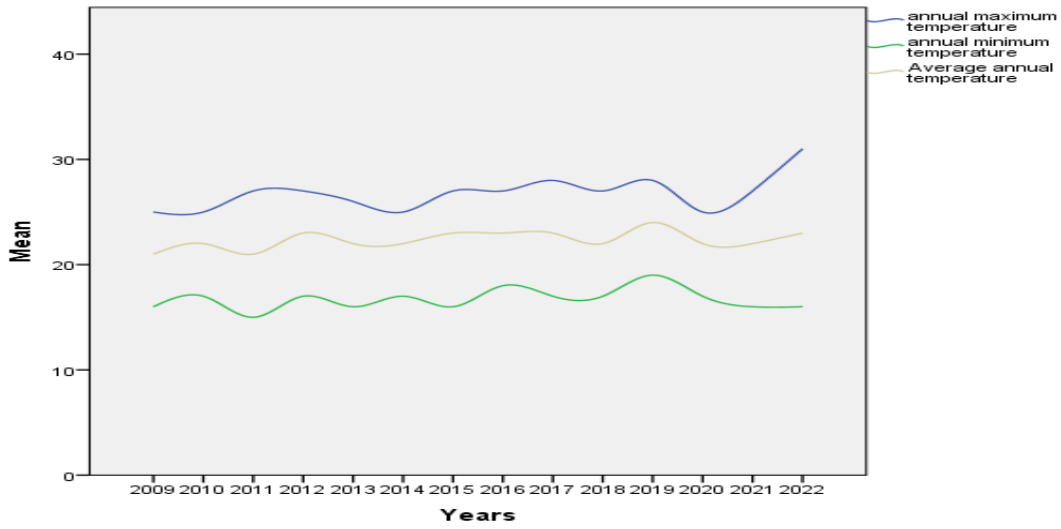

Figure 3..6: Annual Rainfall and Annual Temperature Source: (Field data, 2023)

When temperature was linearly regressed against time (Years), the results showed no statistically significant trend in variation ($p > 0.05$). Even though temperature variations were not significant, the coefficient of variation (CV) for mean annual temperature was positive. This shows that the mean annual temperatures were increasing although the change in temperature was not significant. Also, coefficient of variation for the annual minimum temperature was positive. This is an indication there was an increase in temperature therefore warmer days were being witnessed.

3.5 Community Perception of Climate Variability Matungulu sub County

Whether type of grazing of animals affects their adaptability

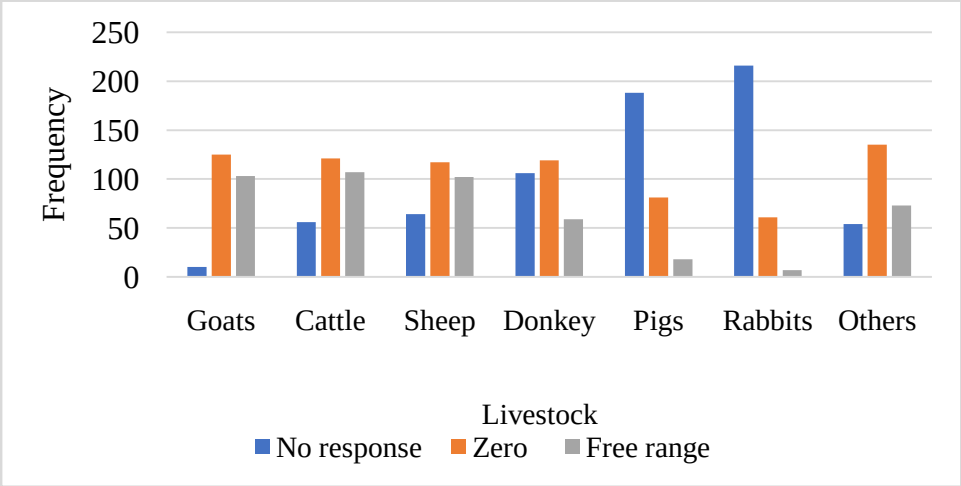

Figure.3.7: Grazing types Source: Researcher 2023

Results show for goats zero grazing was the dominant type of grazing (76.0%) and for rabbits, followed by free range grazing for cattle (37.6%) of goats (36.2%) for free range type of grazing, cattle led at (37.3%) followed by pigs at 28.5%. The high percentage of zero

grazing for rabbits can be attributed to the fact that rabbits cannot be kept in any other form of grazing because of the presence of dogs and other forms of predators like eagles. Also, for free range grazing, cattle and goats led because there exist large tracks of unoccupied land especially in Matungulu west which permits free range grazing. Livestock is taken to those areas by herders especially during dry weather. Pigs, goats and cattle can easily be kept under rotational type of grazing. Livestock grazing leads to many negative environmental effects like deforestation, desertification, ecological disturbance, and ecosystem stability.

Further to find out the correlation between the type of grazing and animals' ability to adapt. Results obtained show that there was very weak negative correlation in all variables with the correlation between goats and ability to adapt to climate variability being at (-201), cattle (-170), sheep (-172), Donkey (-148), pigs (-038), Rabbits (-080) and others (-014) all (p=.01). The ability to adapt of the animals can be influenced by other factors like household income. Which can buy hay for the animals in drought and veterinary services when the animals are affected by diseases. Studies done by Rojas in (2017) on climate change and livestock production. This impacted on quality of forage and feed crop, livestock diseases, availability of water, milk and production, biodiversity and animal reproduction.

3.6 Perception of the effects of drought on animals

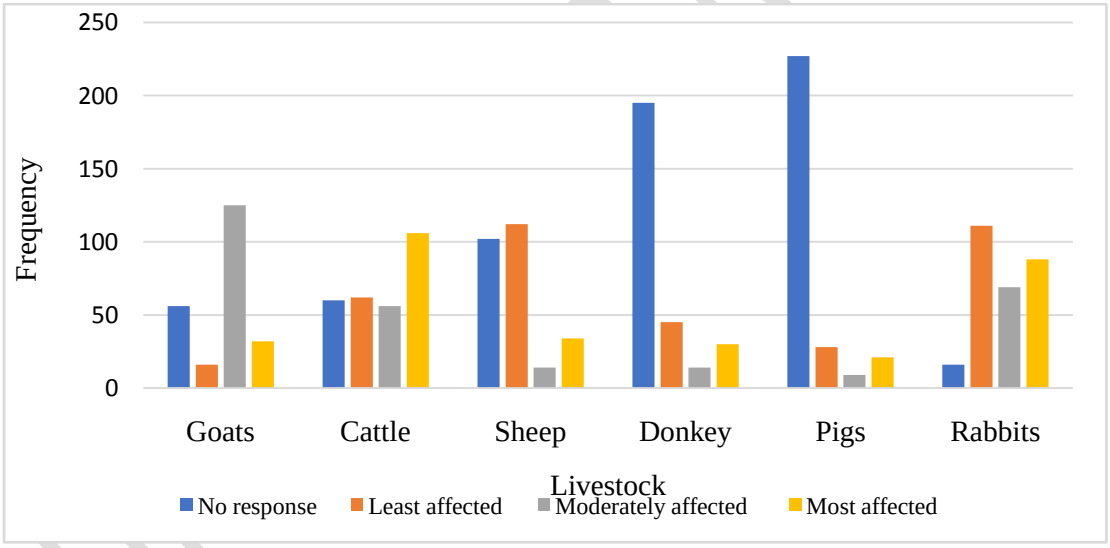

Figure.3.8: Effects of drought on LivestockSource: Researcher 2023

From figure 8 above results showed that majority of Goats (44.0%) were moderately affected by climate variability. This could be because of small pieces of land which restricts grazing to zero grazing. Results further showed that cattle (37.3%) were least affected. This could be attributed to the fact that due to small pieces of land and the rampant drought, farmers have chosen to keep small numbers of cattle which is sustainable. Respondents rated sheep at (39.0%) and as least affected. This is because sheep can feed on both grass and vegetation. Donkey most respondents give a rating of no response of (68.6%) because few farmers kept them and that donkey feeds on different types of feed. On pig's majority of the respondents (79.9%) rated it at (0) no response because almost all pigs are zero

grazed and depends on keeper for food. On rabbits (39.0%) rated it as least affected. Like pigs, rabbits are mostly zero grazed and mostly depends on the keeper for food.

Statistical results show a very strong positive correlation in all selected livestock with drought. When goats were correlated with drought results showed the strongest correlation of (.070). This is because goats and camel are perceived to be drought-resistant livestock which are positively related to wind and its direction. There is clear significant correlation between goat farmers and socio-economic characteristics respondents and adaptation strategies to climate. Goats can browse on shrubs more than the other types of livestock especially when there is no grass.

3.7 Awareness of Climate Variability

Understanding of climate variability is crucial because it helps in understanding and addressing the impacts brought about by climate crisis. Awarenessempowers the community with skills, values, knowledge and attitude needed to respond correctly to climate variability and act as agents of climate change. Smallholder farmers who were not carrying out adaptation practices were more vulnerable to climatic variations unlike those who were carrying out adaptation practices as a way of cushioning climate (Kimoni *et al.,* 2022).

. Therefore understanding climate variability helped the people in knowing how climate used to be, how it is now and predict how it will be in future. This knowledge helps them in knowing; what adaptation strategies exists, which ones to adopt, what are the challenges one faces when adapting and adopting and whether there are viable solutions to them. Responses were obtained analysed and presented as shown in the figure 9 below.

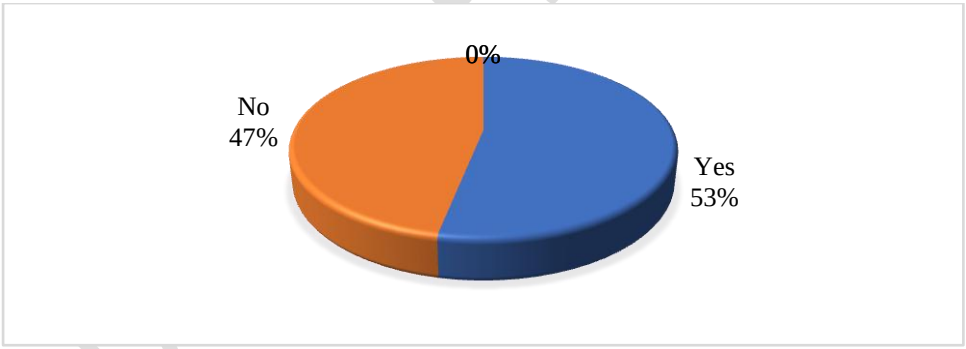

Figure3.9: Awareness of climate variability. Source: (Field data, 2023)

From figure (9) above the responses were almost similar with a very minor difference. Majority (53%) agreed that they were aware of climate variability while (47%) said they were not aware. The study further sought responses through descriptive statistics and obtained results which showed majority respondents said they were aware coded (1 Yes) (Mean 1.48) (Std. Deviation ±.507) on gender men were slightly more aware of climate variability than women coded 1 (Men) women coded (2) (Mean 1.43) Std. Deviation ±.495) though not much from women. While on education those who had secondary education coded 3 (Mean 3.17) (Std. Deviation ±.956) seemed to be more knowledgeable of climate variability than the rest of the education levels.

3.8 Sources of Information

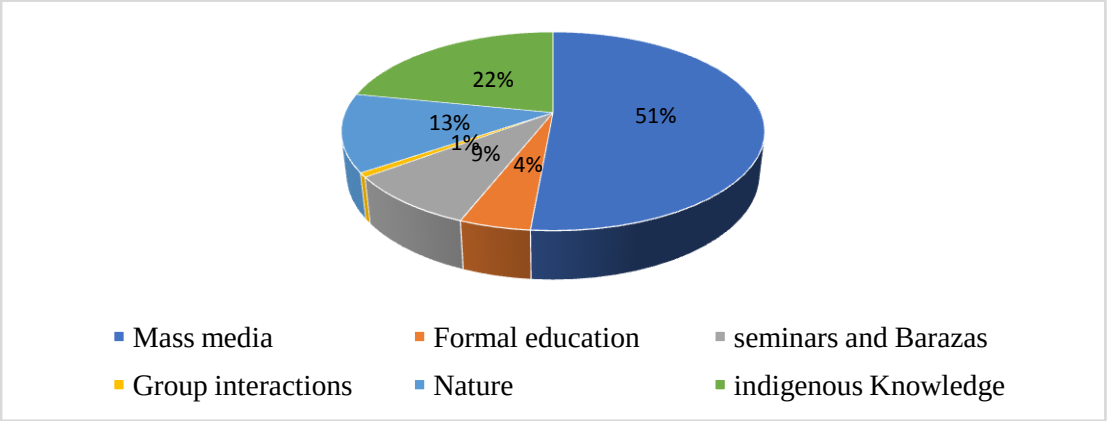

Figure 3.10: Sources of information. Source: (Field data, 2023)

Results indicate that majority (51.4%) of the respondents relied on mass media for information about climate variability. The results could be because many farmers in the area have access to newspapers, publications, radio, TV sets and mobile phones which acts as a source of information.

Indigenous knowledge (expert knowledge) followed at (22%). This is as a result of the knowledge passed on to the young generation from their parents on issues of climate and the young have continued to practice them. Indigenous knowledge can operates at a much finer spatial and temporal scale than science. This includes people's understandings on how to adapt and cope with environmental variability and trends. Indigenous knowledge therefore makes a significant contribution to Sustainable Development Goal (SDG13) which urges people to take matters climate seriously and its related impacts. This can be done by enacting climate variability policies, finding local adaptation methods, climate financing, adapting to impacts, locally observing changing climates, and contributing to local and global mitigation efforts.Schools played a role in informing the pupils about climate variability with (4.6%) indicating they gained information through schools. Generally, all sources of information played a big role in informing people about climate variability.

3.9 Changes in rainfall in the last 5years

A majority (71.1%) accepted noticing a change in rainfall in the last five years. Kenya has experienced warmer temperatures due to global warming. High temperatures heat the land and causes more water to evaporate into the atmosphere allowing that air to hold more water. This accumulation of more water sets the stage for heavier downpours. Further, global temperatures influence the way moisture and heat move around the planet earth. This means that drier conditions will occur in some regions of the world and those areas might experience drought conditions. While (28.8%) said they did not experience any change. This could have been due to climate variability, sometimes no rainfall, and little rainfall much rainfall and drought and the cycle continues to alternate.

Descriptive Statistics gave a mean of (1.42 stdev ± .495) for gender while for rainfall changes the mean was (1.58, stdev± 1.028). When correlation was done between gender people's perception of rainfall in the last five years, results gave moderate negative correlation of (-051). Statistical (R) tests showed that the level of significance (-051) was statistically significant. Meaning that the respondents had truly noticed a change in rainfall in the last five years.

3.10 Temperature changes in the last 5 years

Similar analysis was done on temperature and results obtained gave a similar trend. Majority (68.0%) (n=193) of the respondents had noticed a change while (32.1%) (n=91) said they had not noticed a change. When a cross tabulation was done, between perception and gender, results showed that there were more males (39.4%) (n=112) who noticed a change that women (28.5%) n=81. while (18.3%) n=52 males did not see any change and (13.7%) (n=39) female said there was no change.

3.11 Perception of Rainfall in the last five Years (2015-2020)

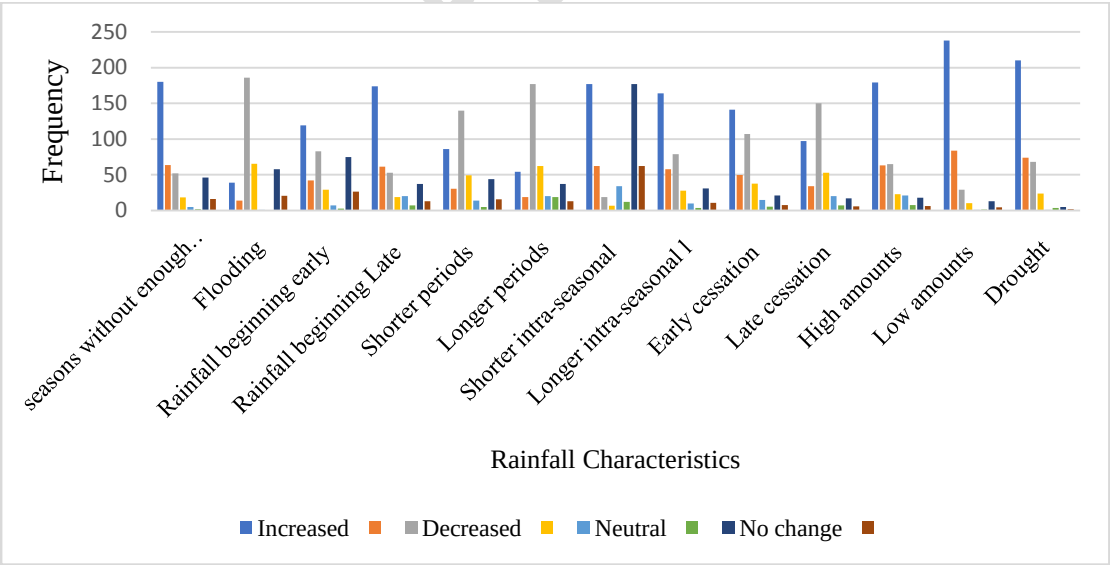

Figure 3.11: Rating of rainfall characteristics in last 5 years. Source: (Field data, 2023)

On rainfall, perception results (Figure 11) above indicate that about (63.4%) of the farmers reported observing decrease in rainfall patterns. On low amounts (75.7%) indicated that the most perceived and observed pattern was that low amounts of rainfall and drought which have an association. Results showed an increasing and decreased variability trend. Low

amounts of rainfall recorded the highest response with (83.8%) noting a change. They can now see clearly what climate change is and what consequences it can bring. On flooding, majority (65.5%) agreed that there was a general decrease. However, (20.4%) did not notice any change. This is because most of the landscape is hilly allowing water to drain easily. Those who said that it has increased were (13.7%) and could have been from Matungulu west where the landscape is generally flat with black cotton soils which are easily waterlogged and flooded. On rains beginning early, (41.9%) said it has increased contrary to expectation that it could have decreased. This is because of the erratic nature of the rainfall patterns. Sometimes it comes early sometimes late. Similarly, on rains beginning late majority (61.3%) noted an increase, while (18.7%) said it has decreased. In last ten years, the duration of rainfall has been shorter while the intensity has been much so it is no longer about the spread but the intensity. This has pushed farmers to change their planting modes and adopted the staggered method of planting.

Their perception on longer period of rainfall was that (62.3%) noted a significant decrease while those who noted and increase and those who chose to remain neutral were almost the same at 19.0% and 18.7% respectively. In the other characteristics, respondent noted an increase with shorter intra seasonal rainfall at (62.3%) longer intra seasonal at (62.3%), early cessation of rainfall at (49.6%) and high amount of rainfall at (63.0%). On late cessation of rainfall, majority 52.8% noted a decrease while 34.2% noted an increase. This result could again be related to the unpredictable seasons, which has left farmers confused and unable to determine and read the patterns correctly. Clearly, the varying responses from respondents in the same locality is a strong signal of rainfall variability in the area and the confusion of unpredictable weather has caused.

3.12 Perception of Temperature in the last 5 Years (2015 to 2020)

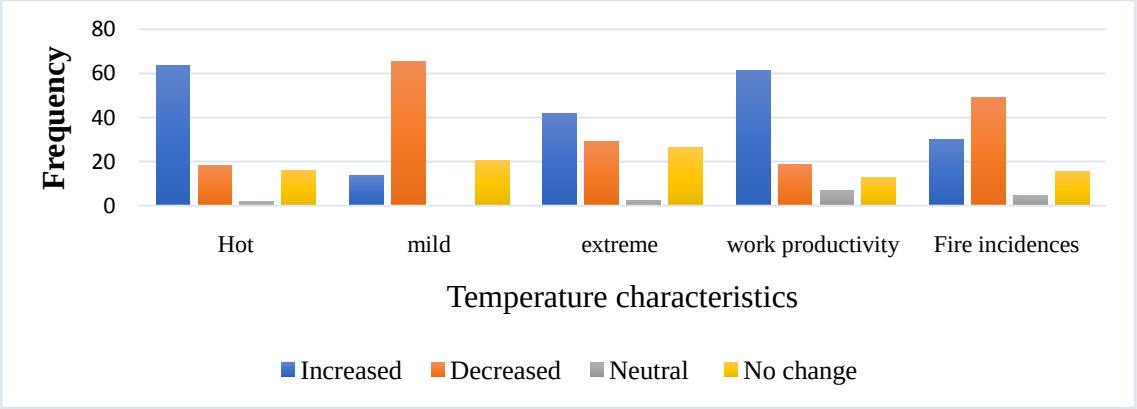

Figure 3.12: Perceptions of temperature in Matungulu Sub-County.Source: (Field data, 2023)

Results shows that Majority (36.3%) noted an increase in hot temperature while (19.0%) did not notice any change. This results could be because of the general increase in global warming which has caused a gradual increase in temperatures of the area. On mild temperatures, (32.0%) said it has decreased while (29.2%) said there was no change. This can be attributed to the erratic weather of the area. The highest percentage of the responses was recorded in extreme weather, with majority (61.6%) indication that it has increased, while (1.4%) chose to be remain neutral. This result could be due to the fact that as result

of instability in global weather cold seasons are getting colder while hot seasons getting hotter.

On cold weather, majority (51.1%) indicated that there was an increase in the cold season, while (8.5%) chose to remain neutral. The study further explored the respondent's opinion on temperature and work productivity during the day, results showed that rise in temperatures during working hours had a great impact on work. Most of the respondents said as a result of increased temperatures they preferred to wake up very early, work, rest during the hot sun and resume work in the evening. Results shows that majority (61.6%) of them indicated that work productivity had decreased, while (13.7%) choose to remain neutral. On fire incidences, majority (56.7%) said there was an increase while (9.5%) did not notice any change. This result compares with Nathaniel (2018) study results, which stated that since the beginning of the 21st century, there has been considerable media and scientific focus on numerous costly episodes of extreme temperatures, such as extreme summer heat waves, frequent incidences of severe snowy and cold winters of 2009 to 2010, 2010 to 2011, and 2013to 2014 in some areas of North America and Eurasia.

3.13 Adaptation strategies

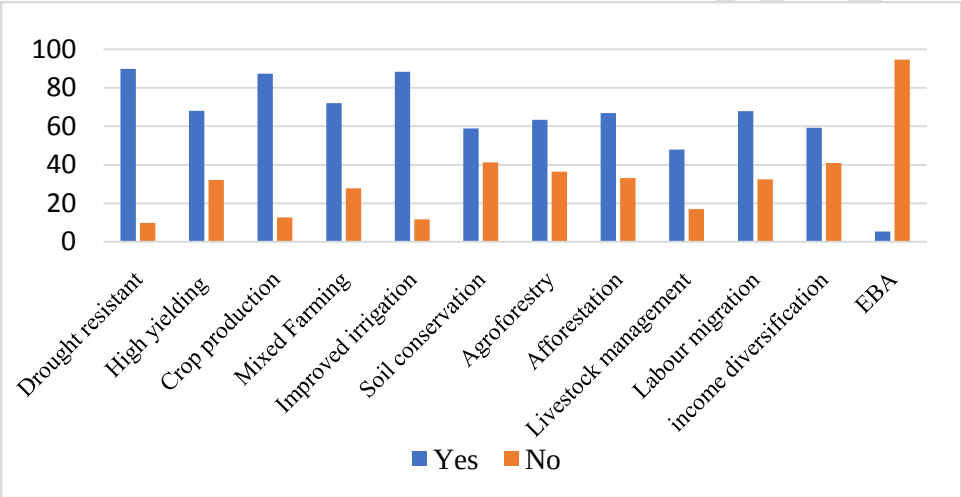

Figure 3.13: Adaptation strategies Source: (Field data, 2023)

Results showed that majority (89.8%) (n=255) of the respondents were planting drought resistant crops in their farms. This is some of the drought resistant crops planted by the farmers produce high crop yields. Results shows that farmers plants drought resistant crops including hybrids such as SAWA a new seed variety in the area of study, millet, pigeon peas all types, sorghum, green grams Bambara nut and groundnuts, while (42.9%) said that they just buy seeds from the market or keep some of the harvest as seeds to plant in the next rain season. (49.7%) said that since the introduction of high yielding seed varieties like KDV4, (STMA, 2017) Duma 43 (EzzyAgri, 2023)and medium and lowland maize varieties like H515, (Kenya Seed Company, 2020)one of the farmers said that he used to get 1to 2 bags of maize from his two acres farm but since he started using KDV4 maize variety, he now gets 4bags from the same piece of land. This was closely followed by soil conservation method at (88.4%) (n=251) Land conservation helps the farmer to grow enough food. This measureis Conservation Tillage consists of a variety of practices used in agriculture to

reduce water and wind erosion. Other methods include strip farming, contour farming, windbreaks, cover cropping, grassed waterways and buffer strips.

Mixed farming at (87.3%) (n= 248). The method involves crop rotation, using of composite manure in their farms, mixed cropping is the growing of two or more cultivars or species of the same species simultaneously in the same field and the use of fertilizers in their farms some said that there was a rumor that some of the fertilizers they buy is poisoned and will kill their soils and people with cancer. Additionally, mixed farming provides a lot of stability to farmers. The farmer can sell cereals and other crops, when prices in the market is favorable and there is enough feed on their farm for livestock the farmer can adjust the livestock numbers. According to (Akinnagbe, 2014) The major agricultural adaptation strategies adopted by farmers are the planting of drought resistant crop varieties, changes in cropping calendar and pattern of planting, crop diversification, conserving soil moisture by suitable tillage methods, agro-forestry, improving irrigation efficiency and afforestation.

All the other suggested adaptation methods recorded fairly good response which was a clear indication that the respondents had embraced adaptation strategies.Further the study explored adaptation strategies by analyzing the data using Spss Pearson's correlation method. Results obtained show a negative correlation in all the variables expect in mixed farming which had a positive correlation of (0.052). However, education and drought resistant crops had almost a perfect negative correlation of (-247) ($p = 0.01$). Age showed a strong positive correlation with traditional knowledge of (0.048). Probable reason could be that the area of study is a rural setting and most of the farm practices depend on both modern and traditional knowledge to cope with climate variability. Further, there was a negative correlation between mixed farming of negative (-0.091) ($p = 0.01$).

3.13 Effectiveness of adaptation strategies

The study sought the opinion of farmers concerning how the adaptation strategies helped them cope with climate variability. The study established that adaptation strategies were applied differently in different parts of the county. On planting drought resistant crops, (79.2%) of the farmers said it helped them, (64.4%) said that crop diversification helped them cope with harsh climatic conditions especially when the rains are depressed. They said that it helped them to use their resources better, it gave them a quicker and regular returns, which are obtained from different crops and helped them reduce farm risks. The variety being used during the planting season determines the kind of harvest to get. They sighted marketing problems which they said were insufficient, mismanagement and insufficient supervision of the farms and that lack of funds to buy enough equipment for their farms was not possible.

On crop production, (72.2 %) agreed that the method helped them adapt. Ploughing was being done using Cow driven ploughs and use of tractors to those who could afford. Sowing was done by people using cow driven ploughs followed by people who sow the seeds. Adding of Manure is done by the people while irrigation was done by means of canal's, water pumps for large scale farms while small farms, people used water Jerri can to water their small vegetable farms. Harvesting is done using human labour, who harvest and put the harvest in bags and carry it to their homesteads. Storage is done in homemade silos

which hold limited quantity of the harvest. When there is bumper harvest, some of the excess harvest is taken to government owned silos for storage like in Tala town.

The study found out that mixed farming was the most preferred adaptation mode by the respondents. This allowed farmers to raise livestock and grow crops on the same piece of land. 90.5% of the farmers agreed. On improved irrigation, (52.5%) said improved irrigation methods did not help them much to adapt because most of the farmers interviewed said they were aware of the method, but sighted cost implication of adopting it. 42.1% said they had adopted it though water was a great challenge.

3.14 Challenges of adaptation Strategies in Matungulu Sub- County.

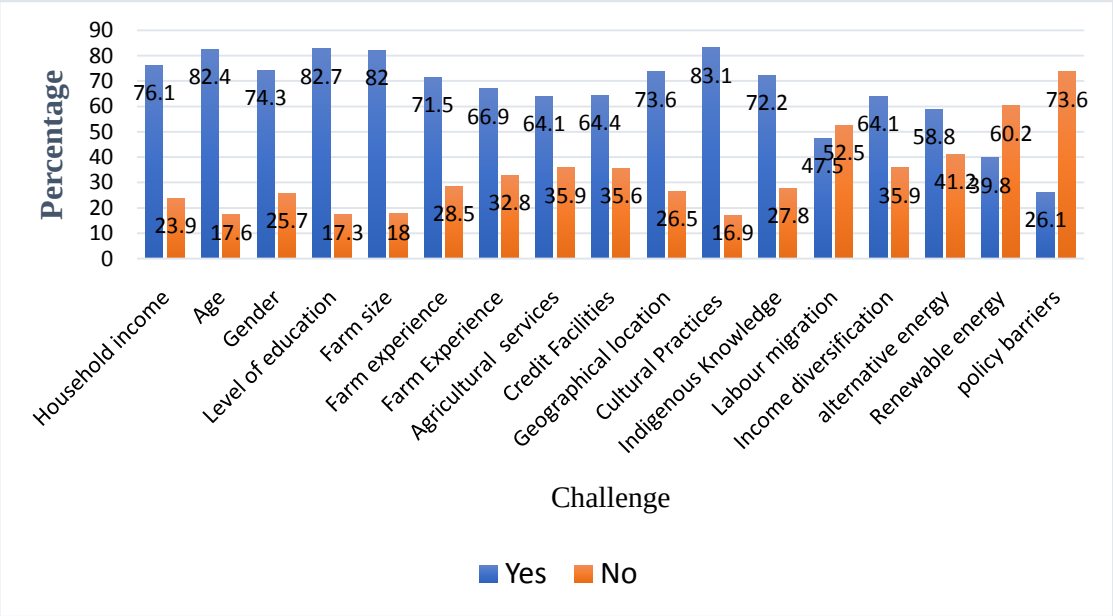

Figure 3.14: Adaptation challenges Source: (Field data, 2023)

The fact that people in the area of study are still living in the same locality despite the harsh climatic conditions, is evident that they have devised means of circumventing the problem. This does not negate the fact that there are challenges they face when trying to adjust to climate variability. Results obtained showed that lack of enough farm experience affected their ability to adapt, (71.5%) of the respondents agreed that it affected them. Farm experiences is a trial-and-error profession, as a farmer requires strong problem-solving skills. In most cases, a farmer is expected to look for the best ways to increase their farm harvest. When unexpected weather occurs like prolonged rain during harvesting season, it can bring harvesting delays.

On whether agricultural extension services is a challenge to their adaptation, (66.9%) agreed. depression, low morale, less productivity and economic worries are now common in extension organizations as a result of HIV/AIDS and other diseases among the farmers. Extension workers who are trained by the government are in return expected to motivate farmers and help them adopt new agricultural technology are themselves frustrated and depressed and this affects their output. It is expected that extension programmes will support the farmers to increase farm revenue, reduce poverty, farm productivity, and

reduce food insecurity but this was not the case and this justifies the 45.5% of the respondents of the study.

On access to credit facilities (64.1%) of the respondents agreed that capital was a major determinant of the methods of adapting to climate variability. This is because a large percentage of these adaptation measures are not natural. Finance determined what they buy for their farm to mitigate the effects of climate variability. However, facilities didn't affect their ability to adapt since most of the money lenders looked at what the farmer can offer in terms of surety of the loan. Lack of demonstration farms, land management of crops preparation, planting, pruning, fertilizer application, post-harvest handling, mulching, value addition and marketing and proper animal management if given timely could greatly improve their farm produce.

Further, even if all this facility were availed, and the rains still fail they and the effects will be felt by the farmers in equal measure. Geographical location affected their ability to adapt, (64.4 %) indicated that geographical location was a major hindrance to their adaptation. The area is classified as a semi- Arid area therefore prone to desert like condition. This influence how climate variability implications unfold. Respondents living in Kilimambogo, along Athi River, and Near Tala Town were not affected by climate variability like those living in Matungulu west and North especially in terms of water availability, food scarcity and high temperatures.

Further, the most exposed people are those politically disenfranchised, the marginalized and poor communities. These are usually among the first group to experience the impacts of climate variability and not well equipped to diversify their incomes. As a result, most of the low-income people are mainly dependent on subsistence farming and increasingly face severe hardships. This is because they are less flexible to buffer potentially great shifts in their production bases, building sustainable rural livelihood and eliminating poverty. Therefore, any climate stresses push these populations over an all-too-low threshold into poverty and insecurity that violates their basic human rights.

On whether geographical location affected their ability to adapt, (64.4 %) indicated that geographical location was a major hindrance to their adaptation. Matungulu is a semi - Arid area therefore prone to desert like condition. Men often leave their families to look for greener pastures leaving the farm work to women. This result are in line with UN Women report (2022)Women are the most affected by climate change. Globally, women rely more on natural resources and yet they have limited access the natural resources. In several areas of the world, women tolerate an unequal responsibility for securing cooking fuel, water and food for the family.

Currently, agriculture is the most significant employment sector for women in lower-middle- and low-income countries. Similarly, during drought and periods of erratic rainfall and as primary procurers and agricultural workers, women work harder to secure resources and income for their families. This increases pressure on girls, who abandon their school to assist their mothers manage the increased burden. On age, (82.4%) agreed that age was a great challenge the above results agrees with an EPA report (2022) on age and climate variability stated that as people grow old, their bodies is unable to withstand the effects of certain environmental hazards, like air pollution and excessive heat and are most likely to suffer from health conditions, which worsens their existing illnesses.

During extreme weather events, older people have limited mobility, while some medications and aging bodies can change their ability to respond to heat, putting them at a more risk of death and heat related illnesses as climate warms up. Many elderly people have compromised immune systems, making them more prone to severe illness from water and insect related diseases, which may become more common as the climate changes. Also, most elderly people depend on the young for their medical assistance and care daily increasing their vulnerability to extreme weather events. Also, as people age their strength reduces affecting their ability to work in the farms and this may affect food production and security.

On cultural practices, (73.6%) agreed that their culture can be a big challenge to their ability to adapt, while others said culture has nothing to do with their adaptation. This finding agrees with flex books finding that cultural adaption is basically the knowledge or behavior which enables groups or humans to adjust, thrive and survive in their environment, one method by which humans culturally adapt to their surroundings by the use of tools. Culture has increasingly become the main method that human beings adapt to the environment. Starting from Homo habilis, culture has been by far one of our primary way of adapting to the environment today.

Culture started by our ancestors to spread and thrive to new areas and areas that served as sources of their livelihoods were zealously protected. Humans began their live in the tropics areas and physically were adapted to the warm climate. Biologically, human's beings are in fact still tropical animals and later, human's beings moved into colder areas and culture permitted them to survive there without the need to adapt biologically. For example, human beings did not develop a layer of blubber or a thick fur like other cold climate mammals. Instead, they lit fire, made clothes and built shelters, to stay warm.

On lack of indigenous knowledge, the study found out that (83.1%) agreed that it was really a challenge. The results on the role of indigenous knowledge on people's ability to adapt is supported by the UNESCO report 2021which states that to face the challenge of climate change, indigenous peoples mobilize their in-depth knowledge of the areas that serves as the source of their livelihoods like water sources and forests and sacred places for generations.

Indigenous knowledge functions at a much finer temporal and spatial scale than science and includes people's understandings on how to adapt and cope with environmental variability and trends. Indigenous knowledge therefore makes a significant contribution to Sustainable Development Goal (SDG13) which urges people to take serious and urgent measures to combat variability and climate change and its related impacts. Climate variability policy, by finding local adaptation methods, adapting to impacts, locally observing changing climates, and contributing to local and global mitigation efforts.

On whether labour migration has been a challenge to adaption in the area, (72.2%) said yes. The study results are in line with Vinke (2020), on "Migration as Adaptation measure" Vinke, (2022) emphasize that migration does not necessarily increase the adaptive capacities for households in all contexts. While it is true that labour migration can be an effective method of adaptation for some groups under some circumstances, for others it actually leads to increased poverty spiral and vulnerabilities in turn reducing their adaptive capacities.

The non-economic losses which are connected to a migration to another place further challenges the idea of successful adaptation. Even when migration increases the situation of a household income, it may hide the lack of action on climate change adaptation from the international community and national governments. In the context of climate variability and change, labour migration in most cases is viewed as an adaptation failure. Conversely, labour migration can be a major adaptive response to people facing slow onset disasters and environmental changes.

According to International Labour Organization (2022) past experience has revealed that when labour migration is run in accordance to the international labour standards, it can play a significant role in developing both countries of origin and destination. Labour migration can also be used to boost community resilience by generation of remittances, through the transfer of skills and knowledge and the development of networks that lead to new markets and entrepreneurship.

Results on ecosystem-based adaptation shows that (64.1%) agreed that it was a challenge, while (58.8%) agreed that alternative sources of energy were a challenge, (39.8%) agreed that un availability of renewable sources of energy was a big challenge, since the facilities have not widely been spread to the rural areas and if available are very expensive. On whether government policy was a problem (73.6%) agreed that it was a great hindrance to their ability to adapt. This is because the government has not rolled out enough climate change intervention policies to the rural areas to help the people to effectively deal with climate change and variability

4. Summary, Conclusion and Recommendations

4.1 Summary: More than half of the respondents lived in households consisting of more than 3 persons or fewer and most of them had attained secondary level of education (59.8%). Farming was the main source of livelihood, which was dominated by men while women dominated most of the trading activities. Majority of the respondents had lived in the area for more than 31years with majority them owning land privately, community ownership was more than public ownership. Majority had an annual income was Ksh > 61,000. While their main occupation was farming which was practiced by both men and women. Most of them agreed that land use affected their ability to adapt to the effects of climate variability.

Annual precipitation in Machakos County varied from 1154.6 mm (1998) the highest while the lowest was 477.6 mm, in the year 2000. The general trend of rainfall amount received per year fluctuated considerably, years 2009,2008,2005,2004 and 1999 being had noticeably very little rainfall. Further, 1990, 1997, 1998, 2006 received the highest amounts of annual rainfall. Temperatures had a gradual increase with general trends averaging 240C (highest) and140C but showed no significant variations. Majority of the farmers were aware of climate and had a moderate positive correlation (.042) between gender and level of awareness and that most of the respondents relied on mass media for information about climate variability. Majority agreed that an individual can help solve climate variability and the best method to fight it was being prepared to face it. Most of the farmers agreed that rainfall affected their daily activities like movement and transport of goods while most males believed that rainfall and temperature affected them than women contrary to the expectation that women could have been more.

Rainfall and temperature affected the growth of all the selected crops, with the maize being the most affected. Further most farmers reported observing decrease in rainfall amounts and changing patterns, with low amounts of rainfall and drought which have an association the most perceived and observed pattern. Majority noted an increase in hot temperature and agreed that rainfall had an effect on vegetation cover and plant growth. However most of them said food availability was greatly affected by rainfall while wetland increased in sizes. Most farmers reported prevalence of diseases which greatly affected their health with increases in rainfall and temperatures and destruction of infrastructure. on crop production, majority agreed that Heat stress affects plant growth and development negatively by disrupting the stability of various membranes proteins and cytoskeleton structures. Pests and animal diseases, increased with increases in temperature. Also, an increase in temperature caused physiological torture to humans. Water scarcity caused a lot of stress to women and girls who are forced to walk long distances to look for water. Lack of food for the family and foliage for the animal's causes a lot of stress to the Men. On ill health an increase or decrease in temperatures causes ill health. Heat also has imperative indirect health effects. Further increased temperatures causes' air pollution, water scarcity and human behavior. Further majority of the respondents were planting drought resistant crops in their farms this was closely followed by soil conservation method and Mixed farming.

The study established that adaptation strategies helped farmers to cope and that they were applied differently in different parts of the county with the most popular being planting drought resistant crops and crop diversification helped them cope with harsh climatic conditions especially when the rains are depressed. Nonetheless, lack of enough farm experience, farm experiences agricultural extension services, finance, geographical location, age, cultural practices, lack of indigenous knowledge, labour migration, and ecosystem-based adaptation, lack of alternative sources of energy availability of renewable sources of energy was a big challenge to the farmer's ability to adapt.

4.2 Conclusion: The study assessed climate variability between 1990 and 2020. Analyzed community perception to climate variability, evaluated the adaptation strategies and their effectiveness and examined the challenges of adaptation to climate variability in Matungulu Sub County, Machakos County. The study successfully met its objectives and based on the results concluded that.For a community to clearly say that climate has actually changed there has to be a recognition that there is a change taking place and that farmers perceived that climate variability and change is a reality in Matungulu Sub County. Some socio-economic factors significantly affected their perception of climate variability in Matungulu sub- County.

Farmers had adopted adaptation strategies to help them cope with climate variability. That farmers in Matungulu Sub- County faced many challenges when trying to adapt to climate variability. These study results are useful and besides providing new baseline information and knowledge will form a foundation for further research, increase the existing knowledge on climate variability, people's perception on the variability, and inform the community on the existing and emerging adaptation strategies and offer some solutions to the challenges facing farmers when adapting. Further it will enhance the farmer's resilience against climate variability effects in the area, and increase their uptake of indigenous environmental knowledge and the use of modern adaptation technologies.

4.3 Recommendations: Use of the current information on climate variability, perception and adaptation mechanisms to assist economic planners in policy formulation of ways of adapting to the changing climate. Community perception of climate variability and adaptation strategies should be enhanced to help them cope with the current and future climate challenges and use the results to assist farmers to improve their understanding, cushion farmers against the impacts of climate variability and improve their farm inputs and minimize loses. The existing adaptation strategies and emerging technologies like overhead sprinklers, drip irrigation, and dry farming be enhanced and availed to farmers to increase their capacity to cope with climate variability. Education on recording local agricultural performance, weather data be enhanced to the farmers to improve their ability to detect trends in turn supplement the lacking climatic information. More efforts should be directed towards improving scientific and outreach education in remote areas, particularly the high sensitivity areas in the county.The community can use Indigenous knowledge which is not fully utilized resource like variation in the nature of the wind which has been used by traditional parents as an indicator of weather change for a very long time. Farmers seeks more services of agricultural extension officers, more credit facilities and increase the use of IEK to help them adapt.

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