Impact of Annual Temperature and Rainfall Anomalies on Maize Yields in Machakos County: An Analysis from 1993 To 2023

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Abstract:

Purpose: To investigate the impact of Annual temperature and Rainfall Anomalies on Maize Yields in Machakos County from 1993 to 2023.

Methodology: The study utilized qualitative and quantitative data, collected through structured questionnaires as primary data and a secondary time series data template for secondary data. The target population included households, agricultural officers, and administrative officers in Matungulu East, Kaani/Kaewa, Mwala/Makutano, Ikombe, and Kangundo East wards. The sampled administrative wards contained 36,976 maize farming households selected through purposive sampling. The population was determined using Yamane's formula, resulting in a sample size of 395 maize farmers (households). Maize farming households were identified using cluster random sampling.

Results: The study found a statistically significant negative effect of temperature variability on maize yields (β=-0.054, p=0.000). This implies that a one-unit increase in temperature variability is associated with a 0.054 tones per hectare decrease in maize yields, highlighting the sensitivity of maize to temperature extremes. Conversely, rainfall variability showed a negative but statistically insignificant effect on maize yields (β=-0.020, p=0.946). This suggests that other factors, possibly adaptation strategies, may mitigate the impact of inconsistent rainfall on maize yields.

Unique contribution to theory, policy and practice: The study underscores the differential impacts of temperature and rainfall variability on maize yields, emphasizing the need for targeted adaptation strategies to manage temperature fluctuations. Recommendations include promoting heat-resistant maize varieties, improving irrigation infrastructure, and enhancing water management practices. These insights contribute to agricultural planning and policy-making, aiming to enhance the resilience of farming households in Machakos County to climate variability.

Keywords: Maize Yield (In Tonnes Output (kgs) .Land size(acres).Temperature variability.Rainfall variability .Seasonality Trends .Climate justice

I. Introduction

Climate variability significantly impacts global crop yields with temperature and precipitation changes becoming apparent over extended periods (Maitah, 2021). A study by Zhang et.al (2018) highlights that irregular precipitation events due to climate change are expected to increase. From 1850 to 2012, the global temperature rose by 0.78℃, and the International Panel on Climate Change (IPCC) projects a further rise of 0.5℃ to 2℃ by 2100 (Esayas et al., 2019). While natural phenomena like volcano eruptions and the El Nino Southern Oscillation (ENSO) contribute to climate variability, human activities are primary drivers of climate change, notably through greenhouse gas emissions (Aggarwal, 2003). Despite the known causes of climate variability across the world climate justice cannot be achieved unless industrialized countries take full responsibility and reduce emission of greenhouse gases, provide climate financial support to help the vulnerable developing countries adapt to climate variability and promote technology transfer and ensure capacity building in vulnerable countries across the world. In Asia, Mendelsohn (2014) reports that climate change models predict a temperature rise of 1.3 to 1.4℃ by 2100. Notably, observed warming between 1960 and 1990 reached up to 3℃, with the impact of climate variability dependent on the extent of climate change. In Africa, Sagero et al. (2018) documented a 0.5℃ warming trend, with temperatures projected to rise by 3 to 4℃ by the 21st century's end, affecting rainfall patterns and economic growth. In Ethiopia, Esayas et al. (2019) noted a temperature increase of 0.2℃ to 0.28℃ per decade since 1960, adversely affecting regions south of Ethiopia. Mohamed (2022) found that Sudan's climate variability, characterized by droughts, floods, and CO_2 emissions, negatively impacts food security. In East Africa, climate variability shows similar trends, with erratic rainfall influenced by factors such as ENSO and the Indian Ocean Dipole (Sagero et al., 2018). In Kenya, Mairura et al. (2021) observed a shift in rainfall patterns in central Kenya over the last 50 years, with reduced river water volumes due to climate change (Jegede, 2018; Pielke, 2017). Sagero et al. (2018) linked extreme weather events like the 2011 and 2014 droughts to climate change, causing significant economic damage. The annual cost of droughts to Kenya's economy is estimated at 2%–2.8% of GDP (Kilavi et al., 2018; GOK, 2018).

Over the years, maize production in Kenya has declined due to climate variability. Bosire et al. (2019) found that climate conditions determine crop choices, with precipitation intensity during planting seasons affecting yields. Temperature variations also influence pollen and seed dispersal. In highland areas like Trans Nzoia and Uasin Gishu, maize takes longer to mature compared to lowland areas like Machakos and Makueni, where warmer climates allow for two planting seasons annually. Arid and semi-arid lands (ASALs) in Kenya, such as parts of Machakos County, face high crop failure risks due to their semi-arid and arid nature (Mwanzia, 2020). Maize yields in these regions have been inconsistent over time. Maize yield trends in Machakos County showed bumper harvests as recorded in 2015 and 2013 while 2017, 2016, 2014 and 2012 recorded meagre yields (Velesi, 2018). It can also be noted that the Size of the land did not affect the production in MT, very little was recorded in some years yet the land size was big enough. For example, in 2012 and 2017 maize yields were 90926 and 63984 metric tons yet land size was 149388 and 129010 ha (KNBS, 2023). This implies that other than the land size, a number of other factors affect maize yields climate variability being key. The above statistics is an indication of the irregular maize yields in the county.

Statement of the Problem

ASAL areas face erratic climatic aspects particularly unreliable precipitation patterns and extreme temperature regimes. The Erratic weather among other factors significantly affect quantity of agricultural yields from the farms. For maximum yields to be achieved, crops need adequate moisture during the flowering and fruiting period. Therefore, with erratic and extreme weather patterns, maize yields will be erratic and in most cases, dwindle thus complicating food sufficiency and livelihood stability status in a good number of households in the County Jeopardizing SDGs goal 1 and 2 on eradicating Poverty and Zero hunger and the Machakos CIDP 2023-2027 efforts on mitigating climate change and food security efforts (Machakos CIDP, 2023). Efforts have been made to mitigate climate change through formulation of coping strategies and development of new maize varieties for different agro-ecological zones. However, it's not clearly known the extent to which climate variability impacts different maize verities for dry lands. This research therefore sought to analyse the extent to which climate erraticism is impacting yields in different maize verities for dry lands and determine the effectiveness of the coping strategies employed by maize farming households in Machakos County with the aim of helping to develop policy response and help farmers to better on existing adaptation strategies to climate change.

Objectives

To analyze how extreme temperature and rainfall anomalies has affected maize yields among farming households in Machakos County for period 1993 to 2023

Research Hypotheses

$H_{O:}$ There is no significant relationship between temperature and rainfall variability on maize yields.

Theoretical Review

The current study was based on the theory of production. This theory was initially suggested by Cobb, Charles W., and Paul H. Douglas in the late 1920s (Cobb & Douglas, 1976). The theory explains the principles in which the producers make decisions on how to use the factors of production to optimize production. That is the link between the prices of commodities and the costs (rents/wages) of the production factors that are used to produce them. The theory helps farmers understand the best combination of factors of production to optimize the production of maize and its products. The decisions on how much of each commodity the farmers sell and against how much they produce depend on how much they produce given the social, economic and environmental factors they are predisposed to. Based on the socioeconomic aspects the following aspects come into play; the land size, crop production systems and yield per annum. Likewise, there are exogenous factors caused by economic disruptions that affect production and these include the climate/weather variations, and natural catastrophes. Therefore, the theory is found relevant in explaining the maize yields in Machakos County, Kenya based on the rainfall variability and the crop production systems they apply.

II. Research Methodology

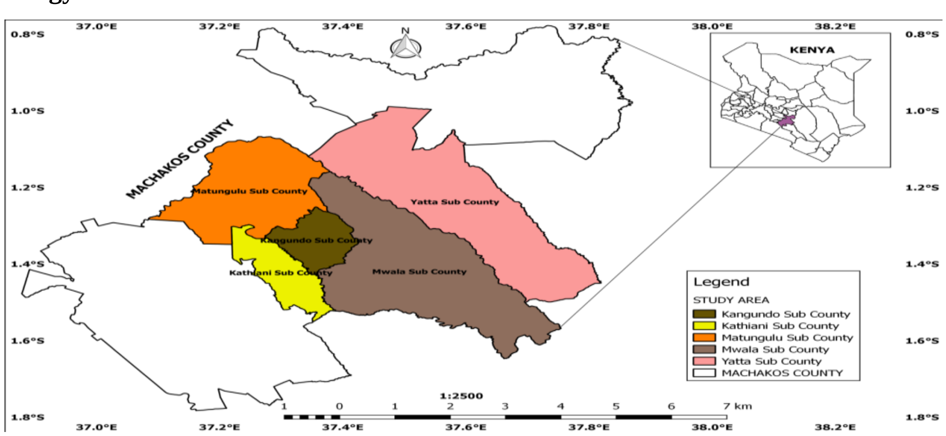

Figure 1: Study area map

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This map illustrates the study location and regional focus of the research. The target population included households, agricultural officers, and administrative officers in Machakos County. The sampled administrative wards contained a total of 36,976 households. The population was determined using Yamane's formula, ($n = \frac{N}{1+N(e^2)}$ n =the number of respondents in the research study. where N = size of the population in the study, e = the level of data accuracy) resulting in a sample size of 395 maize farmers (households). Maize farming households were identified using cluster random sampling from wards including Matungulu east, Kaani/Kaewa, Mwala/Makutano, Ikombe, and Kangundo east. The study utilized both qualitative data from oral interviews, focused group discussions and observations and quantitative data obtained from the Kenya meteorological department (KMD) and Data on maize yields from the National cereals and produce board (NCPB) and Kenya national bureau of statistics (KNBS) reports, collected through structured questionnaires as primary data and a secondary time series data template for secondary data. Quantitative secondary data were analyzed using descriptive and inferential statistics, with descriptive statistics summarizing data through counts, percentages, and means. Correlation analysis tested relationships between variables, while regression analysis determined causal effects of independent predictors on the dependent variable. A significance level of 0.05 (95% confidence interval) was used for error variance. Data were coded and analyzed using SPSS and STATA, and results were presented in tables, diagrams, and charts.

Research Findings, Data Analysis and Presentation

Across the wards the household respondents acknowledged to have experienced temperature variations over the study period. The temperature anomaly experienced in Machakos County within the period of 30 years. The means was calculated for fifteen year period from which the anomaly were computed on 15 year period that is 1993 to 2008 (first Quindencennial) and 2008 to 2023 (second Quindencennial). In Figure 2, the first Quindencennial, 1994 recorded zero deviation, 1999, 2000, 2002, 2004,2005,2006,2007 and 2008 recorded temperature above the mean. Lowest temperature above the mean was recorded in 1999, 2000 and 2002 at 0.2 ºC while the highest temperature above the mean was in 2008 at 0.7 ºC. Seven years recorded negative deviation from the mean, these were; 1993, 1995, 1996, 1997, 1998, 2001 and 2003. The Highest negative deviation was recorded in 1995 and 1998 at -0.4 ºC while the lowest was in 2001 at -0.1 ºC.

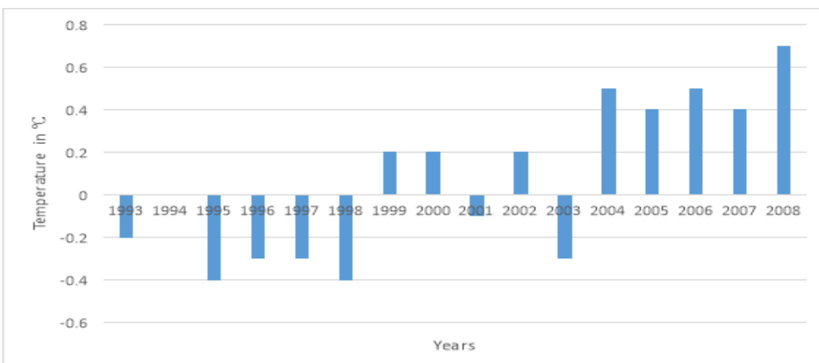

Figure 2: First Quindencennial Temperature Anomaly (1993-2008)

In the second Quindencennial, as captured in (Figure 1.7) below 2013 and 2019 recorded zero temperature variation from the mean 2009, 2011, 2012, 2014, 2015 and 2023 recorded temperature above the mean. 2011 recorded the highest deviation of 0.6 ºC while 2009 and 2014 recorded the lowest temperature of -0.1 ºC. Negative Temperature deviation was recorded in 2010, 2016, 2017, 2018, 2020, 2021 and 2022. Lowest negative deviation was recorded in 2022 -0.1 ºC while the highest was recorded in 2018 at -0.7 ºC. The second Quindencennial had the highest lower temperature deviation of -0.7 ºC while the first Quindencennial had the highest temperature above the mean of 0.7 ºC. Secondly the first Quindencennial period recorded higher deviations from the mean compared with the second Quindencennial.

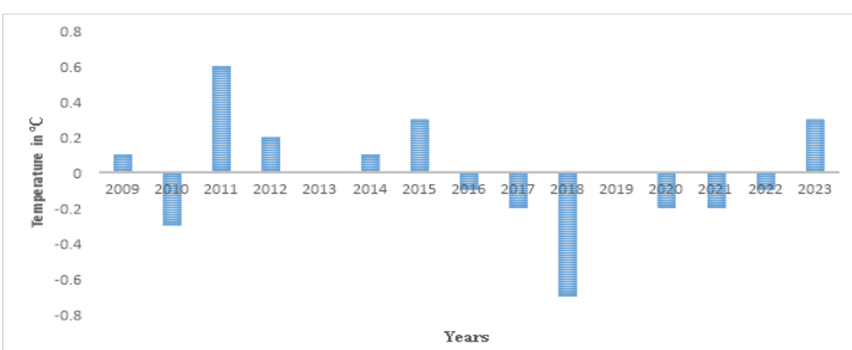

Figure 3: Second Quindencennial Temperature Anomaly (2009-2023)

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Rainfall Trends in Machakos County

The survey presented the results on changes in rainfall patterns over recent years across various wards highlighting notable perceptions and experiences within local agricultural communities. The information in (Figure 1.8), which detail the frequencies of perceived changes in rainfall patterns over the last few years across various wards, across all the wards maize growing households reported to have experienced changes in rainfall patterns though the percentage varied across the wards.

Overall, Mwala/Makutano stands out as the Ward with the highest frequency of perceived changes in rainfall patterns, suggesting the most significant impact or awareness of rainfall variability. Conversely, Kangundo East and Kaani/Kaewa report the lowest frequencies, indicating a comparatively lower perception of changes in rainfall. The results highlight the varying degrees of impact that changes in rainfall patterns have across different wards, reflecting diverse local experiences and potentially differing environmental or climatic conditions.

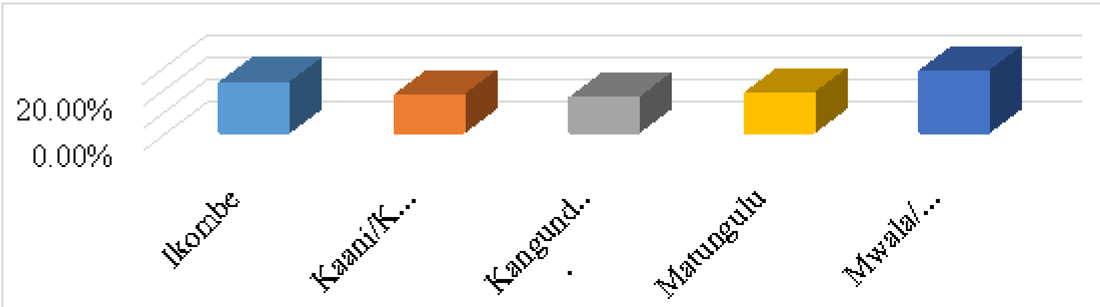

Figure 4: Frequencies of Changes in Rainfall Pattern

Precipitation just like temperature is a determinant of climate, Slight changes in amounts received is key to understanding climate variability. This study purposed to establish rainfall trends in Machakos County for the period 1993 to 2023. It can be concluded that annual rainfall has significantly varied showing a declining trend.

In the first Quindencennial as captured in (Figure 1.9), 1994, 1997, 1998, 2002, 2005, 2006 recorded a positive deviation. 2006 had the highest rainfall deviation above the mean of 34.5mm while 2002 had the lowest at 4.2mm. The years 1993, 1995, 1996, 1999, 2000, 2001, 2003, 2004, 2007 and 2008 recorded negative rainfall deviation. The year 2001 recorded the highest negative deviation of 24.3mm while 1993 recorded the lowest of 4.1mm. These low rainfall amounts were occasioned by the La Niña Modoki events of 2000-2001, 2008-2009 while rainfall above the annual means were recorded in 1994 (81.5mm), 1997 (68mm), 1998 (92.5mm), 2002 (65.9mm), 2005 (79.7mm), 2006 (96.2mm) the Record high amounts are due to the El Niño events experienced in 1997-1998, 2002-2003, 2006-2007.

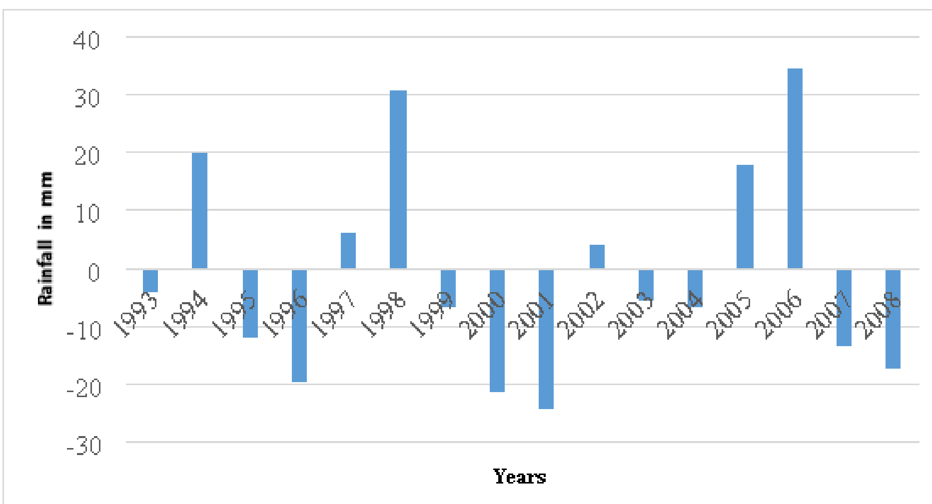

Figure 5: First Quindencennial Rainfall Anomaly (1992-2008)

In the second Quindencennial as shown in (Figure 2.0), 2010, 2012, 2013, 2015, 2018, 2019, 2020 and 2023 had positive deviation from the mean. The highest negative deviation was 34.9 mm recorded in 2018 while the lowest positive deviation was 1.3mm recorded in 2012. Negative deviations from the mean were recorded in 2009, 2011, 2014, 2016, 2017, 2021 and 2022. The highest negative deviation was recorded in 2022 at 36.6 mm while the lowest negative deviation was recorded in 2011 a rainfall of 4.7mm. Rainfall below the annual/Annual mean were recorded in 1996 (42.1mm), 2000 (40.3mm), 2001 (37.4mm), 2009 (40.7mm), 2016 (23.4mm), 2021 (37.6mm) and 2022 (17.9mm). These low rainfall amounts were occasioned by the La Niña Modoki events of 2008-2009, 2010-2011, 2016-2017 and the 2020-2021 while rainfall above the annual means were recorded in

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2010 (66.6mm), 2015 (72.2mm), 2018 (89.2mm), 2019 (66.6mm), 2020 (77.6mm) and 2023 (64.7mm). Record high amounts are due to the El Niño events experienced in 2009-2010 and the October 2023 to January 2024.

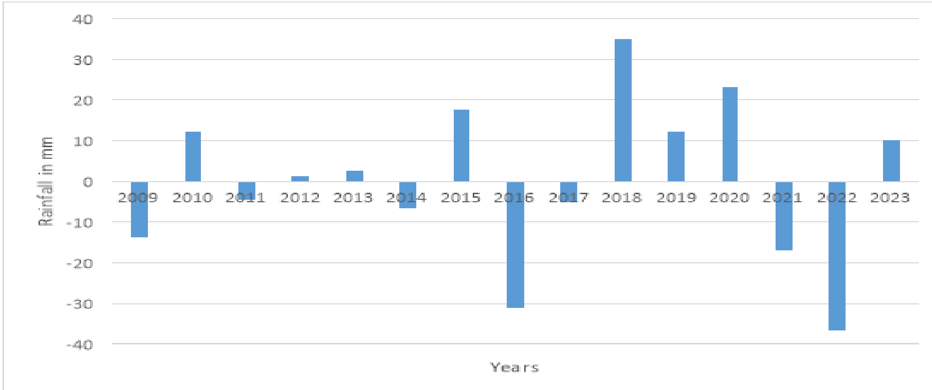

Figure 6: Second Quindencennial Rainfall Anomaly (2009-2023)

Generally the first Quindencennial had many years recording negative deviations from the mean implying the rainfall received was lower than the mean. The second Quindencennial had the least negative deviation from the mean implying the period received high amount of rainfall.

Testing Hypothesis

Based on the analysis of temperature results for Machakos County from 1993 to 2023, (Table 2.2) the following conclusions can be drawn regarding Hypothesis One, $H0_{1:}$ There is no significant variation in the long-term mean annual temperature and rainfall of Machakos County for period 1993 to 2023. Thus, from the results from the trend analysis, and variability test, the study rejected the null hypothesis that there is no significant variation in the long-term mean annual temperature of Machakos County from 1993 to 2023. The findings confirm that there has been a significant variation in mean annual temperatures, with a notable increasing trend and substantial fluctuations throughout the study period.

Table 1Effect of Temperature Variability on Maize Yields

		Source	SS	df	MS Number of obs =	144
					F(1, 142) =	65.18
		Model	3.672615	1	3.67261462 Prob > F =	0
		Residual	8.001312	142	.056347271 R-squared =	0.3146
					Adj R-squared =	0.3098
		Total	11.67393	143	.081635854 Root MSE =	0.23738
Yield (MTHA)	Coef.	Std. Err.	T	P>t	[95% Conf.	Interval
Av temp	-0.054	0.007	8.070	0.000	0.041	0.067
cons	-0.477	0.123	-3.870	0.000	-0.720	-0.233

With an F-statistic of 65.18 and a p-value of 0.000, the model demonstrates that temperature variability is a statistically significant predictor of maize yields. The R-squared value of 0.3146 indicates that approximately 31.46% of the variability in maize yields can be explained by temperature variability. The study showed a negative and significant effect of temperature variability on maize yields among farming households in Machakos County (β=-0.054, p=0.000). This implies that, holding other factors constant, a one-unit increase in temperature variability is associated with a 0.054 decrease in maize yields (measured in metric tons per hectare). Thus, it can be implied that extreme temperature fluctuations can disrupt the critical growth stages of maize, such as pollination and grain filling, leading to reduced yields.

Effect of Extreme Temperature and Rainfall Anomalies on Maize Yields among Farming Households in Machakos County for Period 1993 To 2023

The impact of extreme temperature and rainfall anomalies on maize yields is a crucial area of study, particularly for regions like Machakos County, where maize is a staple crop. This section will explore the relationship between climatic extremes and maize production over the past three decades, from 1993 to 2023. By analyzing the effects of these anomalies on maize yields, we aim to understand the vulnerabilities of farming households to climate variability. This analysis highlights the extent to which extreme

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weather events have influenced maize productivity, offering insights into the broader implications for food security and agricultural sustainability in Machakos County.

Annual Maize Output in Machakos County

The annual maize output in Machakos County, Kenya, is influenced by various factors including climate variability, agricultural practices, soil fertility, pest management, and socio-economic conditions. Maize is a staple crop in Kenya and plays a crucial role in food security and livelihoods, particularly in rural areas like Machakos County. By studying annual maize output, Machakos County can strengthen its agricultural sector, improve food security, and contribute to the overall development goals of Kenya.

Maize Varieties Grown in Machakos County

The respondents were also asked to indicate which major maize varieties they have been cultivating. The survey results provide valuable insights into the preferences and practices of farmers in each region. The data highlights the diversity in maize variety adoption and sheds light on the predominant varieties grown by farmers. In Ikombe sub-county, the majority of farmers primarily cultivate Duma 43, which accounts for 74% of the responses. This is followed by a combination of Kikamba and Duma 43 (6.8%) and other varieties like Dk 47 and Kikamba, each representing smaller percentages. Kaani/Kaewa sub-county also shows a significant preference for Duma 43, with 60% of farmers indicating its cultivation. Pioneer holds a notable share at 7.3%, demonstrating a diverse selection of varieties but with a clear preference towards Duma 43. In Kangundo East, Duma 43 is the most popular, reported by 56.9% of respondents. Pioneer is also significant, with 27.5% of farmers opting for this variety. This suggests a two-fold preference in this sub-county for both established and newer maize varieties. Matungulu exhibits a more diversified pattern in maize cultivation, with combinations like Duma 43/Dana, Duma 43/Sungura, and Katumani/Duma 43 each accounting for 19% of responses. This indicates a preference for hybrid varieties catering to specific farming needs and environmental conditions. Dk 47/Duma 43 and Sungura varieties also hold substantial shares, reflecting a mix of traditional and newer maize varieties among farmers. In Mwala/Makutano, Duma 43 is the dominant variety, chosen by 25.6% of respondents, followed by Dk 47 with 8.9%. This sub-county shows a preference for established varieties like Duma 43, though the presence of Dk 47 indicates some diversity in variety adoption among farmers. The predominance of Duma 43 across multiple sub-counties suggests its popularity due to its adaptability, yield potential, and possibly other agronomic traits valued by farmers.

Effect of Temperature Variability on Maize Yields among farming households in Machakos County

The regression analysis investigating the effect of temperature variability on maize yields among farming households in Machakos County presents significant findings.

Effects of Temperature anomalies on Maize yields in Machakos County

The analysis of the correlation between temperature anomalies and maize yields in Machakos County reveals several insights into how deviations in temperature might impact crop performance. Firstly, the correlation between **minimum temperature deviations** and maize yields is moderately positive, with a coefficient of r = 0.2546. In contrast, the correlation between **maximum temperature deviations** and maize yields is very weak and negative, with a coefficient of r=−0.0233. The relationship between **mean temperature deviations** and maize yields is also very weak and positive, with a correlation coefficient of r=0.0661. The correlation between **temperature deviations from the mean** and maize yields is weakly positive, with a coefficient of r=0.1016. This suggests that deviations in temperature from the average have a slight positive impact on maize yields.

Effect of Rainfall Variability on Maize Yields among farming households in Machakos County

The study investigated the impact of rainfall variability on maize yields among farming households in Machakos County. This is done by performing a regression analysis to determine the relationship between rainfall variability and maize yield.

Table 3: Regression Analyses between Rainfall Variability on Maize Yields

		Source	SS	df	MS Number of obs =	144
					F(1, 142) =	0.000
		Model	0.000373	1	.000373211 Prob > F =	0.946
		Residual	11.67355	142	.082208126 R-squared =	0.000
					Adj R-squared =	-0.007
		Total	11.67393	143	.081635854 Root MSE =	0.28672
Yield (MTHA)	**Coef.**	**Std. Err.**	**t**	**P>t**	**[95% Conf.**	**Interval]**
RAINFALL	-0.020	0.000	-0.070	0.946	-0.001	0.001
_cons	0.506	0.029	17.240	0.000	0.448	0.564

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The results of the regression analysis indicated that the model's Sum of Squares (SS) for rainfall variability was 0.000373 with 1 degree of freedom (df), resulting in a Mean Square (MS) of 0.000373211. The statistical insignificance of the model was evident from the F-statistic value of 0.000 and a corresponding probability (Prob > F) of 0.946, indicating no meaningful relationship between rainfall variability and maize yields. Further, the regression results showed an R-squared value of 0.000, signifying that the model explained none of the variability in maize yields. The adjusted R-squared value was -0.007, reinforcing that the inclusion of rainfall variability as a predictor did not enhance the model's explanatory power. The study showed a negative but insignificant effect of rainfall variability on maize yields among farming households in Machakos County (β=-0.020, p=0.946). This implies that, holding other factors constant, a one-unit increase in rainfall is associated with a 0.020 decrease in maize yields (measured in metric tons per hectare). Thus, rainfall variability has severe implications on the yields of maize.

Effects of Rainfall anomalies on Maize yields in Machakos County

Rainfall mean data shows considerable variability over the years, with fluctuations ranging from a low of 17.9 mm in 2022 to a high of 96.2 mm in 2006. The mean rainfall over the entire period is 59.9 mm. Maize production has varied significantly, with the highest production was 143,825 MT in 1994, and the lowest was 55,300 MT in 2005. There appears to be a general increase in production in recent years, with notable peaks in 2009 and 2015. In years with higher rainfall (e.g., 1994, 2006, 2015), maize production also tended to be higher, suggesting that adequate rainfall supports better crop yields. Conversely, years with lower rainfall (e.g., 2000, 2005, and 2020) often show lower maize production, indicating that insufficient rainfall adversely impacts yields. Periods of excessive rainfall can lead to flooding, for instance, the high rainfall in 2006 coincided with substantial maize production but can also be attributed to potential risks of over-saturation. Insufficient rainfall often leads to drought conditions, which significantly impact maize yields. For instance, the low rainfall in 2000 and 2005 aligns with reduced maize production, highlighting the adverse effects of drought on crop yields. When considering rainfall anomalies, both the mean rainfall (r=0.0540) and deviations in rainfall from the mean (r=0.0619) show very weak positive correlations with maize yields. These low correlations suggest that variations in rainfall have a minimal effect on maize yields. This could imply that other factors may have a more pronounced impact on maize yields, or that the crop is relatively resilient to variations in rainfall within the observed range. Generally, moderate to high rainfall correlates positively with maize yields, provided the rainfall is well-distributed and occurs at critical growth stages. Both excessive and deficient rainfall can lead to anomalies in maize yields. Excessive rainfall may result in waterlogged fields, while deficient rainfall can cause drought stress, both leading to lower yields. In 1994, higher rainfall was associated with high maize production (143,825 MT). In contrast, 2005 experienced low rainfall and correspondingly lower maize production (55,300 MT), highlighting the detrimental effect of drought conditions.

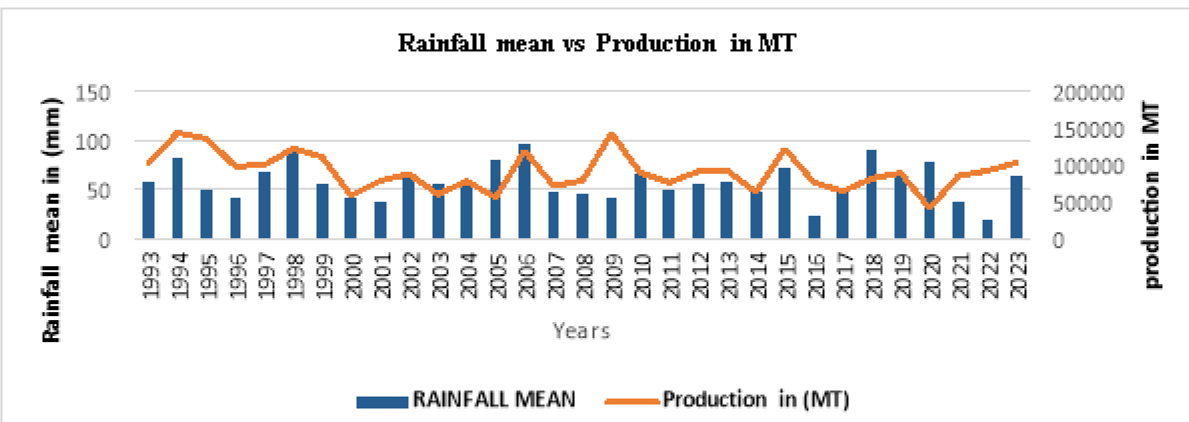

Figure 7: Rainfall mean vs Production in MT

III. Conclusions and Recommendations

The study on the effect of extreme temperature and rainfall anomalies on maize yields among farming households in Machakos County from 1993 to 2023 has yielded several key conclusions. The relationship between cultivated area and production has been volatile, with production showing significant variability despite the cultivated area remaining within a certain range. For instance, in 2000, despite a cultivated area of 162,000 hectares, production plummeted to 58,320 metric tonnes. Similarly, in 2015, the cultivated area was 125,652 hectares, yet production surged to 121,682 metric tonnes. Rainfall variability has a significant impact on agricultural yields across the sub-counties. The years 1993, 1995, 1996, 1999, 2000, 2001, 2003, 2004, 2007, 2008, 2009, 2011, 2012, 2013, 2014, 2016, 2017, 2021, and 2022 experienced positive deviations from the mean rainfall, indicating higher-than-average rainfall. Conversely, the years 1994, 1997, 1998, 2002, 2005, 2006, 2010, 2015, 2018, 2019, 2020, and 2023 witnessed negative deviations from the mean, indicating lower-than-average rainfall. The study found a statistically significant negative effect of temperature variability on maize yields, with a coefficient (β) of -0.054 and a p-value of 0.000. This suggests that as temperature becomes more unpredictable, maize yields suffer considerably. In contrast, the study found a negative but statistically insignificant effect of rainfall variability on maize yields, with a coefficient (β) of -0.020 and a p-value of 0.946. This implies that, holding other factors constant, a one-unit increase in rainfall variability is associated with a 0.020 decrease in maize yields.

Recommendations of the study

Based on the findings of this study, the following recommendations are proposed to enhance maize yields and address the challenges faced by farming households in Machakos County. Firstly, Climate justice through promoting sustainable agricultural practices and providing access to resources can significantly support small-scale farmers in improving their maize yields. This includes initiatives such as land consolidation, access to improved seeds, and targeted extension services. Secondly, promoting more heat-tolerant maize varieties, improving water harvesting and storage techniques, and encouraging the adoption of irrigation systems are key components of these strategies. These measures will help mitigate the adverse effects of unpredictable rainfall and ensure consistent maize production. Thirdly, strengthening integrated pest management programs is essential for effectively controlling pests like armyworms and stock borers that threaten maize crops. This can be achieved by promoting the use of biological control agents, encouraging the adoption of resistant maize varieties, and providing training on proper pest management practices. Lastly, implementing soil fertility management programs is necessary to address soil exhaustion and maintain the long-term productivity of agricultural lands. Promoting the use of organic matter, encouraging crop rotation, and providing access to affordable and sustainable fertilizers are effective ways to enhance soil health.

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