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Evidence of Climate Change and Seasonal Agricultural Drought in Kakamega South Sub-County, Kakamega County, Kenya

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ABSTRACT

Changes in climate have led to shifts in weather patterns outside the normal range of variation over a given time period, attributed to either human action or natural causes. This has led to reduced precipitation, which consequently results in reduced water availability for farming in some seasons, hence the seasonal agricultural drought. This has greatly impacted smallholder farmers, lowering their agricultural productivity. This study was undertaken in Kakamega South Sub-County in Kakamega County to determine the impact of the seasonal agricultural drought. The discrete choice model and capability theory were used in this study. Both qualitative and quantitative research designs were used. Both primary and secondary data sources were utilized, and they included questionnaires, interview schedules, focused group discussions (FGDs), and field Secondary data sources, including rainfall and temperature data, were collected from the meteorological station for a period of 35 years (1985–2020). Using Krejce and Morgan tables, a sample size of 377 households was obtained using simple random sampling from a target population of 26,940. The data was analyzed using the Statistical Package of Social Sciences (SPSS) version 23. The results of this study established that there was evidence of climate change and seasonal agricultural drought in Kakamega South sub-county as rainfall is positively correlated with humidity ($r = 0.834$, $p < 0.05$). Humidity is negatively correlated with annual maize production ($r = -0.869$, $p < 0.05$) and annual average temperature ($r = -0.813$, $p < 0.05$). The study recommended that in order to adapt to the effects of climate change that are a result of seasonal agricultural drought, there was a need to improve the sustainability of crop production in the Kakamega South Sub-County by supplementing rain-fed farming with drip irrigation, rainwater gathering, and greenhouse techniques.

Keywords: Climate Change, Seasonal Agricultural Drought, Kenya

I. INTRODUCTION

Climate change refers to a shift in weather patterns outside the normal range of variation over a given time period that can be attributed to either human action or natural causes. Countries that rely heavily on agriculture for food and livelihoods, such as those in Sub-Saharan Africa, have been hit hard by climate change (Dixon et al., 2001). This is because climate change is linked to both a decrease in available water and an increase in the occurrence of extreme weather events. Both fluctuations in rainfall and temperature can have a significant impact on crop production. Thus, even small shifts in these factors can have a significant impact on agricultural output. These components are crucial for a plant's life cycle, from germination through harvest (Mulinya et al. 2016).

Frequent droughts are evidently a result of modern climate change. According to Ngaira (2004), drought is a type of environmental stress that results from a sustained lack of precipitation and causes low moisture levels, the death of plants and animals, failed harvests, human and animal deaths, as well as other issues. Roughly 630 million people, or about 60% of the global population, live in the world's arid and semi-arid regions (ASALs), which are severely impacted by drought.

According to the Intergovernmental Panel on Climate Change (IPCC), the frequency with which droughts and floods occur is expected to rise due to climate change, further limiting already limited resources (IPCC, 2001). This indicates that small-scale farmers will experience lower agricultural productivity as a result of the rising drought brought on by climate change's negative effects on water levels and availability. Agriculture provides the majority of

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people's food and income needs and is a very vulnerable sector to climate change. It stands to reason that the industry will suffer a number of negative consequences as a result of global warming (IPCC, 2007).

As a result of climate change, precipitation levels may decline, which could reduce the amount of water available for farming. According to the International Water Management Institute (IWMI, 2000), there will be a need for an additional 12–27% more water to produce food for the world's rising population by the year 2025. In order to guarantee food security through consistent agricultural production, it is important to educate farmers on adaptive measures to reduce the effects of seasonal drought, with a particular emphasis on finding and protecting alternate sources of water on the farm.

Kakamega South Sub-County is one of the most food-efficient and food-secure sub-counties in Kenya. However, the growing aridity of the county is often regarded as a consequence and indication of climate change. Given these climatic conditions, it is necessary to investigate the consequences of the seasonal agricultural drought in Kakamega South sub-county. Therefore, it was simple to identify adaptation techniques that may be implemented to assist the small-scale farmers in Kakamega South to deal with the issue.

II. LITERATURE REVIEW

2.1 Theoretical Review

2.1.1 Capability Theory

The theory by Sen and Nussbaum analyzed the abilities required for people to live fulfilling lives. The capabilities approach provides ideas that can be incorporated into the current climate justice paradigm, but in a way that is more applicable to the formulation of adaptation policy (Dryzek et al., 2012).

A capabilities-based approach to adaptability does not rely on a top-down, expert-led command and control system. Instead, locals should be heavily involved in determining their own susceptibilities and crafting equitable adaptation plans meant to protect them against seasonal agricultural droughts (Ribot, 2010).

2.1.2 Discrete Choice Model

The discrete choice model by McFadden serves as the framework for deciding which adaptation alternative to select. This theoretical framework holds that individuals freely decide which options to pursue while leaving the remaining options to chance (McFadden, 1973).

For instance, the decision-maker in this study was a small-scale crop farmer who was presented with choices of adaptive water management options from which to select one in order to maximize his or her utility. It is assumed in the discrete choice model that the farmer selected the most beneficial options. The deterministic part of the analysis was made up of the estimated parameters of the observable explanatory factors, like the characteristics of the farm and the farmer, and the linear combination of these two sets of variables.

2.2 Empirical Review

Over the past half century, the average temperature in Kenya has risen by close to 1°C, and scientists forecast that this rise will quicken to close to 3°C by the year 2050 (IPCC, 2007). Evidence of climate change has decreased agricultural production and decreased water availability in Kakamega South Sub-county.

Droughts in recent years (particularly in 2000) have shown the economic vulnerability of the country, which has resulted in severe power rationing. Kenya Power Company suffered a $20 million loss, economic activity ground to a halt, and the country's GDP fell by 0.3% (Kandji, 2006). In addition, Kenya has suffered from severe droughts in recent years, leading to widespread food insecurity (Ngaira, 2004). Seasonal drought has affected small-scale crop farmers' agricultural production in Kakamega South Sub-county.

According to the Intergovernmental Panel on Climate Change, the frequency with which droughts and floods occur is expected to rise due to climate change, further limiting already limited resources (IPCC, 2001). This indicates that small-scale farmers will experience lower agricultural productivity as a result of the rising drought brought on by climate change's negative effects on water levels and availability.

Since agriculture provides the majority of people's food and income needs and is a very vulnerable sector to climate change, it stands to reason that the industry will suffer a number of negative consequences as a result of global warming (IPCC, 2007).

Developing resistance to high-intensity rainfall and protracted dry spells requires farmers to adapt to the effects of climate change on agricultural systems. Existing agriculture and water systems have been disrupted by

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climate change, with significant repercussions for livelihoods, as evidenced by studies like De Wit & Stankiewicz (2006).

In order to attain food security and raise the standard of living in rural regions such as Kakamega South sub-county, better management of land and water resources is essential (International Commission on Irrigation and Drainage [ICID], 2001). The data collected from the evidence of climate change and seasonal drought will help come up with adaptation strategies. This will help small-scale crop farmers' agricultural production by making them more resilient and less vulnerable to climate change and seasonal agricultural drought effects.

III. METHODOLOGY

3.0 Introduction

The study adopted a mixture of descriptive and research design, as this catered for both qualitative and quantitative data on evidence of climate change and seasonal agricultural drought in Kakamega South Sub-county.

3.1 Study Area

The study was conducted in Kakamega South sub-county, as shown in Figure 1.0 below, which is situated in Kakamega County, Kenya. Previously, it was referred to as the Ikolomani sub-county. It is bordered by Lurambi sub-county to the north, Sabatia and Emuhaya to the south, Shinyalu to the east, and Khwisero to the west. Kakamega South subcounty is divided into four subcounty wards: Idakho East, Idakho South, Idakho Central, and Idakho North. The wards are further divided into six locations: Iguhu, Eregi, Shikumu, Shirumba, Isulu, and Shisele, with a total of twenty-two (22) sub-locations.

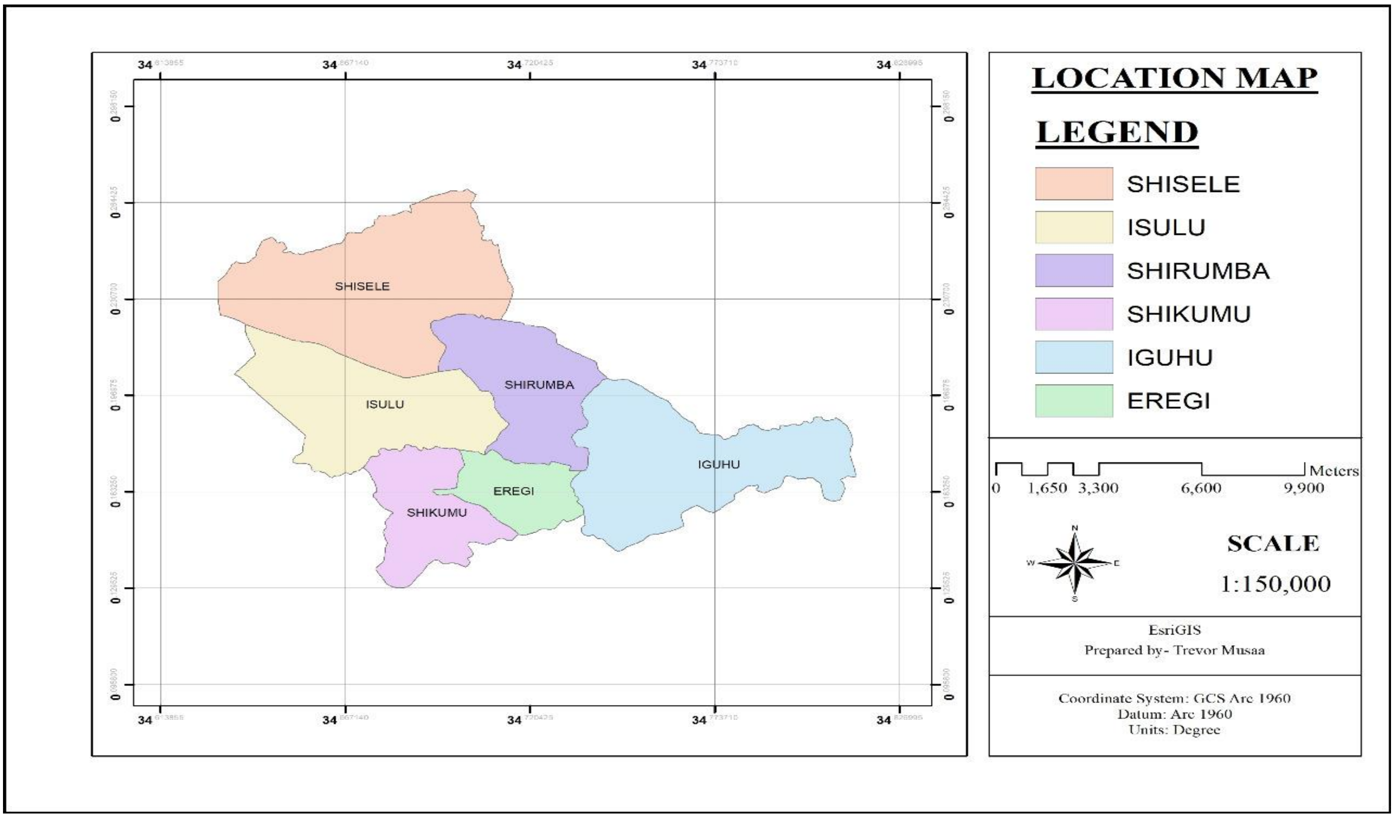

Figure 1
Map of Kakamega South/Ikolomani Sub-county
(Source: Based on ESriGIS 2020)

According to the Kenya National Bureau of Statistics (2019), the study area had a population of 111,743 people with a ratio of 53,219 (47.63%) males to 58,524 (52.37%). The population density is 764 per square kilometer, with approximately 26,940 households and an average household size of 4.1 (KNBS, 2019).

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3.2 Sampling Procedure

The study used the Morgan table (Krejcie & Morgan, 1970) to select a sample of 377 households from a target population of 26,940 households. A simple random sampling method was used to select the 377 households from the six locations in the sub-county. Since 377 households represent only a very tiny subset of the total population, a sampling range of 10–30% was used (Mugenda & Mugenda, 2003). Purposive sampling was used to sample information from agricultural offices and meteorological stations to obtain detailed information on the study problem.

3.3 Methods of Data collection

Both primary and secondary data were collected. Primary data was collected using questionnaires, interview schedules, and focal group discussions (FGDs). Data were collected from household heads using both open-ended and closed-ended questionnaires, as they captured a significant amount of data in a short period of time. The interviewing technique helped in obtaining in-depth information and enabled the researcher to clarify issues that were not clear immediately (Kavulya, 2014). Focus Group Discussion used the views of the small-scale farmers to justify or reinforce the views collected from other small-scale farmers through the questionnaires. Secondary data on rainfall and temperature was collected from Kakamega Meteorological Station and Butere Meteorological Station in Kenya.

3.3.1 Methods of Data Processing and Analysis

Data analysis involves editing, organizing, sorting, and summarizing data extracted from research instruments. The study generated both quantitative and qualitative data. Quantitative data were analyzed through descriptive statistics in the form of frequency distribution counts and percentages, for instance, in demographic information.

IV. FINDINGS

4.1 Evidence of Climate Change and Agricultural Drought in Kakamega Sub-County

The study sought to find out whether there were some indicators used by the farmers to establish evidence of climate change and seasonal agricultural drought. The findings are indicated in Table 1 below:

Table 1
Climate Change and Agricultural Drought Indicators

Climate change and Agricultural Drought Indicators			
Indicators of climate change		**Indicators of agricultural drought**	
Statement	**Percentage (%)**	**Statement**	**Percentage (%)**
Rainfall change	11.8	Crop wilting	49.7
Temperature Change	12.9	Death of crops	11.8
High solar radiation	43.2	Drying up of grass and vegetation	16.2
Both rainfall and temperature change	32.1	Reduced crop production	20.3
Total	**100**		**100**

The majority of the farmers (43.2%) agreed that the greatest indicator was high solar radiation, while both rainfall and temperature change were at 32.1%, temperature change at 12.9%, and rainfall change at 11.8% as indicators of climate change. Similarly, the evidence of seasonal agricultural drought was mainly evidenced by crop wilting at 49.7%, reduced crop production at 20.3%, drying up of grass and vegetation at 16.2%, and death of crops at 11.8%. Changes in climate were also attributed to the hydrological cycle having been disrupted directly and indirectly, resulting in insufficient water for crops to thrive well, especially during the dry seasons. When human activities such as deforestation occur, it reduces the rate of evapotranspiration and consequently the amount of water vapor in the atmosphere, which in turn leads to a shortage of rainfall. A shortage of rainfall causes vegetation, such as agricultural crops, to be stressed due to inadequate water content in the soil.

This study was in concurrence with Fischer et al. (2002), who found that climate change impacts local water systems by altering the frequency and intensity of rainfall. As a result, these factors could shift the timing of the years most suited for various forms of agricultural output due to changes in average temperatures and precipitation.

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4.1.2 Climate Change and Seasonal Agricultural Drought as Evident by Rainfall and Temperature Trends

Annual temperature and rainfall trends for the past 35 years were analyzed and used to indicate climate change and agricultural drought scenarios in Kakamega South Sub-County.

4.1.2.1 Annual Rainfall Trends from 1985 to 2020 in Kakamega South Sub-County

The annual rainfall has had a positive trend, with the months of February and January having low rainfall below 90 mm, indicating a discernible upward linear trend in the annual mean precipitation from the years 1985 to 2020. This trend presents regression coefficient data as 15.16. The coefficient of determination (R^2) for yearly precipitation is 0.3693, which equates to 34.0% of the variability in precipitation levels over time (1985–2020). This means that average annual precipitation rose through time, with a 15.16 mm rise in precipitation for each subsequent year. This forecast indicates that the region will likely experience a rise in annual mean precipitation in the years to come. The findings were presented in Figure 1 below.

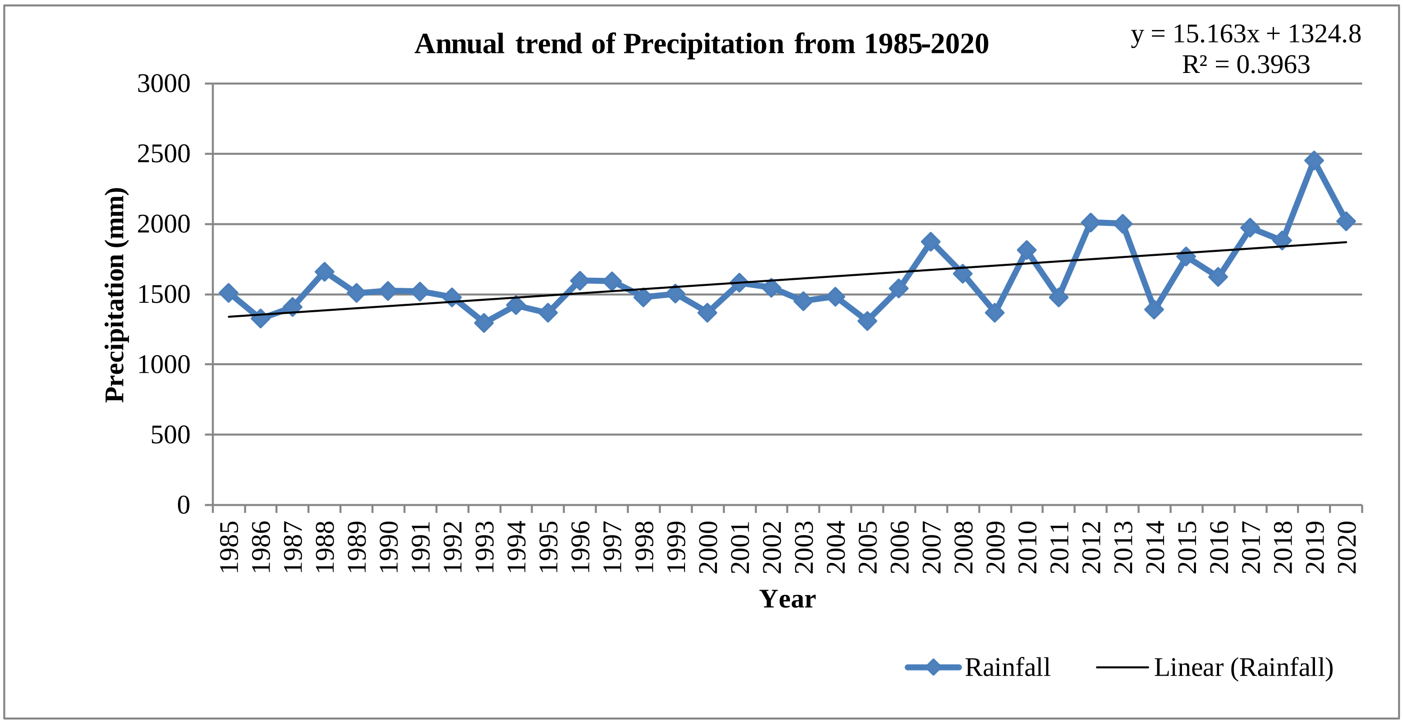

Figure 1
Annual Trend of Rainfall as from 1985- 2020;

4.1.2.2 Annual Temperature Trends for Kakamega Sub- County (1985-2020)

Figure 2 below indicates the existence of a regression coefficient of 0.0208, thus indicating a positive linear trend in annual mean temperature from 1985 to 2020. This tendency is demonstrated by the fact that there is a progression from lower to higher values. The yearly temperature coefficient of determination (R^2) is 0.4259, which indicates that 42.6% of the fluctuation in temperature levels may be attributed to random chance (1985–2020). This means that the average yearly temperature rose with time, with a 0.0 ^{0}C increase in temperature for each consecutive year; an increase in the region's average yearly temperature is forecasted.

This study is in concurrence with O'Brien et al. (2008), who indicated that a considerable proportion of the African population relies on resources that are vulnerable to climatic changes but have limited ability to adjust to these changes. In Africa, water is an essential commodity for supporting human life. Especially vulnerable to climate change is the majority of the population's reliance on rain-fed agriculture, which supports the poor (Hassan & Nhemachena, 2008). Climate change impacts local water systems by altering the frequency and intensity of rainfall. As a result, these factors may shift the timing of when optimal temperatures and precipitation levels for agriculture occur (Fischer et al., 2002).

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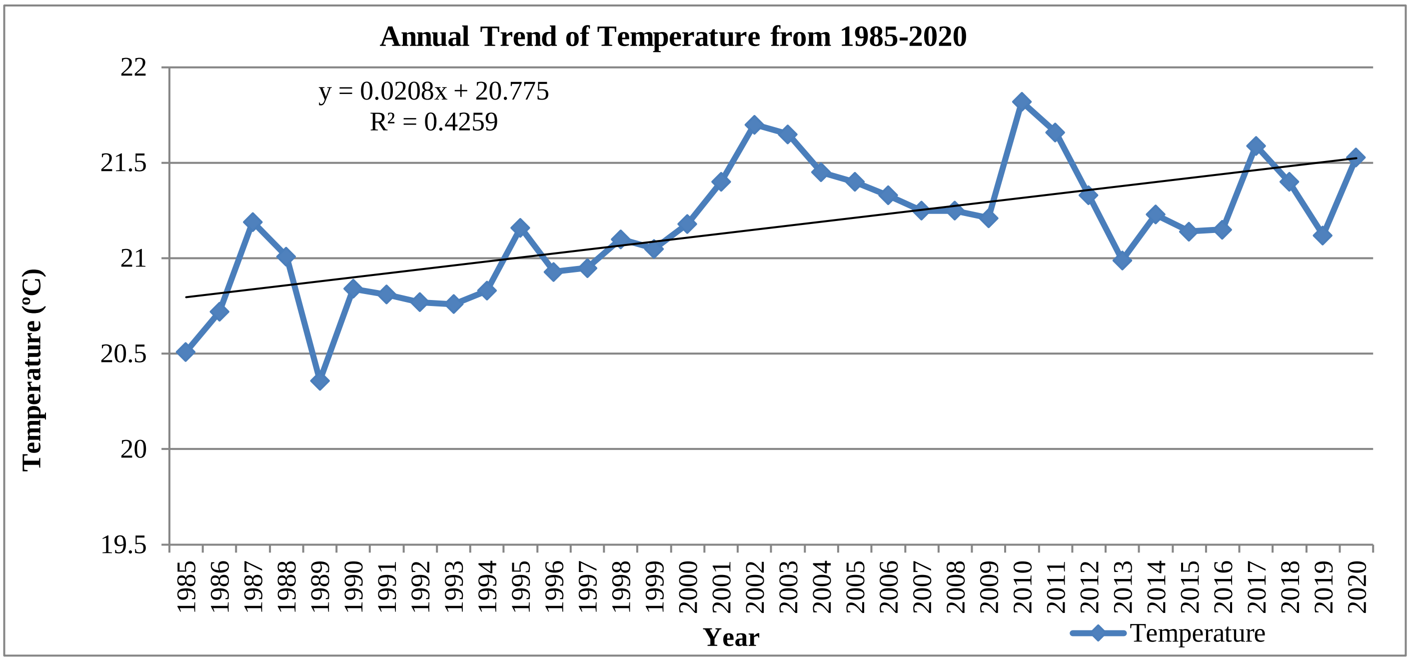

Figure 2

Kakamega South Sub-County Annual Temperature Trends

4.2 Seasonal Agricultural Drought Evidence

The attributes used to assess seasonal agricultural drought in Kakamega South Sub-County were the trend of agricultural production of crops and water variability.

4.2.1 Crops Produced from 2010 to 2020

This research aimed at identifying the most grown crops by small-scale farmers in Kakamega South sub-county. This is shown in Table 2 below, indicating that the most common crops grown over the past decade are maize, which had 68.2%, and beans, which had 66.8%.

Table 2

Crops Grown in Kakamega South Sub-county

Crop grown	Percentage (%)
Maize	68.2
Beans	66.0
Vegetables	48.1
Sorghum	43.9
Sweet potatoes	42.6
Cassava	39.5
Sugar cane	28.6
Yams	24.7
Fruits	19.2
Tea	17.2
Arrow roots	10.7

4.2.2 Production of Maize and Beans from 2010-2020

The main subsistence crops cultivated in Kakamega Sub-County were primarily maize and beans; consequently, there was a need to determine their production over time. This was done using the number of bags produced per acre over the ten-year period. Results indicate a decline in the sub-county's agricultural output. The variation might be attributable to the changes in climate, which impact the length of the growing season of these vital food crops grown in the sub-county.

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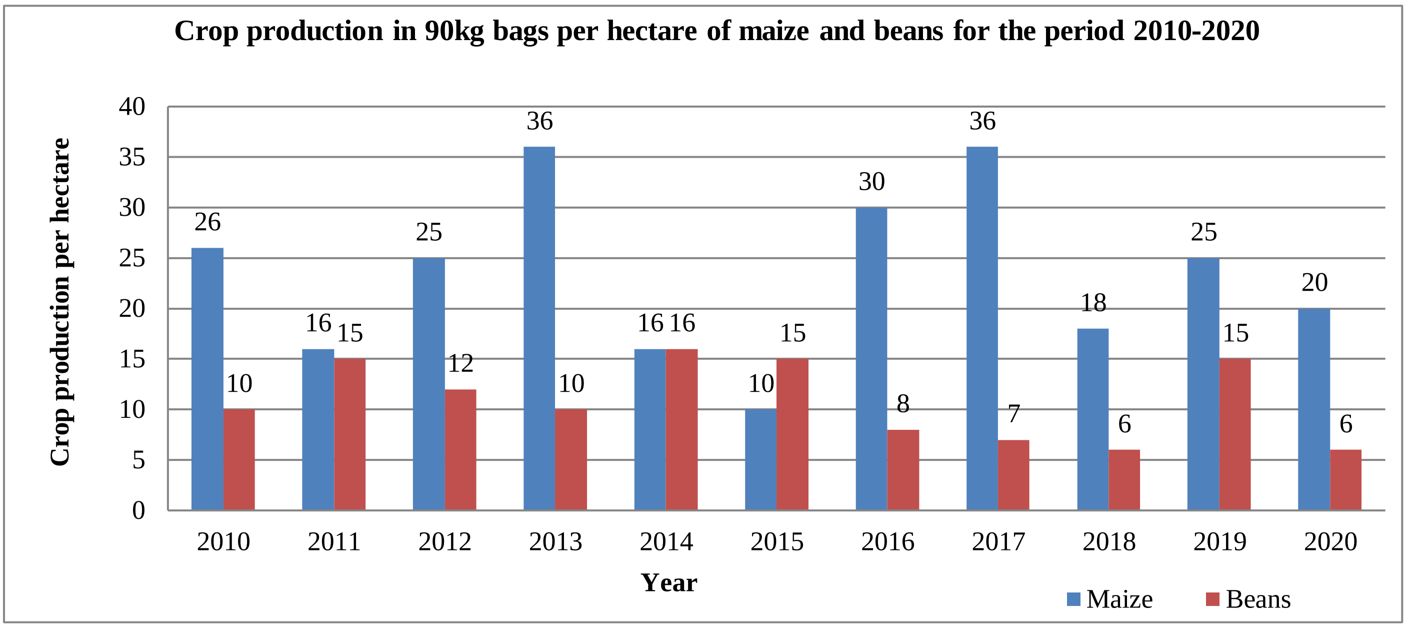

Figure 3
Crop Production in 90kg Bags per Hectare of Maize and Beans between 2010 and 2020

4.3 Crops Grown by the small scale farmers annually Source: *Researcher*

The average number of bags of maize per hectare is 20, although in some years the number has dropped to 10 bags, such as in 2015. The variance can be associated with variation in rainfall amounts, as there was less rain than projected in the year (see Figure 4.6). Although 8 bags of beans are typically harvested per hectare, this number dropped to 6 on several occasions in 2018. Most farmers who responded to the survey on their crop yield over the past decade said that changing weather patterns were to blame.

4.3 Evidence of Climate Change in the Sub-County

There was a need to establish the opinions and perceptions of small-scale farmers on climate change using certain indicators, as indicated in Table 3.

Table 3
Evidence of Climate Change in the Sub-County from Respondents

Climate change evidence	SD	D	UD	A	SA
There is a decrease in crop yield	2.9%	4.5%	1.3%	14.5%	76.8%
The volume of water in streams/rivers during dry seasons reduces	1.3%	2.1%	1.6%	19.2%	75.8%
Climate Change affects Water sources at the farm level	4.5%	2.9%	1.1%	21.8%	69.7%
There is an increased crop wilting	4.2%	5.5%	11.3%	56.1%	22.9%

Table 3 indicates that one of the climate change evidences provided by the small-scale farmers was that the water sources at the farm level had been affected by climate change. The majority of the respondents, 69.7%, strongly agreed that water sources at the farm level have been affected by climate change. This was followed by 21.85% who agreed with the statement. On the contrary, 4.5% strongly disagreed, and 2.9% disagreed. This is attributed to the reduction of the water level underground as a result of reduced transpiration. This can be attributed to deforestation, caused by the clearing of forests to create more room for settlement and agricultural activities, which has resulted in reduced evapotranspiration.

The majority of the respondents (56.1%) agreed that there was an increased incidence of crop wilting, 22.9% strongly agreed, 5.5% disagreed, and 4.2% strongly disagreed. This is a result of water stress on the crops cultivated, as there was reduced moisture content in the atmosphere during dry seasons, making the soil also moisture deficient due to the high rate of water loss to the atmosphere by the crops.

Most respondents (76.85%) strongly agreed that there were decreased crop yields due to reduced rainfall during the seasonal drought, while 14.5% agreed, 4.6% disagreed, and a small percentage (2.0%) strongly disagreed.

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This can be attributed to low moisture content in the soil and atmosphere, whereby crops tend to be stressed and their photosynthesis process is disrupted. This can lead to the plants producing low yields as there is no maximum crop production by the water- and temperature-stressed crops.

The study established that there was a reduced volume of water in the streams and rivers during dry seasons, with a majority of respondents (75.8%) strongly agreeing and 19.2% agreeing that there was a reduced volume of water during dry seasons. Only a small portion of the respondents—1.3% strongly disagreed and 2.15% disagreed. Most respondents observed that the level of water in the streams decreased due to the reduction of water in the water table in dry seasons. This could be attributed to inadequate rainfall to replenish the lost water through the high rate of evaporation during the day when the temperatures are high.

4.4 Climate Change and Agricultural Drought Evidence Summary of the Means and Standard Deviation

The study further used the summary of the means and standard deviation to summarize the findings on climate change and agricultural drought evidence, as shown in Table 4 below, which shows the means of the statements in relation to a scale of one to five: 1 represented strongly disagree, 2 represented agree, 3 represented undecided, 4 represented agree, and 5 represented strongly agree.

The statement volume of water in streams or rivers during dry seasons had the highest mean of 4.66 and a standard deviation of 0.736, indicating that the majority of the respondents strongly agreed with the statement. This was followed by the statement that there is a decrease in crop yield due to rainfall shortages, with a mean of 4.58 and a standard deviation of 0.942. Water sources at farm level being affected by climate change had a mean of 4.49 and a standard deviation of 0.992.

Table 4

Climate Change and Agricultural Drought Evidence Summary of Means and Standard Deviation

Climate change evidence	Mean	Std. deviation
Volume of water in streams/rivers during dry seasons reduces	4.66	0.736
There is decreased in crop yield due to rainfall shortages	4.58	0.942
Water sources at farm level have been affected by climate change.	4.49	0.992
There is an increased incidence for crop wilting	3.88	0.964

4.5 Hypothesis Test of Evidence of climate change and Agricultural Drought

Several variables were used to collect data, and the findings were used to test the correlation, as shown in Table 5. This was established by relating the amount of rainfall and temperature trends in relation to the number of bags of maize and beans produced in the respective years from 2012 to 2010. There was a need to establish the pattern of rainfall and temperature changes in relation to crop production, which was affected by climate change. Most farmers who responded to the survey on their crop yield over the past decade said that changing weather patterns were to blame.

In table 6 below, rainfall is positively correlated with humidity ($r = 0.834$, $p < 0.05$). Humidity can be used to determine the amount of rainfall received in a place. When there is high humidity, the rainfall received will also be high due to the high moisture content in the atmosphere, which in turn will influence the amount of cloud formation that will result in rainfall formation. However, when we have a seasonal agricultural drought due to high temperatures, the amount of water lost to the atmosphere due to humidity will result in crop wilting as a lot of soil moisture will be lost, leading to crop stress, which will affect crop growth and production.

Humidity is negatively correlated with both annual maize and bean production ($r = -0.869$, $p<0.05$) and annual average temperature ($r = -0.813$, $p<0.05$). The higher the temperature, the higher the rate of evaporation, which will result in a lot of soil moisture being lost to the atmosphere. The higher the rate of soil moisture loss, the more the crop will be stressed due to crop wilting. Continued crop wilting will result in reduced crop growth and, finally, low maize production.

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Table 5
Production of Maize and Beans from 2010-2020 in relation to rainfall and annual temperature trends

YEAR	VARIABLE			
	Rainfall Amount(in mm)	**Temperature amount (in °C)**	**Maize Production Amount (in bags per acre)**	**Beans Production Amount (in bags per acre)**
2010	1814.7	21.82	26	10
2011	1479.65	21.66	16	15
2012	2011.47	21.33	25	12
2013	2002.22	20.99	36	10
2014	1390.90	21.23	16	16
2015	1767.17	21.14	10	15
2016	1621.5	21.15	20	5
2017	1971.91	21.59	36	7
2018	1881.02	21.4	18	6
2019	2452.96	21.12	25	15
2020	2020.63	21.53	20	6
Average	**1855.83**	**21.36**	**23.45**	**10.91**

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Humidity is negatively correlated with both annual maize and bean production ($r = -0.869$, $p<0.05$) and annual average temperature ($r = -0.813$, $p<0.05$). The higher the temperature, the higher the rate of evaporation, which will result in a lot of soil moisture being lost to the atmosphere. The higher the rate of soil moisture loss, the more the crop will be stressed due to crop wilting. Continued crop wilting will result in reduced crop growth and, finally, low maize production.

From the above summary, it is evident that climate change has a statistically significant correlation with seasonal agricultural drought in the study area ($p<0.05$). Thus, we reject the Ho (null hypothesis) that there is no evidence of climate change and agricultural drought among small-scale farmers in Kakamega South Sub-county and accept the H_1 (alternative hypothesis) that there is evidence of agricultural drought and climate change.

These findings concur with the available research, which views agricultural drought as a significant barrier to achieving sustainable development through food security. The weather, the amount of carbon dioxide in the air, and the amount of ozone in the earth have all been altered by human activities (Thornton et al., 2006). Warmer climates may be beneficial to food production in temperate regions (IPCC, 2007), but they will create difficulties for farmers in tropical regions due to the increased likelihood of droughts, floods, and heat waves.

Table 6
Evidence of Climate Change and Agricultural Drought

Variable		**Rainfall**	**Humidity**	**Maize and beans bags produced**
Rainfall	Pearson Correlation	1		
	Sig. (2-tailed)			
Humidity	Pearson Correlation	.834*	1	
	Sig. (2-tailed)	.001		
Maize an bean bags produced	Pearson Correlation	-.801	-.869*	1
	Sig. (2-tailed)	.055	.024	
Temperature	Pearson Correlation	-.549	-.813**	.643
	Sig. (2-tailed)	.064	.001	.168

**. Correlation is significant at the 0.01 level (2-tailed). (n=380)

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V. CONCLUSION & RECOMMENDATIONS

5.1 Conclusions

The findings indicated that there was evidence of climate change and seasonal drought in Kakamega South sub-county. There was a positive linear trend in annual mean precipitation from 1985 to 2020, and this prediction shows that there is likely to be an increase in annual mean precipitation in the future years in the area. There was a positive linear trend in annual mean temperature from 1985 to 2020, and this prediction shows that there is likely to be an increase in annual mean temperature in the future years in the area.

5.2 Recommendations

From the above summary, it was recommended that in order to improve the sustainability of agricultural production in the Kakamega South sub-county, it is necessary to use drip irrigation, rainwater collection (including roof water and floods collection), and green house techniques in addition to the traditional method of farming, which relies on rain.

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