Examining the Relationship Between Drought Trends and Food Crop Production in Siaya County, Kenya

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Abstract

Over the years and throughout the earth's history, drought has occurred in both temporal and spatial scales indicating climate change. Siaya County experiences drought that is largely attributed to climate change. These drought events lead to total crop failure or significantly reduce the yield of rainfed crops such as maize, beans, sweet potatoes, cassava and sorghum causing persistent food insecurity. The study examined the relationship between drought trends and food crop production in Siaya County. The research designs are composed of correlational and descriptive designs. Purposive sampling was employed based on the relevance of the source of data for the study. Secondary data mainly of annual rainfall and temperature (1992 – 2022) was acquired from the Kenya Meteorological Department. Annual food crop yield data (2012 – 2022) was sourced from the Department of Agriculture, irrigation, food, livestock and fisheries, County government of Siaya. Analysis methods involved Times series, Man-Kendall, descriptive, inferential analysis to examine annual precipitation, temperature and annual crop yield. Drought was analyzed using Standardized Precipitation Index. Findings reveal that there was a strong negative relationship between drought occurrences and food crops production with a correlation coefficient of -0.540, significant at 0.05, p value = 0.05. This indicates that increased drought trends led to reduction in annual food crop production which declined to 288,990.9 metric tons. There is need for relevant authorities such as KALRO and the departments of Agriculture to increase resources and efforts in educating the small-scale farmers on sustainable corrective drought risk reduction approaches to enhance food crop yield. The findings from this study will help small scale farmers better understand current drought trends and strengthen their capacities to increase production of food crops. Additionally, evidence-based policies can be informed from these findings to foster a risk sensitive development on food security.

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Keywords: Drought Trend, Food Crop Production, Climate Change, Rainfed Agriculture, Small Scale Farmers, Drought Risks, Standardized Precipitation Index (SPI), Mann-Kendall Trend Test, Agricultural Policy, Siaya County

Introduction

Climate change refers to long-term shifts in temperatures and weather patterns. Common weather patterns include hot and dry weather, wet and rainy weather, and cold weather. Such shifts can be natural, due to changes in the sun's activity, large volcanic eruptions or due to Human activities. According to IPCC (2007), Climate change describes a change in average conditions of climate elements such as temperature, precipitation, wind speeds and direction, humidity sustained for at least 30 years that may lead to change in climatic pattern in a given region and time leading to occurrence of climatic extremes such as drought. Climate change may be directly or indirectly attributed to human activities like deforestation and intensive and extensive agriculture that alters the composition of global atmosphere, and which is in addition to natural climate variability observed over a comparable period of time (Holden, 2006).

In the event of climate change, erratic weather events such as reduced or increased amount of rainfall and temperatures occur, hence impacting food crop production differently in different locations and times (IPCC, 2022c). Through the changes in the climate, there are chances of possible increase or decrease in food crop production in both spatial and temporal scales. However, the negative impacts over time outweighed positive impacts in many regions. According to FAO (2022), higher temperature can reduce crop yield where $1^0 c$ rise in temperature may reduce major crop yield by 5 – 10% of the total annual food crop production to add to the possible heat that can also shorten growing season and reduce critical development of food crops during growing seasons. Equally, erratic rainfall patterns have also been identified as having negative impacts on food crop growth and development hence reducing the annual food crop production (FAO, 2015).

Global climate change has occurred throughout earth history in pattern, and this has been determined by a range of factors like astronomical, atmospheric, geological and oceanographic differences that vary naturally over decades (IPCC, 2019a). The difference in the natural forces alters the global climatic patterns in precipitation and temperature among other climatic elements. Notably, findings indicate that the change in the global climate is highly contributed by the anthropogenic activities that involve intensive and extensive combustion of carbon-based fossil fuels like oil and coal. Other factors are attributed to astronomical factors based on the energy from the sun that drives the earth's climate. According to the NOAA (2019), global temperature has increased at an average of 0.07 Celsius degree per decade since 1880. According to Lindsey and Dahlman (2020), from 1900 to 1980, a new temperature record was set on average every 13.5 years. However, since 1981, it has increased every 3 years with the five warmest years between 1880 and 2019 occurring since 2015 while nine of the ten warmest years occurring since 2005. Therefore, on average, the global temperature has increased and this in turn increases evaporation hence increases in the global precipitation. According to NOAA (2019), the global precipitation has increased at an average rate of 0.08inches per decade since 1901. Drought trends founded on the increasing temperatures and reducing the amount of rainfall received leading to drought have led to varying trends in the food crop production globally. According to Loladze (2014), it's true that higher $CO2$ levels can slightly benefit some plant growth; however, the bigger picture from studies shows a decrease in crop yields. Therefore, food crop production is highly sensitive to climate change where it gets affected by the long-term trends in average rainfall and temperatures. If there is no attention to address climate change, things could get much worse. Some models predict a staggering 17% plunge in essential crops like maize, wheat and rice by 2050

(FAO, 2016a). This highlights the urgent need for the world to adopt farming practices to guarantee food security for a world with more and more people to feed.

African is the most affected continent by the negative impacts of climate change resulting from drought. Africa has warmed by over 1degrees Celsius since 1901(IPCC, 2021) with a prediction of reduced precipitation likely in the Northern Africa and Southwest parts of Southern Africa by the end of the century. Africa therefore faces a perfect storm when it comes to drought and food crop production. Already struggling with scarce water and a reliance on rain-fed crops, the continent is expected to see temperature increase exceeding the global average where, some regions may experience an increase of 1.5 to 4 degrees Celsius by 2100 (UNCCD, 2021). This warming will likely bring more frequent and severe droughts. Studies by the FAO and World Bank predict these changes could cause significant drops in crop yields, ranging from 5% to a staggering 50% depending on the location and specific crop (World Bank, 2022). With less food being produced, millions of Africans could face hunger, making food security a critical challenge.

Locally, varying extreme climatic trends causing drought has been experienced since 1960 in Kenya (McSweeney *et al*., 2009). The changes in climatic conditions are attributed to the complex tropical climate that varies significantly between regions due to countries' variable topography and the influence of several regional and global climatic processes (MENR, 2002). According to GoK (2018), there is a mean annual temperature increase of 1.0 degrees that is an average rate of 0.21 degrees per decade since 1960 while the rainfall change has also been noticed however, the change does not show statistically significant trends due to the varying topography with varying annual amount of rainfall received in Kenya. However, the changing patterns of climatic conditions such as droughts have continuously affected subsistence food crop production mainly maize, beans, sorghum, millet and vegetables that is 98% dependent on rainfall (Thorton and Gerber, 2010). Kenya therefore faces a growing threat to its food supply as climate change pushes temperatures higher than the global average. This warming trend brings more frequent and harsher droughts. According to (Onyango, 2016), these changes could cause significant drops in crop yields, ranging from 5% to a worrying 28% depending on location and specific crops. This decrease in harvest could lead to crop failures, jeopardizing the livelihoods of Kenyan farmers who rely on the food crop production for their survival.

Siaya County just like the other parts of Kenya receives a bi modal rainfall pattern with long rains occurring between March and May (MAM) while short rains occurring between September October and November (SON) (GoK, 2013). According to Abura *et al*., (2017), Siaya County has no significant rainfall trend but displays variations in rainfall and Temperature over time (1986 – 2015). However, there are experiences of increased trends of drought frequencies and intensities that are attributed to climate change. These events have led to low food crop production of rainfed crops mainly maize, beans, sweet potatoes, cassava and sorghum causing persistent famine in the study area (GoK, 2022).

Some of the research that have been carried out on food crop production problem in Siaya include first, (Odunga, 2019) on food production and food security of smallholder farmers and their support by County Government of Siaya. This research aimed at investigating the contribution of the relevant policies by the County government in improving small scale holder's crop production to enhance foods security in Siaya. Secondly, (Abura *et al*., 2017) on Rainfall and Temperature variations and their impact on food production in Siaya County which aimed at investigating the possible impacts of the climate variability on food production. Unlike the two-research stated, this study is based on the relationship between drought trends and food crop production in Siaya County. In the best understanding of drought trends and their relationship with food crop production, the small-scale subsistent farmers seize an opportunity to put in place suitable drought risk reduction measures. These measures are those that are expected to improve and strengthen the capacity of rainfed agricultural systems hence fostering a risk sensitive development of food security amidst droughts from the changing climate.

Objective of the study

The objective of this study was to examine the relationship between the drought trends and food crop production in Siaya County, Kenya

Research Methodology

Study Area

This research was conducted in Siaya County, which is one of the six counties within the Lake Victoria Basin in Kenya. Siaya County has a land surface area of 2,530 km² with a water surface area of 1,005 km^2. The water surface area forms part of Lake Victoria. It approximately lies between latitude 0º 26´South to 0º 18´ North and longitude 33º 58´ and 34º 33´ East (GoK, 2015).

Research Design

Descriptive and correlation research design was used to determine the relationship between the drought trends and food crop production. Additionally, the study utilized both qualitative and quantitative approaches. Annual rainfall, minimum/maximum temperature data was acquired from the Kenya Meteorological Department for the period 1992 – 2022). While annual food crop yield was acquired from the Department of Agriculture, irrigation, food, livestock and fisheries of the County government of Siaya (2012 – 2022) based on the data that was available.

Methods of Data Analysis

Analysis of Climate Trends in Siaya County

Analysis of Rainfall and Temperature Trends

Rainfall and Temperature trends were done using both time series analysis and Mann-Kendall (M-K) software. The Mann-Kendall test is a statistical method without fixed parameters that is extensively employed for analyzing trends within climatic and hydrological time series information. The test's underlying principle involves comparing a null hypothesis (H0) suggesting the absence of a trend (with data being self-reliant and randomly arranged) against an alternative hypothesis (H1) positing the existence of a trend. The computation of the M-K statistics proceeds as follows:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \text{sgn}(x_j - x_k) \text{ ……. Equation 1}$$

The trend test is applied to a time series X k, which is ranked from k = 1,2, 3…, n−1, which is ranked from j = i + 1, i + 2, i + 3…. n. Each of the data points x j is taken as a reference point,

Sgn (xj – xk) = 1 if xj – xk > 0
= 0 if xj – xk = 0
= -1 if xj – xk < 0

This particular test has been calculated using XLSTAT 2017 software. A very high positive value of S is an indicator of an increasing trend, and a very low negative value indicates a decreasing trend. The presence of a statistically significant trend is evaluated using Z value

Drought Trends Analysis

The collected Rainfall data (1992 – 2022) was organized systematically and be analyzed using a Standardized Precipitation Index (SPI) to determine the drought anomalies and trends in Siaya County. In this method, the data was categorized based on the main seasons as DJF, MAM, JJA and SON in the region. Therefore, to analyze the drought trends, SPI was computed from the mean and standard deviations of the annual rainfall amount. (Equation 1). Where the severity of drought is measured by the value of the SPI if the computed index is negative the median precipitation = 1.00 the situation will be treated as normal, > 1.00 the situation will be treated as better than normal while < 1.00 the situation will be treated as worse. This may also be categorized as moderate, severe and extreme drought.

$H(x) = q + (1-q)G(x)$ ………Equation 3.7

Where, q is the probability of zero, calculated from the frequency of zero precipitation observations in the time series; G(x) is the cumulative probability calculated from the Gamma distribution for non-zero observations.

Analysis of the Relationship Between Drought Trends and Annual Food Crop Yields

Annual food crop yield was analyzed using time series analysis while the relationship between the drought trends and food crop production was analyzed using both descriptive and inferential statistics from SPSS version 20.0.

Results and Discussions

Rainfall And Temperature Trends in Siaya County

Time series analysis was done using MS Excel software package whereas the Mann-Kendal test was applied to determine the trends significance and correlation coefficients of the two climatic parameters. The measurable variables were time (Years) against annual rainfall (mm) and of Temperature (° C) over the period (1991 -2021). Analysis in Figure 1 shows the trend of average temperature in the study area with the year 2020 experiencing the lowest at 27.6°C, the year 2007 highest at 28.8°C, with the mean temperature of 28.2°C and with a standard deviation of 0.296983°C.

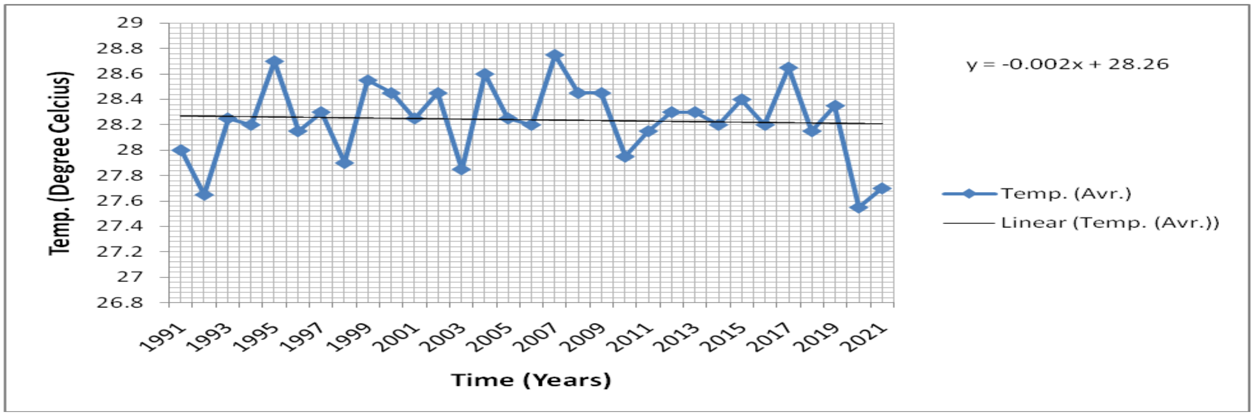

Figure 1: Temperature trend in Siaya County

Source: Kenya Meteorological Department, Siaya

The Mann-Kendall analysis was done to establish trend in the annual average temperatures in the study area under the period of study (1991 - 2021). Results in Table 1 displayed an S value, tau value and p – value. The S was computed for a statistic test to assess the presence of trend in the time series data. Results show that S had a value of 14.00. Analysis therefore shows that there was an upward trend in the temperatures in the study area. Secondly, the study also conducted a tau test to measure the strength and direction of association between Temperature (°C) and time (years) in the study area. Result of τ value = -0.031 was displayed and the nalysis therefore showed that there was weak increasing trend of temperature in the study area. Lastly, p- value analysis was done to test if the observed trend was statistically significant. The results indicated a p – value of 0.82 > 0.05 showing that there was no statistical significance in the observed trends of temperature in Siaya county.

Table 1: Mann-Kendall Test on the Trend of Temperature in Siaya County

	S	**Tau**		**Var S**	**p-value**	**Result Interpretation**
Temp.(°C) trend	14.00	-0.0308		3433.33	0.8244	Reject Hypothesis

Source: Field data (2023)

Studies have shown that there is an increasing trend in Temperature in Siaya County. Abura *et al*., (2017) in a study observed an increase in temperature in Siaya County. However, it lacked significant trends but a had a characteristic that showed variations in temperatures over the years 1986 to 2015. In the larger Lake Victoria basin within which Siaya County is located, findings from related studies on temperature and rainfall trends by Olaka *et al.,* (2019) have confirmed that there is an increasing projection of temperature. The analysis therefore shows that there was an increase in average temperature in the study area, however the increase is not statistically significant.

Rainfall Trends in Siaya County

Figure 2 shows the trend of annual rainfall from 1991 – 2021. Within the period, time series analysis identified a minimum annual rainfal amount in the study area as 1133.79 mm in the year 2016, a maximum rainfall amount of 2684.19 mm in the year 2020 and a mean annual rainfall amount of 1737.94 mm with a standard deviation of 374.03 mm in Siaya County.

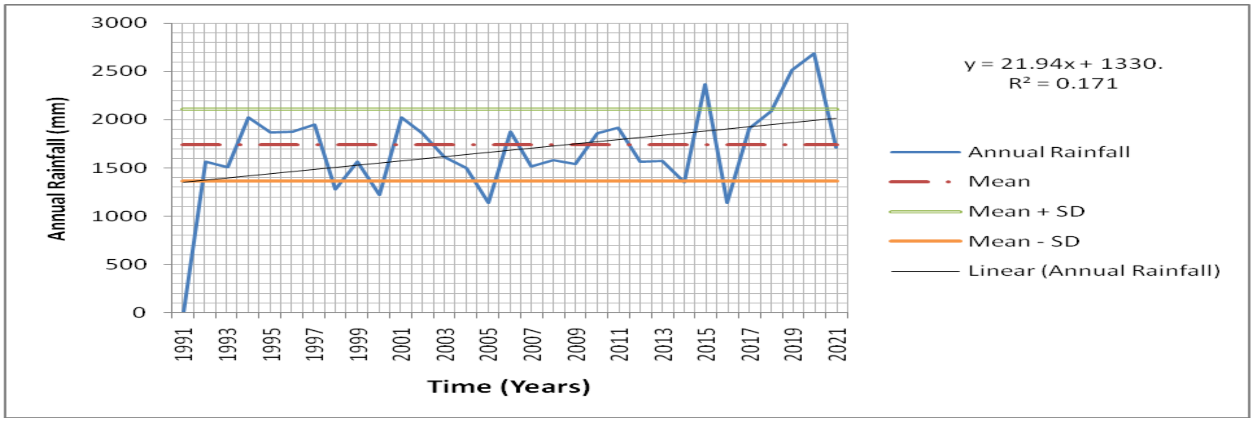

Figure 2: Rainfall trend in Siaya County

Source: Kenya Meteorological Department, Siaya County

In order to profile the years that received low amount of rainfall that could have resulted in drought conditions, time series analysis was conducted as presented in Figure 2. These were classified into below normal < (mean-SD), years that had received low amount of rainfall leading to drought conditions normal (mean-SD and mean + SD) and above normal > (mean + SD) conditions based on the Kenya Meteorological Department (KMD) convention (Mugalavai and Kipkorir, 2015). Using one standard deviation as appoint of reference, the region above (mean + SD) indicated years that received higher amount of rainfall. Rainfall data analysis for the period under consideration (1991 – 2021) show that there was possibility of drought occurrence in 1991, 1998, 2000, 2005, 2014 and 2016 based on the fact that their annual rainfall amount was below the normal, while years that might have experienced wet episodes are 2015, 2018, 2019 and 2020 basing on the higher annual amount of rainfall that was received being above normal in Siaya County. The normal annual rainfall years fall between the (mean + SD) and (mean – SD) considering the period under investigation. The study further conducted a Mann-Kendall test analysis to establish the trend of annual rainfall in the study area for the period under the study (1991 – 2021). Table 2 indicated an S value of 69.00, the analysis therefore showed that there was an observable increasing upward trend of annual rainfall amount received in the study area. Additionally, the results indicated tau value, τ = 0.159. This therefore shows that there was a weak increasing trend of rainfall received annually in the study area. Lastly, a p – value of 0.23, P > 0.05 thresholds was displayed. Analysis hence shows that there is no statistical significance in the observed increasing trend in the annual rainfall received in Siaya County.

Table 2: Mann-Kendall test on the trend of rainfall in Siaya County

	S	**tau**	**Var S**	**p-value**	**Result Interpretation**
Rainfall trends	69.00	0.159	3141.67	0.2251	Reject Hypothesis

Source: Field data (2023)

The results revealed lack of statistical significance in the increasing trends of annual rainfall for the period (1991 – 2021) hence is rejecting the hypothesis. This study resonates with Wabwire *et al*. (2020) findings which established that rainfall extremes have become frequent and there is a general increase in the trends, however, indicating no statistical significance in Lake Victoria Basin. However, Ogega *et al.* (2020) also observed that there had been increased amount of rainfall received within the Lake Victoria Basin that was attributed to the changing climate hence leading to increased levels of water in Lake Victoria over the years.

Drought Occurrence in Siaya County

Drought occurrence analysis was done to establish drought characteristics such as drought duration, intensity and probability of occurrence. Annual and Seasonal drought anomalies were analyzed to assess the possible effects and magnitude of drought on the growing seasons in the study area.

Annual Drought Index in Siaya County

The study sought to establish the nature of drought on an annual level. The results were important in monitoring the annual trends of drought that would also be used to test its cumulative effect on the annual food production of the dominant crops and trends in the study area. The Standardized Precipitation Index (SPI) is a widely used meteorological drought index that quantifies precipitation deficits over various time scales. This index provided a standardized way to assess and compare the severity of drought conditions, making it a valuable tool for drought monitoring in the study area. SPI was used to calculate the difference between the actual precipitation for the time period under study (1991 – 2021) and the long-term average precipitation for the same period. This difference was then normalized by the standard deviation of the historical precipitation to establish the indices. The results are presented in Figure 3.

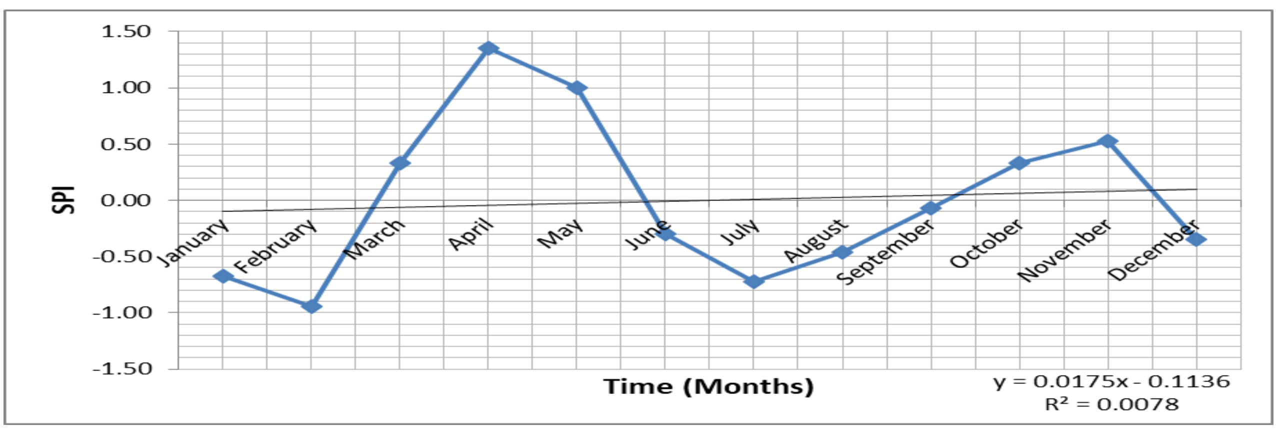

Figure 3: Drought index in Siaya County

Source: Field data (2023)

The analysis indicates that within 12 months' time period, seven (7) months SPI values were below the positive mark while five (5) month time periods were all within the positive values implying normal climate conditions. According to Mckeel *et al*. (1993) a drought event is defined when the SPI value reaches -1.0 or less and drought ends with the values reaching +1 value. The analysis therefore showed that within the time period (1991 – 2021), 58% (7/12) of the months in every year experienced drought conditions while just 42% (5/12) had normal climatic conditions in Siaya County. In reference to Figure 3, these results agree with the periods of drought generally profiled in Siaya County climate change action plan 2023 – 2028 GoK (2023) where December, January and February (DJF), that is the first, second and twelfth month; June July and August (JJA) that is the sixth, seventh- and eighth-month indices are below the positive mark indicating drought. Regression analysis conducted display a weak positive $R^2 = 0.007$ relationship indicating low significance towards the increasing episodes of drought with regard to the trend line.

Drought Duration in Siaya County

In reference to the results in Figure 3, in terms of duration of occurrence, the longest drought episodes occurred from June, July, August and September lasting for 4 months followed by December, January to February lasting for 3 months within the period of study in the study area. This was also supported by participants in the Focus group discussions with the majority indicating DJF as the time when the droughts normally have an impact because of the longer time they take. The participants disagreed with any other duration more than three months of persistence to drought. However, some participants seemed to have consensus that the prolonged drought persisted within three months followed by intervals of short rainfall that occurred for days then the dry conditions resumed.

Drought Intensity in Siaya County

In reference to Figure 3, drought severity analysis shows that the 12-month period displayed a mild drought. According to McKee *et al*., (1993) SPI values between above zero (0) is categorized as no drought, 0 to -0.99 is as mild drought, -1.00 to -1.49 as moderate, -1.5 to -1.99 as severe while -2.00 and less is categorized as extreme. Therefore, cumulatively the drought exhibited in the study area is attributed to the 7 months lying below zero (0) from the analysis that falling between 0 to -0.99. According to NDMC (2021), drought conditions can negatively affect agricultural production and mainly food crops irrespective of level of intensity. The study found out that the response about how intense the droughts have been based on the level of negative impact due to drought episode caused on the agricultural systems like food crops in the study area. According to Mishra and Singh (2010) apart from other physical indicators such as stream flow and rainfall, drought severity can also be measured based on its negative impacts to other interdependent systems like agriculture and water availability and supply.

Frequency of Drought in Siaya County

In reference to Figure 3, the results showed that in Siaya County, there were two drought episodes within a year and mainly in the December, January and February (DJF) and the June, July and August (JJA) seasons. It therefore means that drought occurred and recurred after every three (3) months in a year. These episodes occurred intervaled by other three months of March, April and May of wet season then another drought episode of June, July and August after which another wet season of short rains of September, October November (SON) and the circle continued for rest of the years under the period of study (1991 – 2021). The two episodes of droughts had months falling below 0 mark to the negatives such as DJF indexed at -0.4, -0.6 -0.9 respectively, intervaled by wet seasons of MAM then another drought season of JJA indexed -0.4, -0.8 and -0.50 respectively below the 0 mark.

These results agree with the views of focus group discussion participants that the drought occured every year and twice every growing seasons which which are "*opon and chiri*" in a year in the study area. This was also in accordance with a key informant from the Department of Meteorology, Siaya meteorological weather station's views that droughts occur at least ones a year in Siaya County. However, droughts differ both temporal and spatial scales where Siaya County has varied geographical characteristics that make different parts of the County experience drought at different times. Through Focus group discussions, the participants also agreed that there are instances where the droughts also come between the months of June, July and August then resume from in December, January and February making its twice a year.

Seasonal Climatic Anomalies in Siaya County

The study performed a Standardized Precipitation Index analysis on the seasons that characterize the year in the larger Lake Victoria basin. These Seasons were a) December, January and February (DJF), b) March, April and May (MAM), c) June July and August (JJA) and d) September, October and November (SON) as presented in Figure 4.

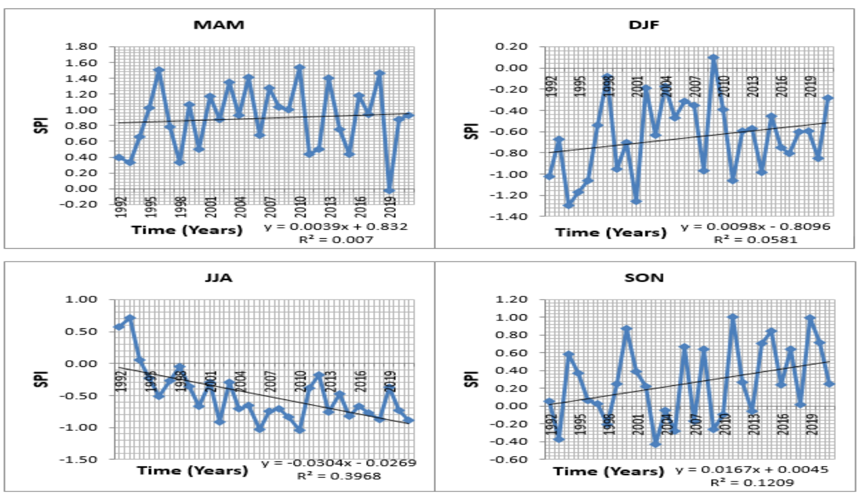

Figure 4: Seasonal climatic anomalies in Siaya County

Source: Field data (2023)

The study sought to test the climatic anomalies for each and every season that may inform the level of risk to the crops mainly in the growing seasons in Siaya County. The analysis in Figure 4 showed that MAM had relatively higher amount of annual rainfall compared to other seasons in the study area. The trend line also displays an increasing trend in rainfall amount over the years under study (1991 – 2021) however of low significance with $R^2 = 0.007$. Results indicate no drought events within the MAM seasons over the period of study with all the years falling above 0 value on the SPI scale during MAM seasons. Results therefore show that just for one year (2019) MAM season experienced mild drought conditions in Siaya County. This means that 1/30 (3%) was mild drought while the rest of the season experienced normal and extremely wet conditions in Siaya County.

Analysis for season JJA shows that annual rainfall received in that season under the period of study reduced as displayed by the trend lines. However, there is low significance with R^2= 0.396 of the decrease in amount of annual rainfall. The analysis therefore shows an increase in drought episodes within the season of every year within the time period of study. Out of the 30 years, just 3 years (1991, 1992, and 1993) were above 0 SPI value indicating normal years; 27 years had JJA falling below 0 SPI value indicating drought where, 25 years exhibited mild drought while 2-year (2005 and 2009) JJA seasons exhibited a moderate drought falling between -1.00 and -1.49. The results showed that 3/30 (10%) of the seasons were on the normal, 25/30 (83%) were on the mild drought while 2/30 (7%) were on the moderate drought categories.

September, October and November (SON) season displayed an increasing annual rainfall amount R^2= 0.120 having low significance. The analysis shows that within the 30 year period, just 10 years had their SON falling below 0 SPI value, that is 33.3% of the seasons experienced mild drought while 66.3% of the seasons experienced normal and wet climatic conditions.

The results further showed that there was an increasing amount of rainfall in the DJF season in the study area which was exhibited by the increasing trend line. The analysis revealed that within the time period under study, just 1 year (2008) had its DJF season above the 0 SPI value depicting a normal climatic condition. It means that 29 years of the period under study were below 0, meaning they had drought episodes where 23 years experienced mild drought conditions in their DJF while 6 years experienced moderate drought conditions in their DJF seasons. It can therefore be deduced that 3% of the DJF seasons over the years were normal, 77% of the seasons experienced mild drought while 20% of the DJF seasons within the time period experienced moderate drought in Siaya County.

Trends in the Individual Dominant Food Crop Yields in Siaya County

This section analyzes and discusses trends of individual dominant food crop yields including a) maize, b) sorghum, c) beans, d) cassava, d) sweet potatoes and e) total annual crops production trends as presented in Figure 5.

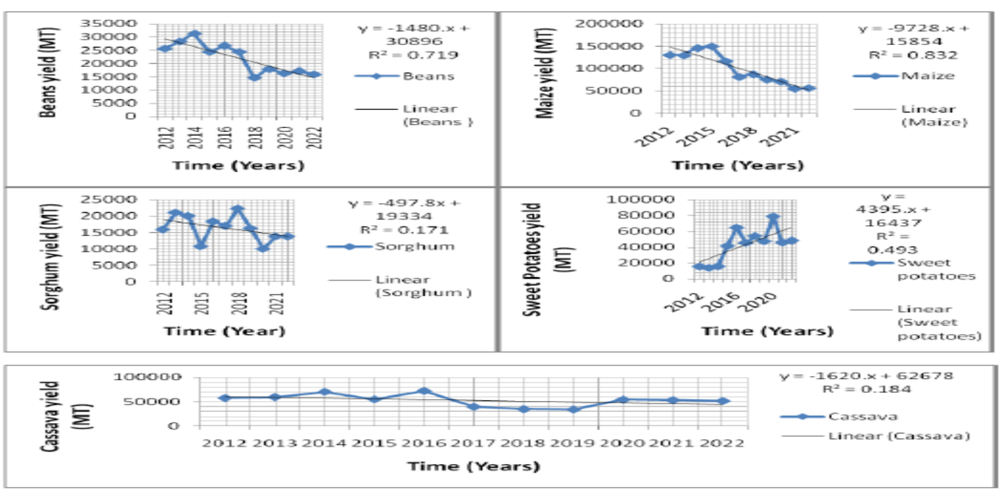

Figure 5: Annual individual dominant food crop trends in Siaya County

Source: Department of Agriculture, irrigation and Livestock of Siaya County (2023)

The analysis illustrates that under the period (11 years), maize as the most dominant food crop had a mean of 100, 166.8 tons with a standard deviation of 35,375.19 tons. The analyses further reveal that there is a declining trend in annual maize yields in the study area with R^2 = 0.832, which reveals a significant decline in annual maize production with R^2 being much closer to the 1 threshold regresion. This finding is supported by Odunga (2019), who observed that maize plays a critical role in addressing food security in Kenya, however, its production has been on the decline due to climate change, pests and diseases, erratic rainfall and droughts hence affecting food crop production.

Sorghum, had a mean of 16,346.46 tons with a standard deviation of 3,991.07 tons. The analysis shows that there was a decreasing trend in annual sorghum yields over the period under the study in the study area with R^2 = 0.171. Sorghum is an important food crop towards food security in the ASALs of Kenya due to its ability to tolerate various climatic risks (FAO, 2019). However, according to Njiju *et al*. (2022) most farmers who are mainly small-scale famers in the rural areas of Kenya have limited resources to sufficiently address the challenges that are not only based on the climatic conditions but of market dynamics therefore causing decline in the sorghum yield annually.

Beans as the most dominant leguminous food crop in the study area had a mean of 22,015.46 tons with a standard deviation of 5,786. 53 tons. The analysis shows that there was a declining trend in beans annual yield over the period that was under study. The trend line analysis show an R^2 = 0.719 indicating a strong positive significance relating to R^2 nearing 1 threshold relationship. Beans farming greatly contributes to the Kenyan economy apart from being a staple food to majority in Kenya and other parts of the world (Chianu *et al*., 2008). The crop, however, has encountered a mirage of challenges thereby affecting its production, hence contributing to food insecurity as a staple food. The challenges according to Kadenge *et al*. (2012) were attributed to low soil fertility, drought, pests and erratic rains in the crop growing seasons. This therefore contributed to its declining trend in yield however it has an average yield of 1 tone per hectare in the whole country.

With regard to the tubers food crops in the study area, sweet potatoes had a mean of 42,807.45 tons with a standard deviation of 20, 756.22 tons. Annual sweet potatoes yields indicated an increasing trend over the period under investigation within the study area. The increase in production had a moderate positive significance with R^2 = 0.493. Lastly, Cassava as the other dominant food crop tuber in the study area displayed a mean of 52, 955. 73 tons with a standard deviation of 12,496.81 tons. Cassava production analysis indicated a declining trend in annual production for the period (2012 – 2022). However, the results displayed weaker significance but positive R^2 = 0.184 in relation to the rate of decline in the study area.

The study further sought to establish the trend from the cumulative dominant food crop yields in Siaya county. This was to test the trend that exists regarding total food crop yield to ascertain whether the crop production was increasing or decreasing in Siaya county. The study therefore summed up the yields of all the crops per year for the period (2012 – 2022) then calculated the mean of the total yield per year. This was then used to plot in an excel for line graph and the trend is as shown in Figure 6.

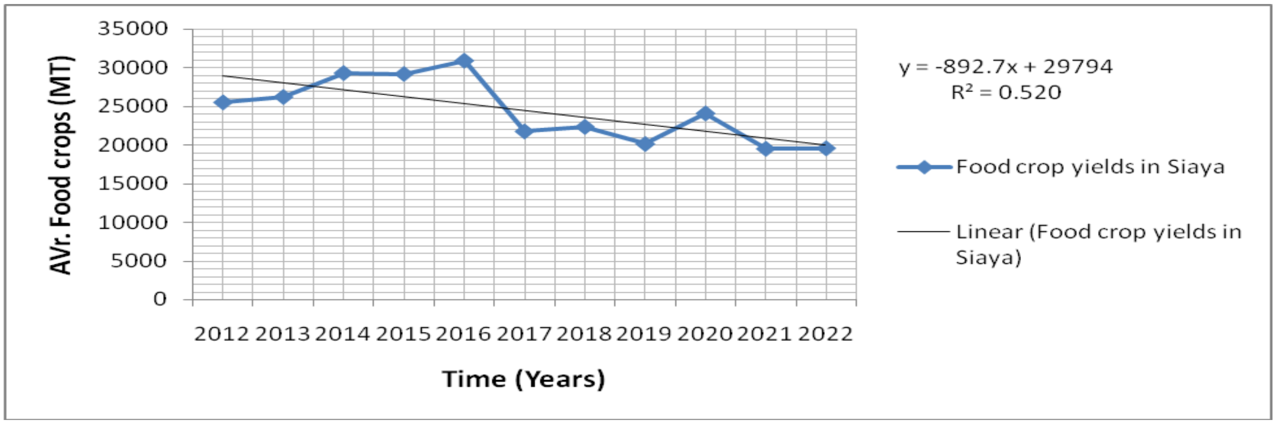

Figure 6: Annual means food crops production in Siaya County

Source: Department of Agriculture, irrigation and Livestock of Siaya County (2023)

The study analyzed the yearly mean of the total dominant food crops in the study area under the period of study (2012 – 2022). The results in Figure 6 Show that the dominant food crops had a mean of 234,291.9 tons with a standard deviation of 41,034.06 tons. The analysis displays a generally declining trend in food crops production in the study area with $R^2 = 0.520$. The trend therefore reveal that the decline had a strong positive significance over the years (2012 – 2022) that may have affected food security in Siaya County.

Correlation Between Drought Trends and the Dominant Crop Yields in Siaya County

The study conducted correlation test involving drought episode through the annual indices and the annual crop yields of the dominant crops of Maize, beans, sorghum, cassava and sweet potatoes focusing on the 2012 – 2022 period in Siaya County.

Correlation Between Drought Trends and the Dominant Food Crop Yield for Food Security in Siaya County

The study sought to establish the relationship between climate anomalies of drought occurrence and food production. Correlation was used with null hypothesis (H_0) that there is no statistically significant relationship between drought episodes and the dominant food crop yields in Siaya County. Results are as presented in Table 3.

Table 3: Summary of the relationship between Drought and crop yields in Siaya County

SN	Crop type	correlation coefficient	P -– value
1	Maize	-0.276	0.040
2	Sorghum	-0.468	0.172
3	Beans	0.207	0.567
4	Sweet potatoes	0.298	0.003
5	Cassava	0.485	0.155
6	Yearly average crop yield	-0.540	0.05

Drought trend and annual Maize yield relationship was tested. The analysis showed that there exists a negative relationship where the increase in drought episodes reduced maize production. The analysis generated a correlation coefficient of -0.276 signifying a negative weak relationship between drought trends and maize production. However, with a 0.040, $P < 0.05$ which was statistically significant resulting to reduced maize yield due to the existence of drought episodes in Siaya County. The results of this study are consistent to Shengli Liu *et al*. (2022) who established that the probability of maize yield failure increases with drought occurrences in China confirming that maize yields despite varying timescales have been negatively correlated with drought intensity in many parts of the world and mainly under moderate drought conditions.

Correlation between drought trends and Beans yielded a correlation coefficient of 0.207 indicating a positive though weak relationship where, existence of the drought episodes did not affect beans production to a larger extent indicating a no significance level of 0.567, $P > 0.05$. This reveals that the drought trend on the beans annual yield for the period under study was of no statistical significance. This finding resonates with GoK (2014) on Siaya County risk profile where it is stated that drought has remained to be one of the greatest challenges to beans farming affecting it during its phenological stage mainly during germination and flowering.

Sorghum and drought trends level of the association was tested and results showed that existence of drought episodes within the period under study reduced annual sorghum yields in the study area. Correlation analysis displayed a correlation coefficient of -0.468 indicating a negative though weak relationship between drought trends and sorghum production. The analysis also generated a 0.172, $p > 0.05$ level of significance suggesting low significance in the association of reduced sorghum yield to drought episodes in the study area. This finding could be based on the fact that sorghum is a drought tolerant crop and hence however much the results show a negative association, there is a null hypothesis on the impact of drought on the sorghum annual yields in the study area. Agreeably, GoK (2013) confirmed that sorghum is drought tolerant and is steadily replacing other staple food crops like maize in Siaya County

Sweet potatoes production in the study area exhibited a positive relationship with drought trends in Siaya County. Analysis displayed a 0.298 correlation coefficient indicating that existence of drought episodes within the time period under study did not reduce the annual yield of sweet potatoes. Analysis showed an association with significance 0.003, $p < 0.05$. It can be derived that sweet potatoes production had nearly no effect from the drought occurrences in Siaya County during the (1991 – 2021) period of study. It therefore showed that due to its nature of tolerance to droughts conditions, the annual crop yields were not affected negatively. Zagipa *et al*., (2023) on sweet potatoes as a key crop for food security under the conditions of global climate change findings confirmed that sweet potatoes is an adaptable crop that produces large amount of food per unit area and time during dry and even short rainy periods giving it an advantage over other crops and hence should be adopted by communities.

Cassava annual yields and drought trends in Siaya County posted a positive relationship with a correlation coefficient value of 0.485. The analysis showed that with the drought occurrence, cassava annual production trends were not affected but increased. Statistical analysis gave significance level of 0.155, $p > 0.05$ indicating a non-significant increase in cassava annual yields hence drought however impacted negatively on the cassava crop production in Siaya County. These results hence resonate with Muiri *et al*., (2021) on mechanisms and approaches towards enhanced droughts tolerance in cassava which is a drought tolerant crop mainly used for human consumption. However, increased drought and drought like conditions are projected to affect cassava productivity in future.

Lastly, the study sought to establish if there was a statistical relationship between drought trends and annual total food crop production in the study area. Analysis indicated that there was a negative strong relationship where occurrence of drought episodes in the period under study reduced cumulative annual food crops yields in Siaya County relating to a correlation coefficient of -0.540. Level of significance of 0.05, p = 0.05 indicating a close association that the drought occurrences influenced negatively the total annual food production, reducing the yields of total food produced hence contributing to food insecurity in Siaya County. Globally, there has been a negative correlation indicating a decreasing trend of dominant food crop yields with the increasing trend of drought conditions (Hendrawan *et al*., 2023). This therefore shows that the continued increase in drought episodes will result in gradual decrease in food crop production, hence increased low food crop production in many parts of the world including Siaya that has shown an increase in temperatures and trends in drought episodes.

Conclusion and Recommendation

There is a strong negative relationship between climate trends (drought) and food crop production where an increased trend in drought reduced annual food crop production to 288,990,9 metric tons in the study period. However, floods and food crop production had a relatively positive relationship where, annual food crop yield wasn't adversely affected from a total of 288, 990, 9 metric tons despite flood occurrences over the years under study in Siaya County.

Evidently, climate trends through drought episodes and floods occurrence and recurrence impacted food crop production therefore affecting the households' food security. There is therefore need for relevant stakeholders such as KALRO to sensitize households on suitable crops for suitable seasons and regions with guidance from the Agricultural Ecological Zones to reduce risks of household food insecurity from flood and drought negative impacts.

Declaration of Competing interest

The author declares that there is no known competing financial interests or relationships that could have had influenced the work as reported in this paper.

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