Applied Ecology and Environmental Sciences, 2019, Vol. 7, No. 2, 45-55
Available online at http://pubs.sciepub.com/aees/7/2/2
Published by Science and Education Publishing
DOI:10.12691/aees-7-2-2

Impacts of Climate Variability on Maize Yields in Bahati Sub-County, Kenya

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Received January 18, 2019; Revised February 20, 2019; Accepted March 18, 2019

Abstract This study analyzed the effects of climate variability on maize yields among farm holders in Bahati Sub-County, Kenya for the period 1985 to 2015. The climate parameters used included rainfall onset, rainfall cessations, seasonal rain, annual rainfall, annual mean temperature, maximum and minimum temperature. Maize yield data for Bahati Sub-County was collected from the Ministry of Agriculture, Tegemeo Institute and Nakuru County Agricultural Office, while data on rainfall and temperature was collected from Nakuru Meteorological Station. The strength and direction of the relationship between rainfall, temperature and maize yield was determined using SPSS software version 23 (correlation analysis) and Microsoft Office Excel 2010 to generate frequency tables, pie charts, graphs and moving averages. The findings revealed that there is a significant, positive and strong relationship between rainfall trend and maize yield ($r = 0.741$, $p = 0.000$). The study also revealed that there is a significant, moderate and negative linear relationship between maximum temperature and maize yield ($r = -0.510$, $p = 0.03$). However, the study findings also revealed that the relationship between minimum temperature and maize yield had an insignificant, weak and negative relationship ($r = -0.166$, $p = 0.372$).

Keywords: *climate variability, maize yields, rainfall, temperature*

Cite This Article: Jackson K. Koimbori, Chris A. Shisanya, Shadrack K. Murimi, and Rickard Petterson, "Impacts of Climate Variability on Maize Yields in Bahati Sub-County, Kenya." *Applied Ecology and Environmental Sciences*, vol. 7, no. 2 (2019): 45-55. doi: 10.12691/aees-7-2-2.

1. Introduction

Scientists have been tasked with coming up with global response to this global challenge termed as climate change by various climate change bodies. The global surface temperatures in the last three decades and past century have warmed up by 0.6°C and 0.8°C respectively [1]. In 1992 the International Political Response to Climate Change (IPRCC) began with the ratification of the United Nation Framework Convention on Climate Change (UNFCCC). Stabilizing the greenhouse gases concentration in the atmosphere at a threshold that would avert severe anthropogenic interference with the present climatic systems in our world was the main purpose of the convention. This led to the signing of the Kyoto protocol of 1997 committing countries towards taking up climate action. According to the National Climate Change Action Plan (NCCAP) 2013 report, climate change can be monitored through measurement of the climatic parameters like wind, pressure, temperature and rainfall among others. Climate change research studies have predicted an increase of precipitation and temperature throughout the year with an annual average of 4.2mm and +2.8°C per month respectively over tropical Africa. Africa is predicted to have greater impacts in relation to changing climate because of weak adaptive capacities to climate variability and change, as evidenced by the impacts of current weather extremes e.g. floods and droughts [2]. Africa is particularly more vulnerable due to high poverty levels [3] and the reality that 66% of the total active population in Africa rely on agriculture as their primary source of livelihood [4]. According to World Bank 2013 report, 39% of people in ASALs live in Africa [5]. As a consequence of unresolved climate variability issues at local levels, Africa risks tilting towards becoming a global food crisis focal point [6]. In Kenya data from National Climate Change Response Strategy (NCCRS) in 2010 indicated that the country's day and night temperatures have increased by as much as 2.1°C and 2.9°C respectively in western parts of Kenya in the last twenty years. Meanwhile in central Kenya, which includes Nairobi the night and day temperatures have risen by 2.0°C and 0.7°C respectively. In the southern-eastern region, which includes Kenya's food basket, the rift valley temperatures have risen by 1°C. In Nairobi both maximum and minimum temperatures have shown an increasing trend for the period 1966 to 1999 [7]. Increased rainfall and temperature variability are likely to introduce additional vulnerabilities in ASALs and this would eventually lead to a pronounced impact on drought as a result of water availability (NCCAP, 2013). This is because only 20% of the territorial surface area in Kenya is classified as highly potential area receiving high amounts of rainfall to support agricultural productivity. The largest part of the country comprising of approximately 83% of the total territorial area is ASALs with minimal annual rainfall ranging from 200mm to 850mm [8]. However, over 80% of the total population occurs within the potential areas while only 20% of the population occurs in the vast ASALs [9]. Agriculture in Kenya dominates the economy in terms of contribution to income generation, employment creation, food security and raw material for industries [10]. Climate change and variability in Kenya has led the Government of Kenya to commit approximately Kenya Shillings (KES) 37 billion, while development partners have committed KES 194 billion between 2005 and 2015 to programs they have earmarked as having a major impact on climate change components (NCCAP, 2013). The farmers of Bahati Sub-County, Nakuru County have been counting loses as maize yield levels have been declining according to the Kenya economic review of agriculture report of 2015 (Table 1.1) and many attribute this failure partly due to climate variability among other factors. The proposed research study therefore sought to assess the impacts of climate variability on maize yields in Bahati Sub-County, Kenya with the aim of providing the farmers with a better understanding of the maize yield variations as a function of climate.

2. Methodology

2.1. Study Area

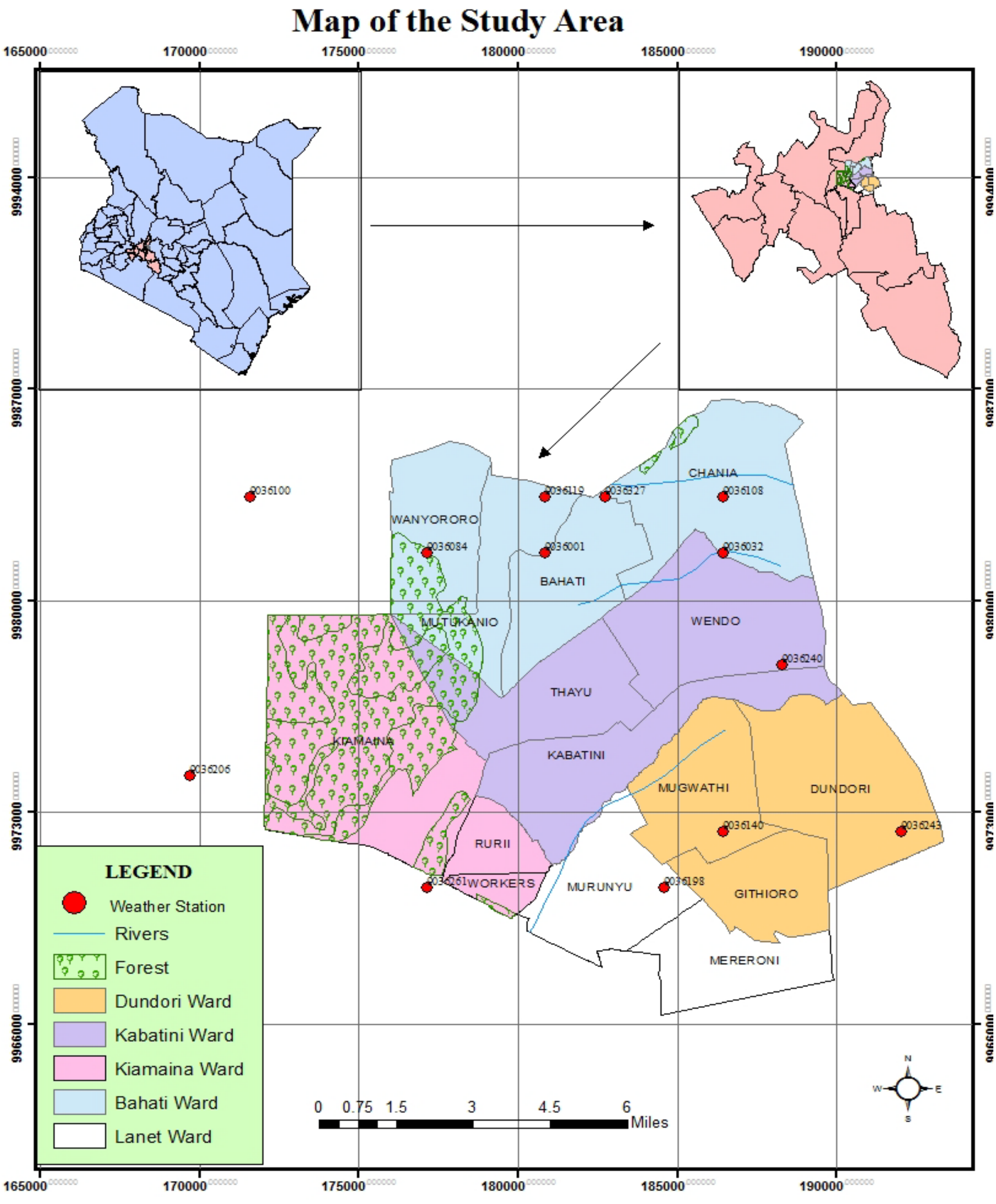

Figure 1. A Map of Bahati sub-county showing study site

The study was carried out in Bahati Sub-County which is located within Nakuru County, Kenya (Figure 1). It is made up of 5 wards of which 4 wards will be studied; Dundori ward, Kabatini ward, Kiamaina ward and Bahati ward, since Lanet/Umoja is not an agricultural area. The greater Nakuru County is in Rift valley province and occupies an area of 7,242.3km^2. It is located between longitudes 35°28' and 35° east and Latitude 0°13' and 10°10' South at an altitude of about 1912 meters above sea level. Bahati Sub-County has a population of 141,352 covering an area of 375.40km^2 [11]. Nakuru County has predictable weather patterns with temperatures ranging between 10°C during the cold months (July and August) and 20°C during the hot months (January to March). Bahati Sub-County receives between 700mm and 1200mm of rainfall annually, with average annual rainfall being an approximated 960mm. Nakuru County which covers Bahati Sub-County has two rainy seasons; March, April, May (long rains) and October, November, December (short rains) [12]. The soils are complex due to influence by variations in relief, climate and underlying rock types. The major soils fall into three categories; Latosolic soils, Planosolic soils and Alluvial soils [12].

2.2. Climate Data

A span of the most recent thirty year records from 1985 to 2015 was collected from Nakuru Meteorological Station. The climate data was a representative of the most recent average climate in the study region and the 30 years' span was sufficient duration to encompass a range of significant weather anomalies depicting monthly rainfall and temperature trends in Bahati Sub-County, Nakuru County. The rainfall and temperature characteristics for Bahati Sub-County were recorded in a summary check sheet and this included rainfall onset, rainfall cessations, seasonal rain, annual rainfall, seasonal maximum and minimum temperature.

2.3. Maize Data

Data on maize yields was collected from the Ministry of Agriculture (MOA), Tegemeo Institution and Nakuru County Agricultural Offices. This data was also collected from various literature sources, including books, journals, articles, reports and periodicals.

2.4. Data Analysis

The collected data was analysed using descriptive and inferential statistics. Descriptive statistics included measures of central tendency and measures of dispersion. The mean rainfall and temperature for the period 1985 to 2015 was determined from Nakuru Meteorological Station. Consequently, statistics on the inter-annual standard deviation and variance of rainfall and temperature for the same period were calculated. Inferential statistics was used to illustrate the relationship between variability in climate and maize yield levels. This included Pearson's correlation test, which was used to analyse the effect of climate variability on maize yields. Descriptive analysis was used to compute moving averages of two weather elements (rainfall and temperature) and maize yield levels for over the 30-year period.

3. Results

3.1. Rainfall Trends

3.1.1. Annual Rainfall Trend

The results in Figure 2, shows that the annual rainfall amount has reduced between 1985 and 2015 in Bahati Sub-County. High amounts of rainfall are noticed in the years 1988 (1244mm), 1992 (980mm), 1997 (1094mm), 2001 (1130mm), 2002 (1084mm), 2003 (1138mm), 2007 (1217mm), 2010 (1436mm) and 2013 (1185mm), while low amounts of rainfall are noticed in the years 1987 (697mm), 1993 (704mm), 2000 (610mm) and 2009 (705mm). The rainfall variability shown in the results above supports the argument that the ASALs in Kenya have been impacted negatively by high rainfall variability [8,13].

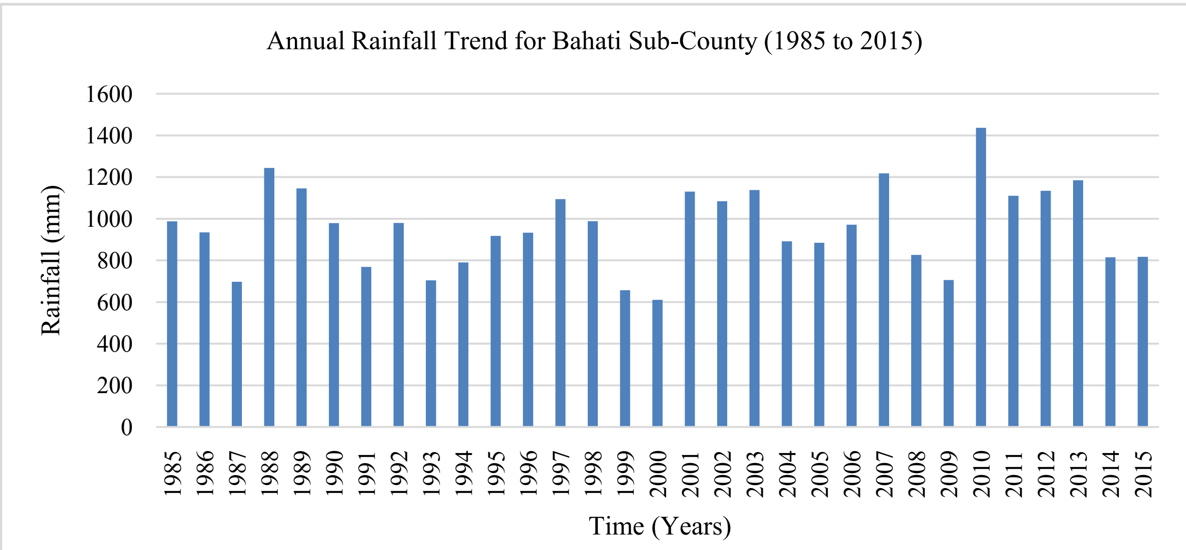

Figure 2. Annual Rainfall Trend for Bahati Sub-County

3.1.2. Seasonal Rainfall Trends

The extreme events were observed both during the long and short rainfall season. During the long rainfall season high amounts of rainfall were recorded during the years 1985 (505mm), 1988 (575mm), 1990 (487mm), 2003 (464mm), 2010 (585mm), and 2012 (453mm), while low amounts of rainfall were recorded in 1993 (125mm), 1996 (199mm), 2000 (69mm), and 2008 (179mm) (Figure 3). Further, during the short rainfall season high amounts of rainfall were recorded during the years 1989 (347mm), 1997 (464mm), 2002 (384mm), 2006 (352mm), 2008 (311mm) and 2015 (315mm), while low amounts of rainfall were recorded in 1985 (106mm), 1993 (126mm) and 2005 (112mm) (Figure 3). According to a 2007 report by Intergovernmental Panel on Climate Change (IPCC), changes in rainfall pattern in East Africa is as a result of the El Niño phenomena [14] and this supports our findings on the seasonal rainfall pattern fluctuations in Bahati Sub-County.

3.2. Rainfall Variability

The annual rainfall variability characteristics for Bahati Sub-County (1985 to 2015) were computed when annual rainfall anomalies were presented in the graph as shown in Figure 4. Annual rainfall variability ranges from -350.40mm in 2000 to +475.80mm in 2010 as shown in Figure 4. The highest rainfall anomalies were recorded in years 1987 (-263.2mm), 1988 (+283.2mm), 1993 (-256.5mm), 1999 (-303.6mm), 2000 (-350.4mm), 2007 (+256.9mm), 2009 (-255.1mm), 2010 (+475.8mm) and 2013 (+224.4mm).

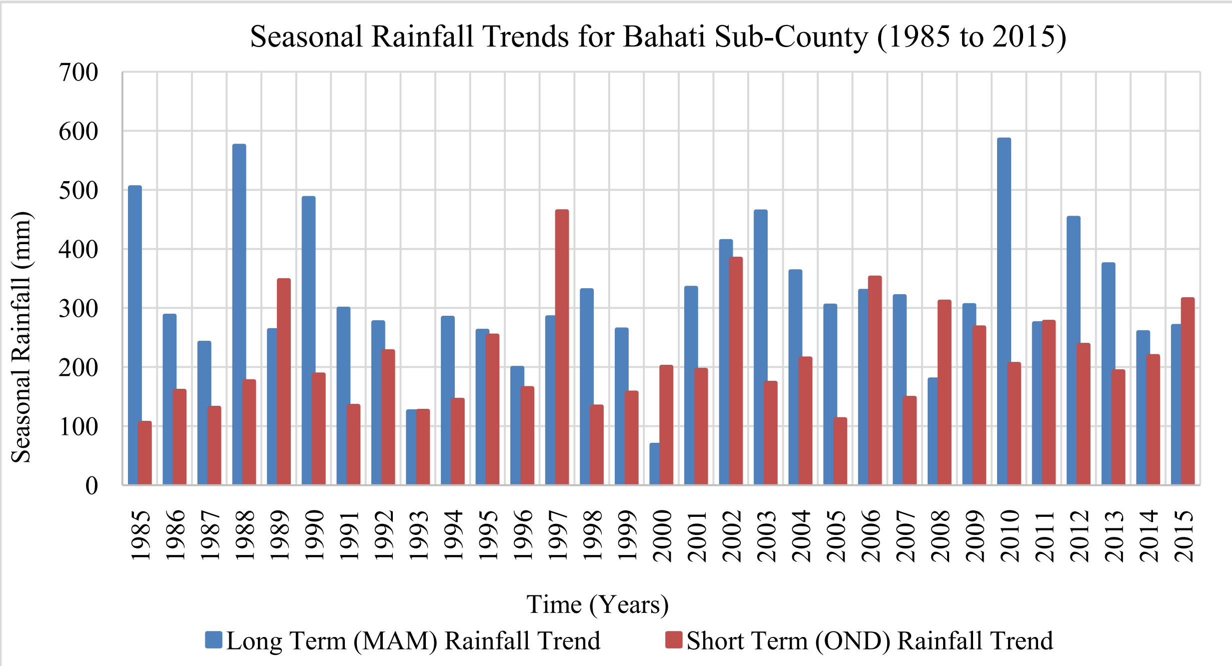

Figure 3. Seasonal Rainfall Trend for Bahati Sub-County

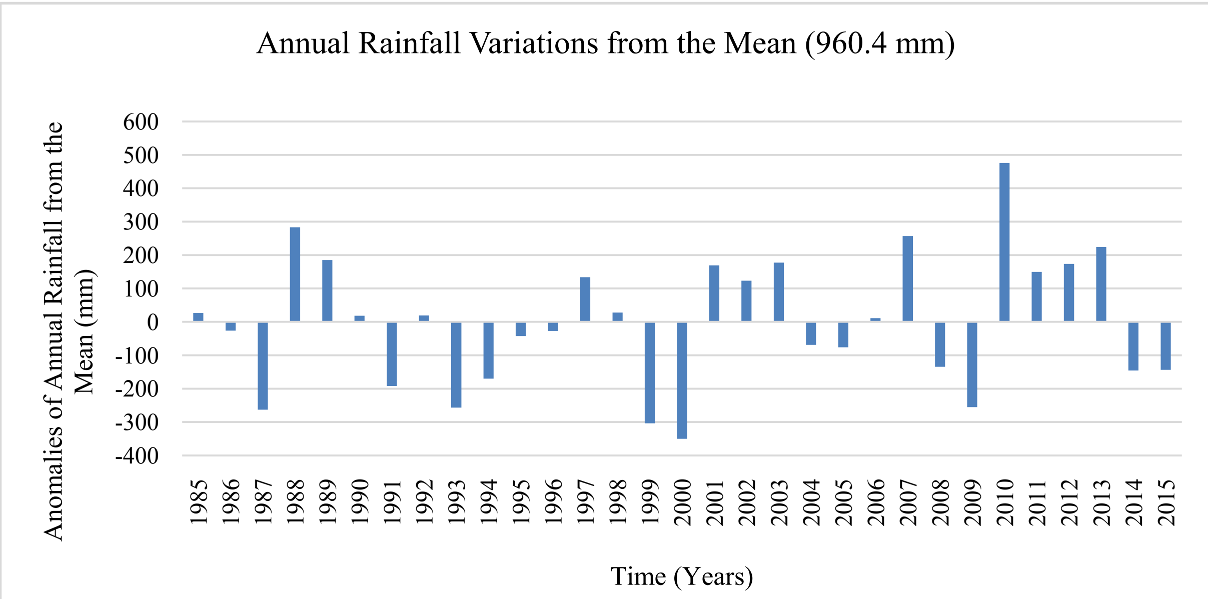

Figure 4. Annual Rainfall Variations for Bahati Sub-County

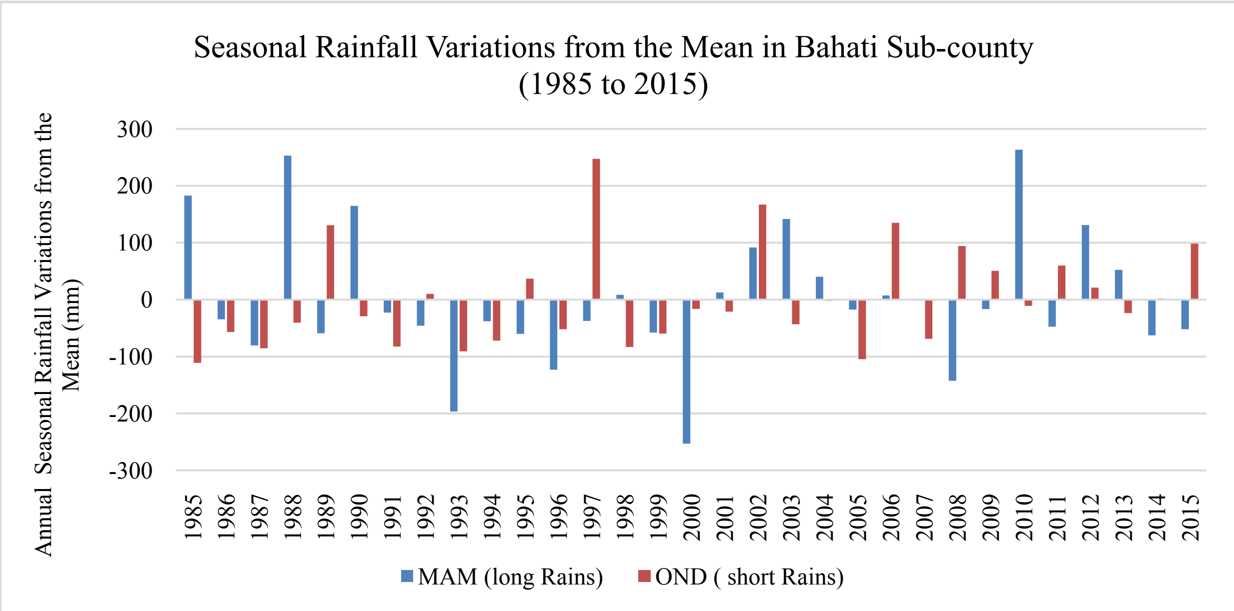

Figure 5. Seasonal Rainfall Variations for Bahati Sub-County

Table 1. Summary of Seasonal Rainfall Characteristics for Bahati Sub-County

Year	Peak Month of Rainfall During the Long Rain Season	Onset Month of Rainfall During the Long Rain Season	Cessation Month of Rainfall During the Long Rain Season	Peak Month of Rainfall During the Short Rain Season	Onset Month of Rainfall During the Short Rain Season	Cessation Month of Rainfall During the Short Rain Season
1985	April	April	July	November	November	December
1986	April	April	July	December	December	January
1987	May	April	July	November	October	December
1988	May	March	June	October	October	January
1989	April	April	June	October	October	January
1990	April	March	June	October	October	December
1991	March	March	June	November	November	December
1992	April	April	June	October	October	November
1993	May	April	July	November	October	December
1994	May	March	July	November	November	December
1995	March	March	July	October	October	December
1996	May	March	September	November	November	December
1997	April	April	June	November	October	December
1998	May	April	July	November	November	December
1999	March	March	June	December	November	January
2000	April	April	September	November	October	December
2001	April	March	September	October	October	December
2002	April	March	June	December	October	January
2003	May	March	June	October	October	December
2004	April	March	June	December	October	January
2005	May	March	July	October	October	December
2006	May	March	June	November	October	January
2007	May	April	June	October	October	December
2008	March	March	June	October	October	December
2009	May	April	June	December	October	January
2010	March	March	June	October	October	December
2011	May	March	June	November	October	December
2012	April	April	June	October	October	January
2013	April	March	August	December	November	January
2014	May	March	June	October	October	January
2015	April	April	June	November	October	January

3.2.1. Seasonal Rainfall Variations

The variability in seasonal rainfall (long and short), and occurrence of extreme events have effects on maize yield in the area exposing small scale farmers to climate change vulnerability. This collaborates with various studies that have shown that changes in seasonal rainfall patterns have a negative effect on rain fed agriculture [15,16]. Rainfall variability is significant in the long rain season trend and ranges from (-253.17mm) in 2000 to (+263.53mm) in 2010 as shown in Figure 5. Rainfall variability is also significant in the short rain season trend and ranges from (– 111.08mm) in 1985 to (+247.31mm) in 1997 as shown in Figure 5. During the long rains (MAM) the highest rainfall variations were recorded in 1985 (+182.8mm), 1988 (+253.0mm), 1993 (-196.6mm), 2000 (-253.2mm) and 2010 (+263.5mm), while during the short rains (OND) the highest rainfall variations were recorded in 1985 (-111.08mm), 1989 (+130.7mm), 1997 (+247.3mm), 2002 (+167.0mm), 2005 (-104.6mm) and 2006 (+134.8mm).

3.3. Seasonal Rainfall Onset and Cessation

The results in Table 1 shows that onset month for Long rain season has varied, alternating between March and April. 18 times representing 58.1% the onset was in March and 13 times representing 41.9% the onset was in April. Cessation month has also varied alternating between June, July and August. When farmers are informed on the onset date they plan on when to prepare their land and acquire the necessary inputs. This finding supports the earlier findings by [17] that the onset time for long term rainfall is normally used by farmers to determine the time they clear and prepare the land for planting. The peak months' range from March, April and May. The results in Table 1 shows that the onset month for the short rain season has varied, alternating between October, November and December. 23 times representing 74.2% the onset was in October, 7 times representing 22.6% the onset was in November and 1 time representing 3.2% the onset was in December. Cessation month has also varied alternating between November, December and January. The peak months' range from October, November and December. The results found that seasonal rainfall change is a challenge to Bahati Sub-County farmers and they need to be updated at all times to enable them plant on time.

3.4. Temperature Trends

3.4.1. Annual Average Temperature Trend

Temperature being the other key indicator of climate variability, this study also seeked to determine the temperature variations of the area for the last 30 years (1985 to 2015). The mean annual temperature in the area has generally been increasing since 1985 to 2015. The lowest average temperature recorded in Bahati Sub-County was 17.7°C in 1989, while the highest temperature recorded was 19.7°C in 2009, (Figure 6) and this coincides with the years 1987, 2000 and 2009 when Kenya experienced the worst droughts. According to [18], seasonal temperature changes observed could alter the growing, planting and harvesting time for agricultural production.

3.4.2. Annual Average Maximum Temperature Trend

The maximum average temperature for the Bahati Sub-County (1985 to 2015) was 25.8°C, while the highest maximum annual temperature was recorded in 1987 and 2009 at 27.0°C and the lowest in 1989 at 24.8°C as shown in Figure 7. The Trend line equation shows that Bahati-Sub-County has been experiencing a slightly gradual increase of 0.008°C annually in the maximum temperature for the period 1985 to 2015.

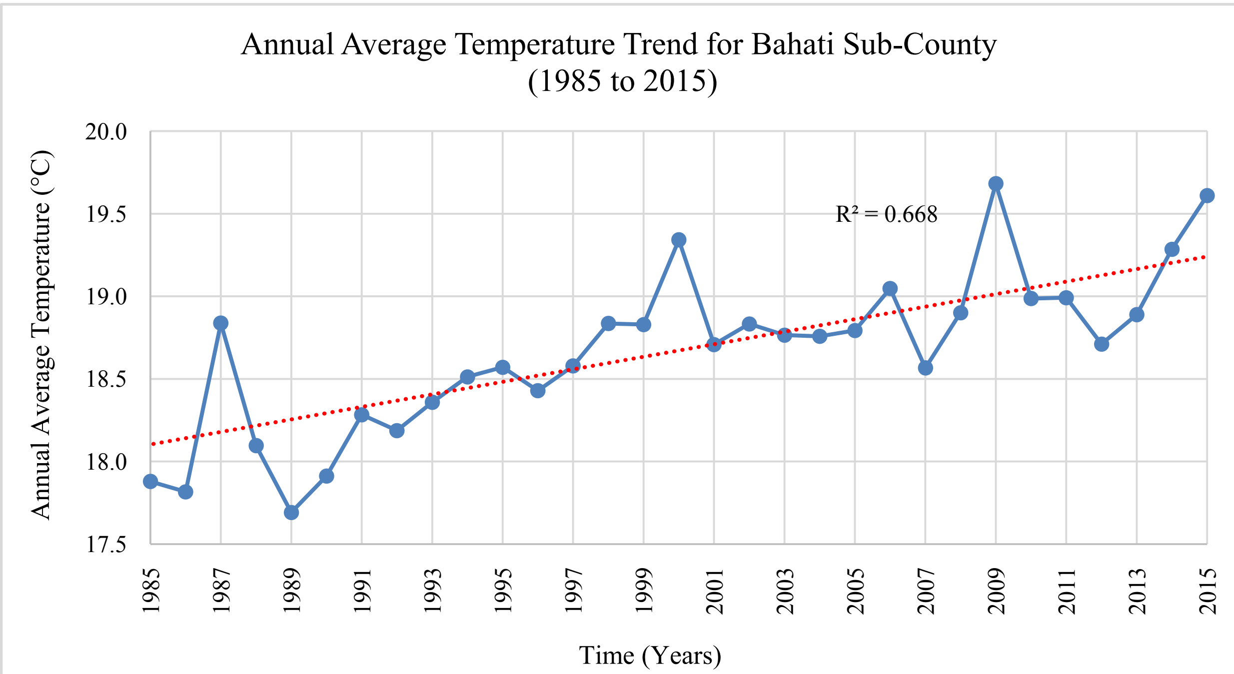

Figure 6. Annual Average Temperature Trend for Bahati Sub-County

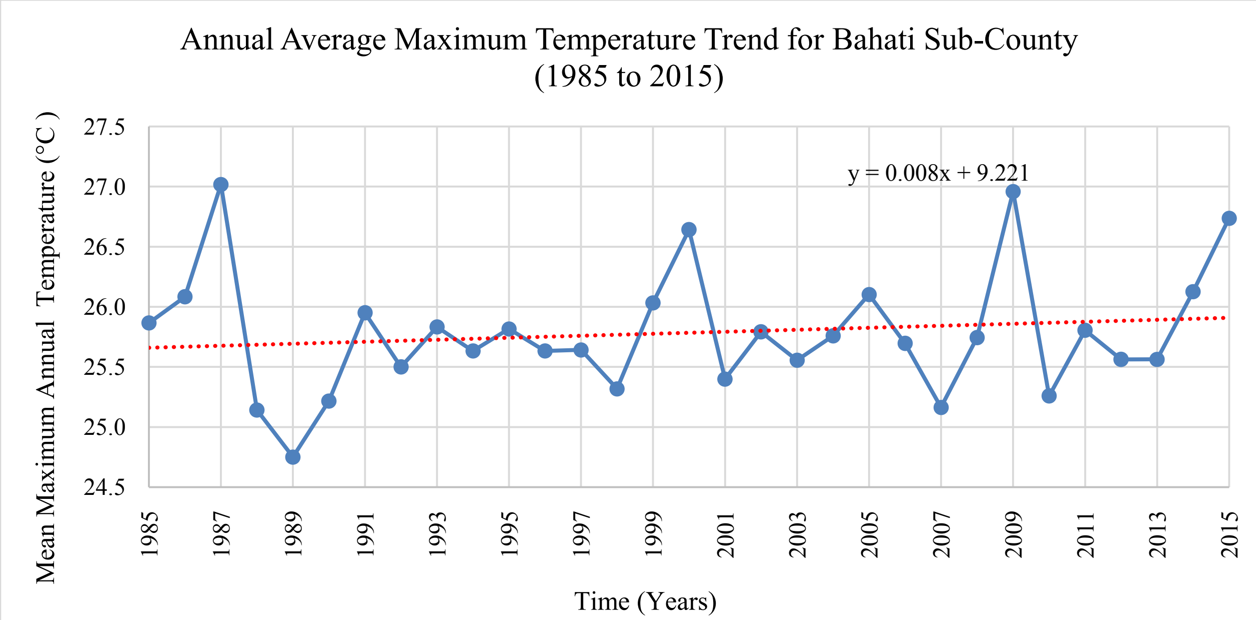

Figure 7. Annual Average Maximum Temperature for Bahati Sub-County

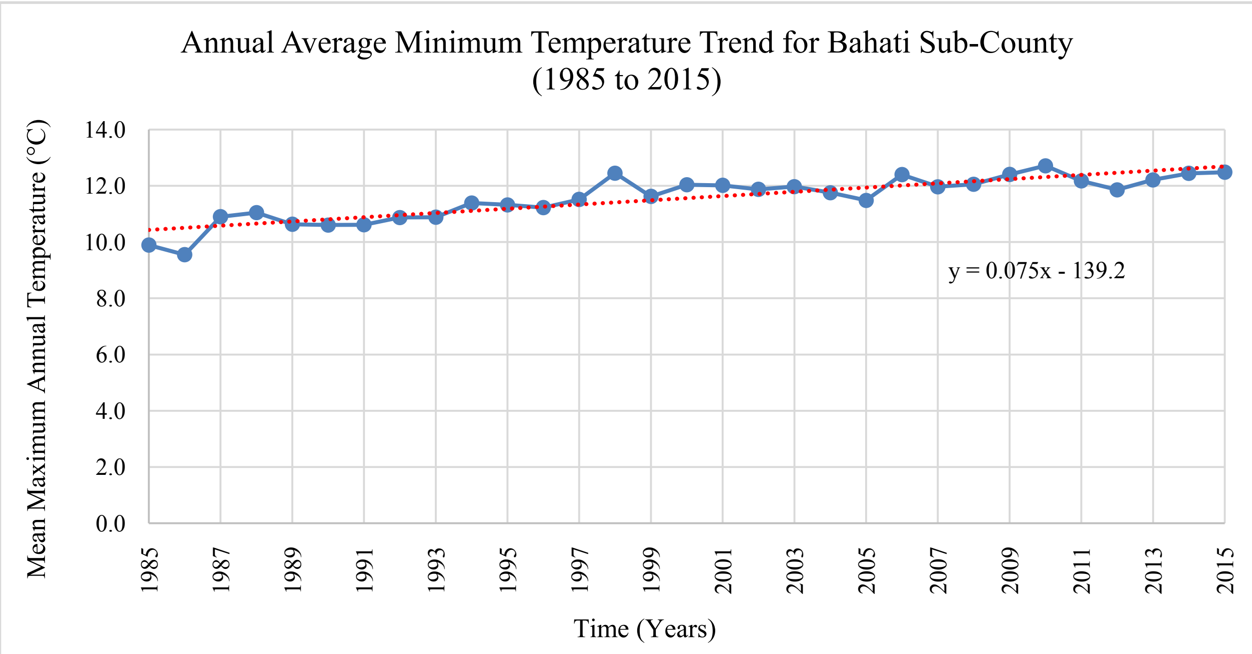

Figure 8. Annual Average Minimum Temperature for Bahati Sub-County

3.4.3. Annual Average Minimum Temperature Trend

The minimum average temperature for Bahati Sub-County for the period 1985 to 2015 was recorded at 11.6°C. The lowest temperature recorded was in 1986 at 9.6°C and the highest minimum temperature recorded was in 2010 at 12.7°C as shown in Figure 8. The trend line equation shows that there has been a gradual increase of 0.075°C in minimum temperature for Bahati Sub-County for the period 1985 to 2015.

3.5. Temperature Variability

3.5.1. Annual Average Temperature Variations

Annual average temperature variability characteristics for Bahati Sub-County showing the anomalies for the period 1985 to 2015 was presented in a graph as shown in Figure 9. Annual average temperature variability ranged from 17.7°C in 1989 to 19.7°C in 2009 (Figure 6). The highest average temperature anomalies were recorded in the years 1986 (-0.88°C), 1989 (-1.0°C), 2009 (+0.98°C), and 2015 (+0.91°C) as shown in Figure 9.

3.5.2. Annual Average (Maximum and Minimum) Temperature variations from the Mean

Maximum and minimum temperature variability for Bahati Sub-County for the period 1985 to 2015 was recorded as significant with maximum temperature variations peaks noted during the years 1987 (+1.2°C), 1988 (-0.7°C), 1989 (-1.1°C), and 2009 (+1.2°C) as shown in Figure 10. During the minimum temperature variations, high temperature variations were recorded during the years 1985 (-1.7°C), 1986 (-2.1°C) and in 2010 (+1.1°C).

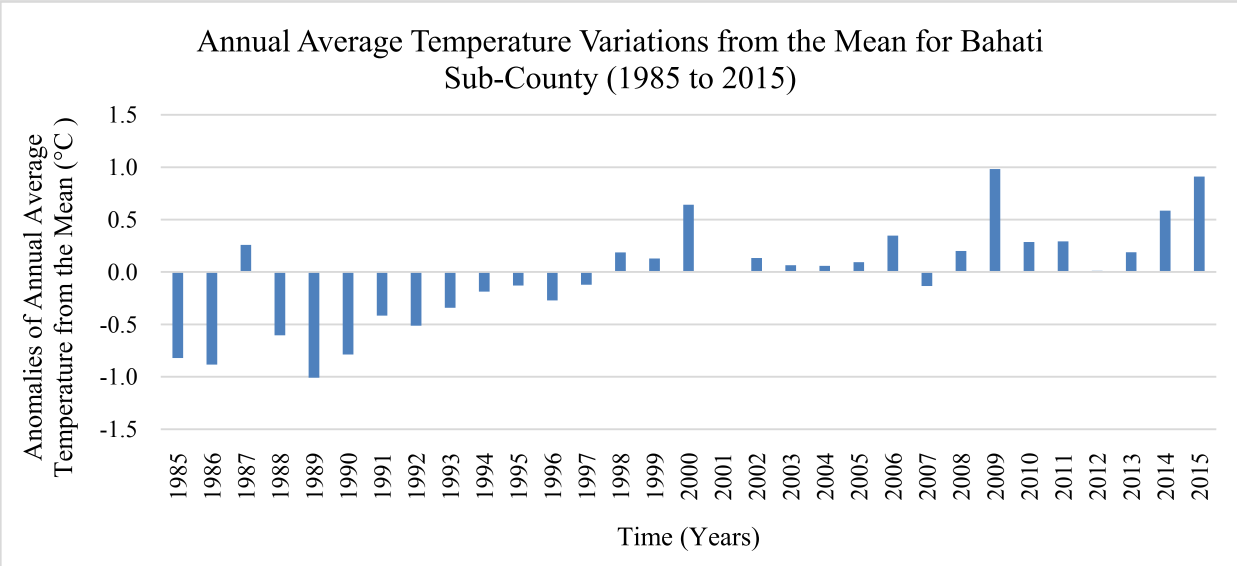

Figure 9. Annual Average Temperature Variations for Bahati Sub-County

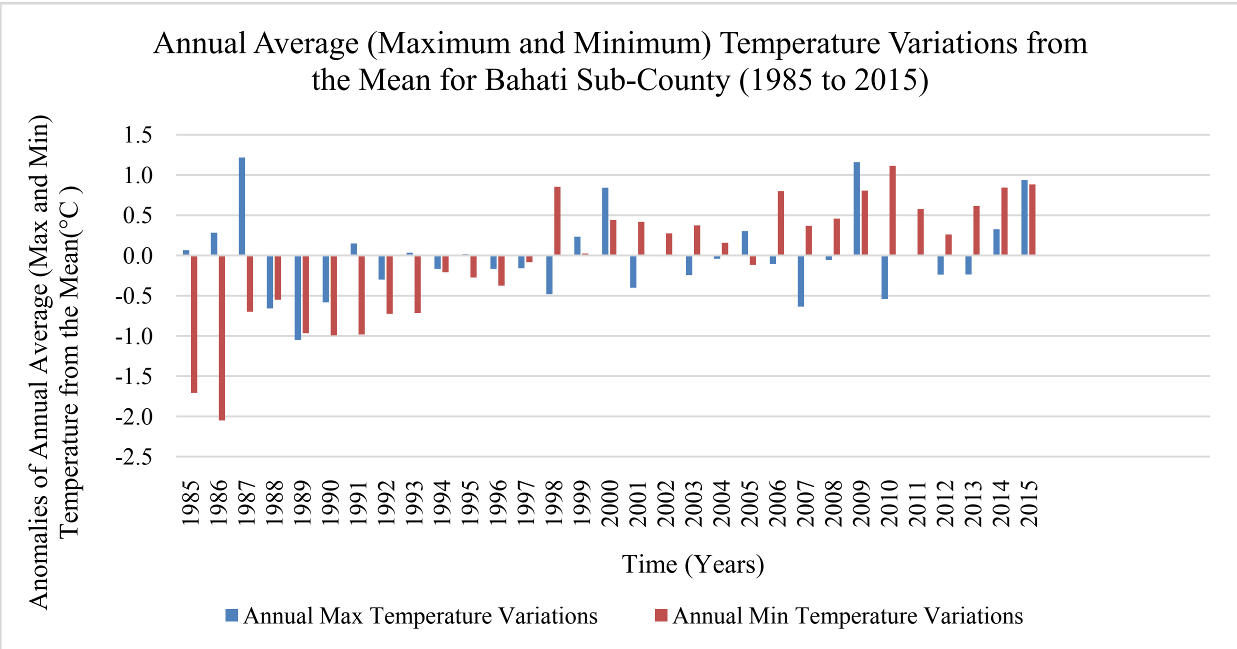

Figure 10. Annual Average (Max. and Min.) Temperature Variations for Bahati Sub-County

3.6. Trend of Maize Yields

3.6.1. Annual Maize Yield Trend in Tonnes

The annual maize yield trend for Bahati Sub-County is significant showing a gradual decline in maize yield from 1985 to 2015 as shown in Figure 11. This is partly attributed to rainfall and temperature variations which had a significant correlation coefficient of 0.741 and -0.51 respectively with maize yields, as shown in Table 2. The mean annual maize yield was recorded at 39,363 Tonnes. The peaks in maize yields were observed in 1986 (55,800 Tonnes), 1988 (62,615 Tonnes), 1989 (53,151 Tonnes), 2007 (59,019 Tonnes), 2010 (61,623 Tonnes), and 2011 (50,045 Tonnes). The dips were observed in the years 1993 (17,802 Tonnes), 1999 (13,832 Tonnes) and 2000 (11,913 Tonnes) as shown in Figure 11.

3.7. Maize Yield Variability

3.7.1. Annual Maize Yield Variability in Tonnes

A significant amount of variability in maize yields has been recorded in Bahati Sub-County for the period 1985 to 2015 both spatially and in temporal terms as shown in Figure 12. The decline in maize yield trend in Bahati Sub-County is mainly attributed to the increase in surface temperatures and variation in seasonal rainfall. These findings appear to support the research findings that high rainfall variability has an effect on maize yield variability in Benue State-Nigeria [19] and that climate variability has wide impacts on maize yields in southern part of Nigeria [20]. The highest variations in maize yields were observed in the years 1986 (+16,437 Tonnes), 1988 (+23,252 Tonnes), 1993 (-21,561 Tonnes), 1999 (-25,531 Tonnes), 2000 (-27,450 Tonnes), 2007 (+19,655 Tonnes) and 2010 (+22,260 Tonnes).

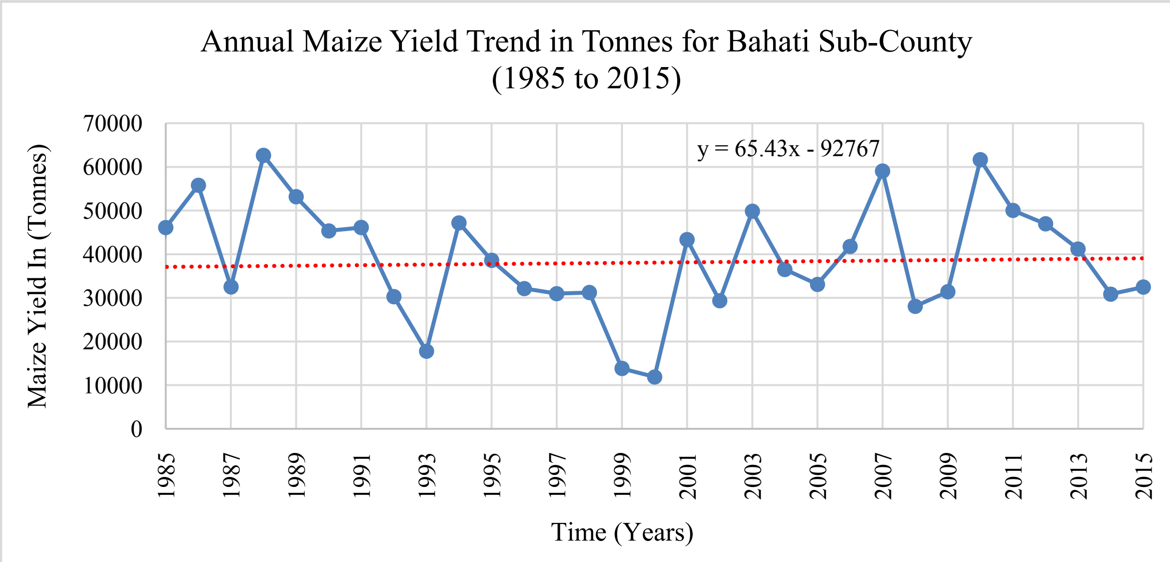

Figure 11. Annual Maize Yield Trend for Bahati Sub-County (1985 to 2015)

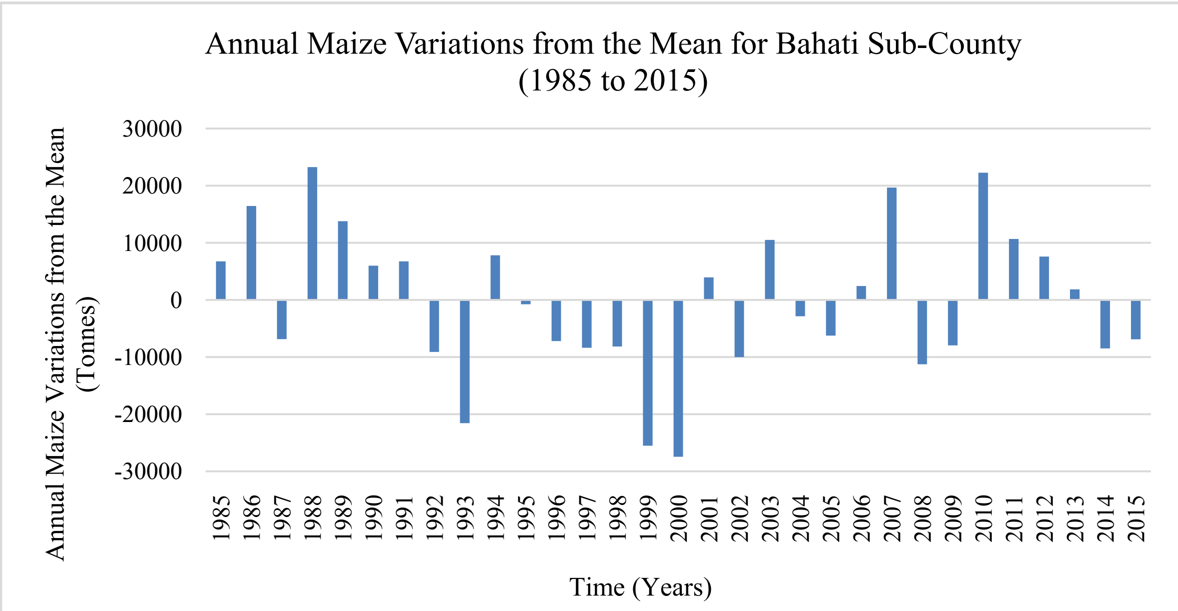

Figure 12. Annual Maize Variations for Bahati Sub-County

3.8. Correlation Analysis

3.8.1. Correlations of Climatic Variables and Maize Yield Data

The annual rainfall trend, maximum temperature trend, minimum temperature trend and annual maize yield trend as shown on Table 2 were correlated to determine the significance of their relationship. When Pearson's r is close to 1, this means that there is a strong relationship between the two variables and that changes in one variable are strongly correlated with changes in the second variable. When Pearson's r is close to 0 this means that there is a weak relationship between the two variables and that the changes in one variable are not correlated with changes in the second variable. From the findings on Table 2, Pearson's (r= 0.741, p= 0.000) is close to 1 showing that there is a significant strong and positive linear relationship between rainfall amount and maize yield. Pearson's r (r= -0.510, p= 0.003) recorded between maximum annual temperature and maize yield indicated a significant moderate and negative linear relationship between the two variables. Pearson's r (r= -0.166, p= 0.372) recorded between minimum annual temperature and maize yield indicated an insignificant but weak and negative linear relationship between the two variables. A positive Pearson's r indicates that as one variable increases, the second variable also increase in value or vice versa. While a negative Pearson's r indicates that as one variable increases the second variable decreases or vice versa. The p value for maize yields and rainfall is 0.00, while the p value for maize yield and maximum temperature is 0.003 in which both are less than 0.05 meaning that there is a statistically significant correlation between rainfall trend, maximum temperature and maize yield. A p value of 0.372 between minimum temperature and maize yield is above 0.05 meaning that the relationship is statistically insignificant.

Table 2. Summary of Correlations between the Climatic Variables and Maize Yield for Bahati Sub-County

		Rainfall (mm)	Maximum Temperature (°C)	Minimum Temperature (°C)	Maize Yield (Tonnes)
Rainfall (mm)	Pearson Correlation	1	-.716**	.151	.741**
	Sig. (2-tailed)		.000	.418	.000
	N	31	31	31	31
Maximum Temperature (°C)	Pearson Correlation	-.716**	1	.081	-.510**
	Sig. (2-tailed)	.000		.663	.003
	N	31	31	31	31
Minimum Temperature (°C)	Pearson Correlation	.151	.081	1	-.166
	Sig. (2-tailed)	.418	.663		.372
	N	31	31	31	31
Maize Yield (Tonnes)	Pearson Correlation	.741**	-.510**	-.166	1
	Sig. (2-tailed)	.000	.003	.372	
	N	31	31	31	31

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

4. Discussion

4.1. Climate Variability

The study found out that the annual rainfall had reduced between 1985 and 2015 in Bahati Sub-County. High amounts of rainfall were noticed in the years1988 (1244mm), 1992 (980mm), 1997 (1094mm), 2001 (1130mm), 2002 (1084mm), 2003 (1138mm), 2007 (1217mm), 2010 (1436mm) and 2013 (1185mm), while low amounts of rainfall are noticed in the years 1987 (697mm), 1993 (704mm), 2000 (610mm) and 2009 (705mm). Seasonal rainfall variability was found to be significant in the long and short rain season trend and ranged from -253.17mm (2000) to +263.53mm (2010) and from – 111.08mm (1985) to +247.31mm (1997) respectively. The mean annual temperature in the area has generally been increasing since 1985 to 2015. The lowest average temperature recorded in Bahati Sub-County was 17.7°C in 1989, while the highest temperature recorded was 19.7°C in 2009, (Figure 6). The trend line equation showed that Bahati-Sub-County has been experiencing a slightly gradual increase of 0.008°C annually in the maximum temperature for the period 1985 to 2015. While the highest maximum annual temperature was recorded in 1987 and 2009 at 27.0°C and the lowest in 1989 at 24.8°C as shown in Figure 7. The trend line equation showed that there has been a gradual increase of 0.075°C in minimum temperature for Bahati Sub-County for the period 1985 to 2015. The lowest temperature recorded was in 1986 at 9.6°C and the highest minimum temperature recorded was in 2010 at 12.7°C as shown in Figure 8.

4.2. Maize Yield Variability

The annual maize yield trend for Bahati Sub-County is significant showing a gradual decline in maize yield from 1985 to 2015 as shown in Figure 11. The peaks in maize yields were observed in 1986 (55,800 Tonnes), 1988 (62,615 Tonnes), 1989 (53,151 Tonnes), 2007 (59,019 Tonnes), 2010 (61,623 Tonnes) and 2011 (50,045 Tonnes). The dips were observed in the years 1993 (17,802 Tonnes), 1999 (13,832 Tonnes) and 2000 (11,913 Tonnes) as shown in Figure 11.

4.3. Effect of Climate on Maize Yields

The study findings revealed that there is a significant, positive and strong relationship between rainfall trend and maize yield (r= 0.741, p = 0.000). The study also revealed that there is a significant, moderate and negative linear relationship between maximum temperature and maize yield (r= -0.510, p= 0.03). However, the study findings also revealed that the relationship between minimum temperature and maize yield had an insignificant, weak and negative relationship (r= -0.166, p= 0.372). This helped support the fact that maize yield variability is a result of annual rainfall and maximum temperature variability.

5. Conclusions

The main objective of the study was to assess the impacts of climate variability on maize yields in Bahati-Sub-County, Kenya for the period 1985 to 2015. The study found out that the annual rainfall amounts had decreased over the years, while maximum and minimum temperatures over the years have gradually been increasing. Furthermore, the study findings revealed that there has been a shift in the onset and cessation of rainfall. According to [21] more effective adaptation and coping strategies to climate variability should be introduced to the farmers so as to cushion them from the impacts of climate variability, thus ensuring Bahati Sub-County is food secure. The County government in Nakuru should educate the farmers on the impacts of climate variability and on the importance of monitoring the maize-climate relationship in the area, since any variation in climatic variables negatively affects stability and supply in agricultural production [22]. The farmers should also be encouraged to enhance crop diversification to help cushion them from climate variability. To the policy makers and stakeholders, they should ensure that they provide climate rellated information to the farmers that is timely, reliable and proven so as to ensure that the farmers are in a better position to cope with climate variability. This will ensure that the area is food secure. In view of the high correlation between annual rainfall, maximum temperature and maize yields, adoption of maize varieties resistant to heat stress and drought should be bred for farmers in Bahati Sub-County. Nakuru meteorological station should provide forecast prediction to the farmers on the onset and cessation of the growing season so as help maize farmers plant and harvest on time.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Acknowledgements

I would like to acknowledge the assistance and support accorded to me by the MOA, Tegemeo Institute, Nakuru County Agricultural Officers, Kenya Meteorological Department, Department of Geography in Kenyatta University and Department of Earth Sciences in Uppsala Universitet.

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