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Effects of Rainfall Variability on Maize Production in Migori County, Kenya

Augustine W. Ochola[1], Daniel O. Nyamai[1], Francis O. Olal[1] & Steve O. Ngodhe[2]
[1]*Rongo University, Kenya*
[2]*Maasai Mara University, Kenya*

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Abstract
Maize is the main staple food crop in Kenya and is of vital concern to agricultural policy decisions, food security, and the overall development of the sector and the economy. It is also the dominant staple food crop in Migori-County. However, there has been a declining trend in maize production among farmers in the study area threatening household food security. This study was conducted in Migori County using cross sectional survey research design. A sample size of 384 households was selected through stratified and systematic sampling techniques though just 310 households accepted to be interviewed. Data was collected using a structured questionnaire. Validated secondary weather data for the period 2011-2023 was obtained from the Migori Meteorological Station. The collected data was entered into SPSS software, version 20, and analysed using both descriptive and inferential statistical methods. The results indicated that 60% of households have an adequate food supply, while 40% face food shortages. Further, there was a strong positive and significant relationship between maize production (yield) and annual weather conditions from 2018 to 2023 (r = 0.845, p = 0.05). This indicates that changes in weather patterns, such as rainfall and temperature, had a significant influence on maize yields during the study period. Hence, farmers should be encouraged to use income from cash crops to purchase food stocks and engage in non-farm activities as alternative income sources to mitigate the effects of rainfall variability and climate change on food security.

Introduction

Food security is one of the most critical global concerns, as it affects the well-being and livelihood of billions of people worldwide (Khan et al., 2020; Wijerathna-Yapa & Pathirana, 2022). Achieving food security involves four key dimensions: food availability, food access, food utilisation and food stability (Clapp et al., 2022; Ayinde et al., 2020). The World Health Organization (2024) estimates that in 2023, around 2.33 billion people globally faced moderate or severe food insecurity, with a significant portion residing in developing countries. In 2022, Africa had 282 million people facing hunger, accounting for over 38% of the global total of 735 million. Eastern Africa had the highest number of undernourished individuals at 134.6 million, followed by 62.8 million in Western Africa, 57 million in Central Africa, 19.5 million in Northern Africa, and 7.6 million in Southern Africa (FAO, AUC, ECA & WFP, 2023). Global trends such as population growth, climate change, economic disparities and environmental degradation are making the goal of food security increasingly elusive for many communities worldwide (Maja & Ayano, 2021; Poudel & Gopinath, 2021; Auya, Sutter & Barasa, 2023; Walyaula & Luvaso, 2024; Steier, Kang & Ramdas, 2022; Molotoks et al., 2021).

Like many other countries in Sub-Saharan Africa, Kenya struggles with food insecurity, particularly in rural areas where agriculture is the primary source of livelihood. According to Save the Children (2023), Kenya is among the top 10 countries with over 25% of the population experiencing chronic hunger. Recurrent droughts, unpredictable rainfall patterns, and rising temperatures, all associated with climate change, have significantly affected the country's agricultural output, making food security a persistent challenge (Ochieng et al., 2017; Obwocha et al., 2022; Ndiritu & Muricho, 2021; Ngure et al., 2021; Liru & Heinecken, 2021). According to Markos et al. (2023), climate change has led to increased weather variability, impacting the agricultural calendar and causing fluctuations in crop production, especially for rain-fed crops like maize. This variability has reduced yields and food shortages, particularly in arid and semi-arid regions, where food insecurity is most pronounced.

Maize is Kenya's main staple food crop and is vital to agricultural policy decisions, food security and overall development of the sector and the economy (Olwande, 2012; Wanyama et al., 2021). As the most widely grown crop, maize is the primary source of calories for most of the population, particularly in rural areas where alternative food sources are scarce (Mwangagi, 2021). Maize contributes over 3% to the gross domestic product (GDP) and 12% to the agricultural GDP and is consumed by 85% of the population (Ngeno, 2024). Hence, any disruptions in maize production, whether due to climatic factors, pests, or market instability, can severely affect food security at both household and national levels (Samwel, 2021; Mutegi et al., 2024). Over recent years, the effects of climate change have intensified, leading to increased unpredictability of weather patterns, significantly affecting crop yields in Kenya (Walyaula & Luvaso, 2024; Tanui, 2023; Yator, 2024).

Maize serves as both a staple food and an economic lifeline for millions of smallholder farmers, with over 80% of Kenya's maize production coming from these small-scale farmers (Ngeno, 2024; Koskei, 2022; Kipkorir, Ngeno, & Chumo, 2023). The crop is grown in nearly all counties, with regions such as the Rift Valley, Western, and Nyanza serving as the leading maize-producing areas (Otieno, 2021; Mwasame, 2021). However, despite its importance, maize production in the country faces increasing threats from climate change, which has led to unpredictable weather patterns, especially rainfall variability, affecting crop yields and overall agricultural productivity (Kogo et al., 2022; Makokha & Obiero, 2021; Oluoch et al., 2022). Studies have shown that when maize production declines due to unfavourable weather conditions, the effects ripple across the entire food system, leading to higher food prices, reduced access to food, and increased malnutrition, particularly among children (Vargas et al., 2023).

Maize is the dominant staple food in Migori County but has seen declining trends over the past years (Gikemi, 2022; Olwande, 2012; Nyamohanga, 2017). With the local economy depending highly on rain-fed agriculture, changing rainfall patterns have seen maize yields decline, threatening the livelihoods of small-scale farmers and increasing food insecurity. Further, smallholder farmers in the county have limited access to irrigation and other climate adaptation resources, they are especially vulnerable to the negative impacts of rainfall variability (Gikemi, 2022; Opiyo et al., 2024). Maize production, being highly sensitive to rainfall, is particularly vulnerable to these fluctuations. Bassu et al. (2021) found that the timing and distribution of rainfall during critical maize growth stages, such as planting and flowering, are essential for determining yields. Hence, this study evaluated the effects of rainfall variability on maize production in Migori County, Kenya.

Materials and methods

The study was conducted in Migori County, one of Kenya's forty-seven counties. It is situated in the South-Western part of Kenya. It borders Homa Bay County to the North, Kisii and Narok Counties to the East and the Republic of Tanzania to the South. It also borders Lake Victoria to the West (Wandolo, 2024). It is located between latitudes 1°24' and 1°40' South and longitude 34°50' East, covering 2,596.5 km², including 478 km² of water (Gikemi, 2022). The Kenya National Census of 2019 indicated that

Migori County had a population of 1,116,436 (Odongo, 2023). The study utilised a cross-sectional survey design, focusing on approximately 10000 households from the Awedo, Uriri, and Nyatike sub-counties, as these areas are the most significantly impacted by climate change. Yamane's formula (Yamane, 1967) with a 5% level of precision (e) was applied, and questionnaires were administered to 384 participants. A structured questionnaire was distributed to households using purposive random sampling to gather sociodemographic information, while data on maize yields was obtained from various individual farmers. Secondary data was obtained from published meteorological and maize yield records, with data from 2011 to 2023 collected from Migori Meteorological stations. The 13 years were considered long enough to capture all the significant weather anomalies that may have taken place in Migori County. Characteristics of onset, cessation, seasonal rainfall, and annual weather were summarised on a check sheet. Collected data was then coded into Statistical Package for the Social Sciences (SPSS) version 26 and analysed using both descriptive and inferential statistical methods. Descriptive analysis was used to compute variations in weather and maize yield levels over 5 years. Pearson's correlation test was used to analyse the effect of weather variability on maize yields.

Results and Discussion

Gender of the respondents

Gender roles determine the amount of maize production and the kind of activity carried out by the household head, depending on whether the household head is a male or female. Males and females often have complementary roles, sharing or dividing tasks in crop production. Figure 1 presents the gender of the respondents.

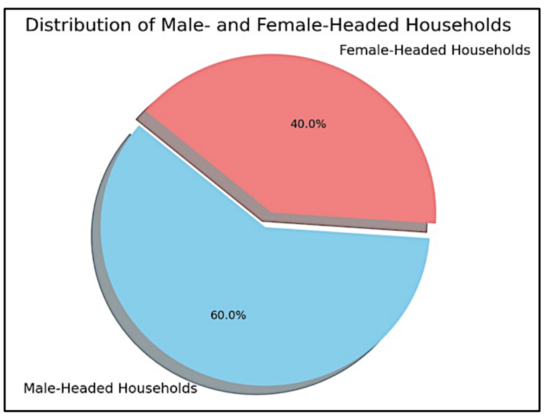

Figure 1: Gender of the respondents

Figure 1 revealed that 186 (60%) households were male-headed, and therefore, most of the farming decisions were made by the male gender, while 124 (40%) of the households were headed by the female gender.

Age of the household head

Age of the household head is a critical factor in maize production. Results indicated that majority of respondents (36.7%) were aged between 41-50 years followed by 26.5% aged between 31-40 years; 17.6% between 51-60 years while 10% were 18-30 years with 6.5% and 2.7% between 61-70 and over 70 years respectively.

Table 1: Age of Respondents

Age group (Years)	Frequency	Percentage
18-30	31	10
31-40	82	26.5
41-50	114	36.7
51-60	55	17.6
61-70	20	6.5
Over 70	8	2.7
Total	**310**	**100**

Education level of the respondents

The study also requested respondents to specify their level of education, and Figure 2 provides a summary of their responses.

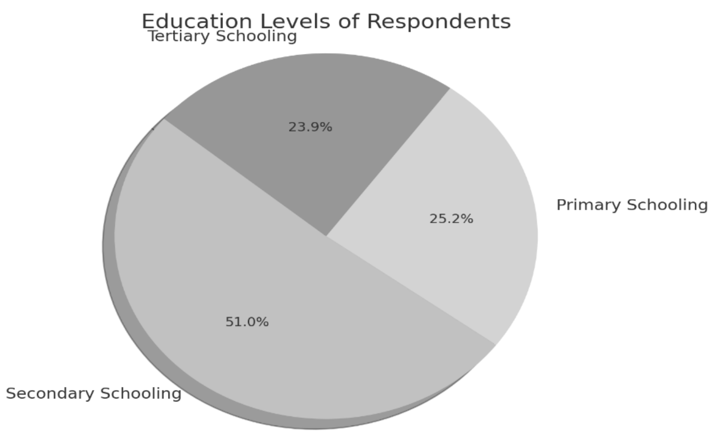

Figure 2: Level of education of the household head

From Figure 2, it is observed that 158(51%) of the respondents had a secondary schooling level, 78 (25.2%) had a primary and 74(23.9%) had a tertiary schooling level.

Rainfall Trends in Migori-County (2011 to 2023)

Rainfall is one of the critical indicators of weather variability, and this study sought to establish the weather distribution pattern of the area over 13 years. The annual rainfall data for the period is shown in Table 2.

Table 2: Annual total rainfall trends in Migori County (Extracted from KMD. 2023)

SN	Year	Short	Long	Mean
1	2011	500	900	700
2	2013	600	750	675
3	2015	500	900	700
4	2017	400	750	575
5	2019	600	900	750
6	2021	750	1000	875
7	2023	600	750	675

According to the results presented in Table 2 above, Migori County has two main rainy seasons. The long rains fall between March and May, while the short rains occur between September and November. Dry seasons are experienced in two annual phases: December-February and June-September (County Government of Migori, 2018). The mean annual rainfall ranged from a low of 575 mm in 2017 to a high of 875 mm in 2021. The short rainy seasons exhibited more variability, with rainfall ranging from 400 mm in 2017 to 750 mm in 2021, while the long rainy seasons consistently ranged between 750 mm and 1000 mm. The annual weather trends showed a slight decrease and increase since 2011 for the long rainy season. Just like the long rainy season, the short rainy season also recorded a sharp increase and reduction in precipitation (Figure 3).

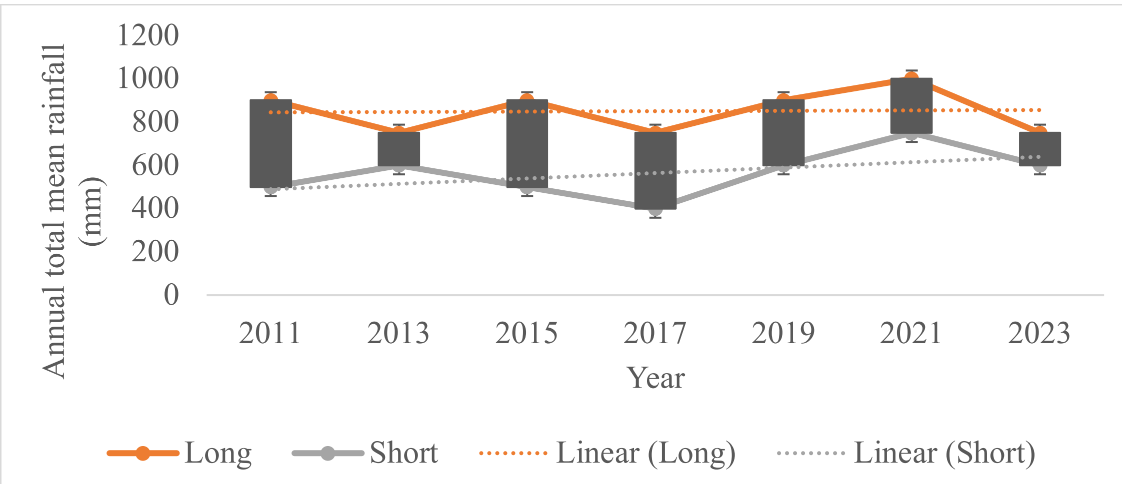

Figure 3: Annual total rainfall trends for the long rainy and short rainy seasons in the past (2011-2023)

Source: KMD. 2023

The variations suggest irregular rainfall patterns in the region over the observed years, potentially impacting agricultural activities such as maize production. Studies have shown that changes in the timing and distribution of rainfall, particularly during the critical stages of crop development, can lead to reduced yields or even complete crop failure (Kilungu et al., 2019). Kogo et al. (2021) similarly observed that rainfall variability in Kenya has significantly contributed to declining maize productivity, particularly in regions that depend on short and long rainy seasons, like Migori. Mafongoya et al. (2022) further explain that due to climate change, the rainfall patterns have become more unpredictable, a factor that diminishes the possibility for smallholder farmers to estimate the best times of the planting and harvesting seasons, affecting food security.

Temperature Trends in Migori-County (2011 to 2023)

Figure 4 illustrates the temperature trends in Migori County from 2011 to 2023. It highlights the annual average temperature variations and any significant anomalies during this timeframe.

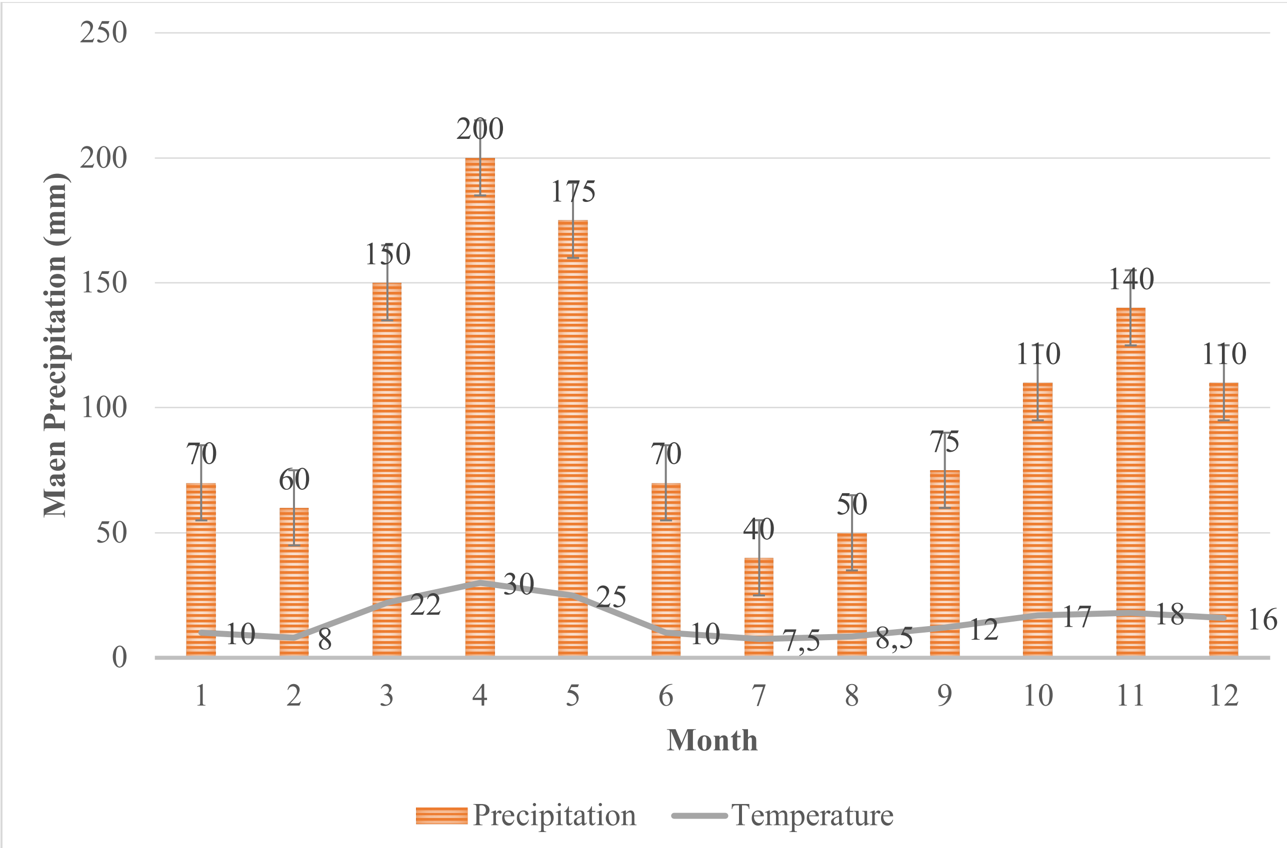

Figure 4: Monthly mean precipitation and temperature trends for the long rainy and short rainy seasons in the past (2011-2023)

Source: KMD. 2023

It is evident from Figure 4 that the monthly mean temperature and precipitation have also recorded a similar trend with an increase and decrease since 2011, with peaks of 200mm and 30^{0}C, respectively, both in the fourth month and the lowest figure recorded in the seventh month with precipitation and temperature being 40mm and 7.5^{0}C seasons. However, the annual mean temperature revealed a minor variation between long and short rains and even between the years 2011 and 2023. The highest temperature was recorded during the brief rainy period between 2021 and 2023 at 27^{0}C, while the lowest figure was registered during the 2013 long and short rains at 24^{0}C. This was also the case in the year 2017, during the long rainy season, as indicated in Figure 5.

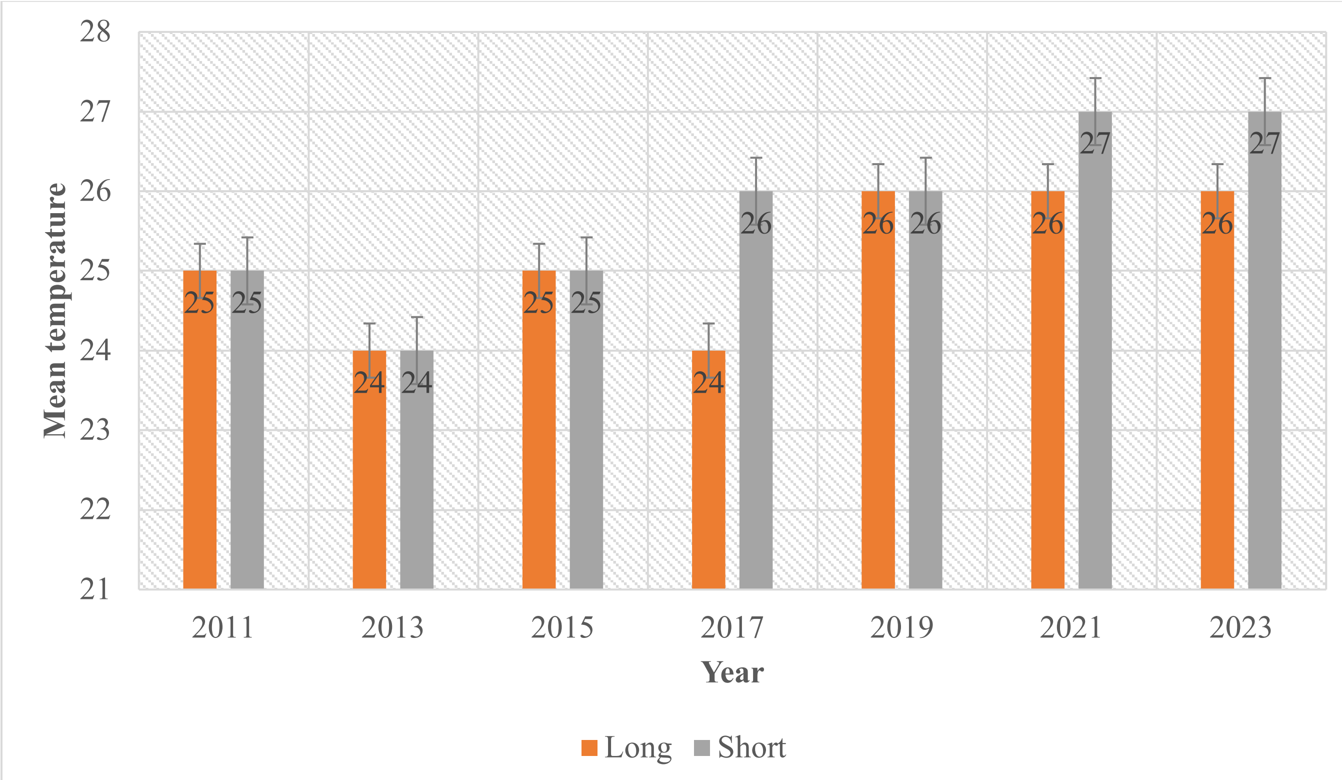

Figure 5: Annual mean temperature trends for the long rainy and short rainy seasons in the past (2011-2023)

The fluctuating patterns over the 13-year period 2011-2023 indicate temperature variability in the County. According to Waqas et al. (2021), temperature changes significantly affect the growth cycles of crops such as maize, which are sensitive to high and low-temperature extremes. Therefore, the observed temperature fluctuations could have direct consequences on crop development, impacting both yields and food security in the region.

Various studies have shown a growing concern for fluctuating temperatures in Kenya and its impact on agriculture. For instance, Siminyu (2023) noted that temperatures are rising in major agricultural regions in Kenya, such as highlands and lowland areas, leading to fluctuating crop production. Some crops are sometimes set to undergo heat stress at critical growth stages. Therefore, with temperature variation, the staple food crop may fail to develop well in Migori County. Poor establishment typically contributes to low flowering and grain filling, leading to reduced yield. Ngetich et al. 2014, point out that more elongated periods of high temperature during the growing season can also enhance evapotranspiration and, consequently, water stress in rain-fed farming systems.

According to Obwocha et al. (2022), the combination of rising temperatures with irregular rainfall has an additive negative impact on agricultural productivity in Kenya. Overall, their findings verified that small-scale farmers around areas such as Migori, where changes in temperature and variability of rainfall are well manifested, are highly susceptible to such climatic changes.

Indeed, the study by Makokha et al. (2017) on the impacts of climate change in Western Kenya confirmed that increasingly erratic temperatures have turned out to be a common phenomenon during the last decades, with the most significant impact on maize yields. They pointed out that when temperatures became extremely high at critical stages of maize growth, the growing season shortened, the rate of photosynthesis was reduced, and a lot of stress occurred for this plant. It was more pronounced in areas like Migori County, whose maize is basically grown under rain-fed conditions. In such areas, the combination of unpredictable rainfall and temperature variability presents a double challenge to smallholder farmers, who often lack the resources to implement adaptive measures.

Relationship between annual weather totals and maize production

Figure 6 shows maize production in the County between 2018 - 2023 against the mean annual weather during the same period. Maize production (yield) was recorded in terms of number of bags per year.

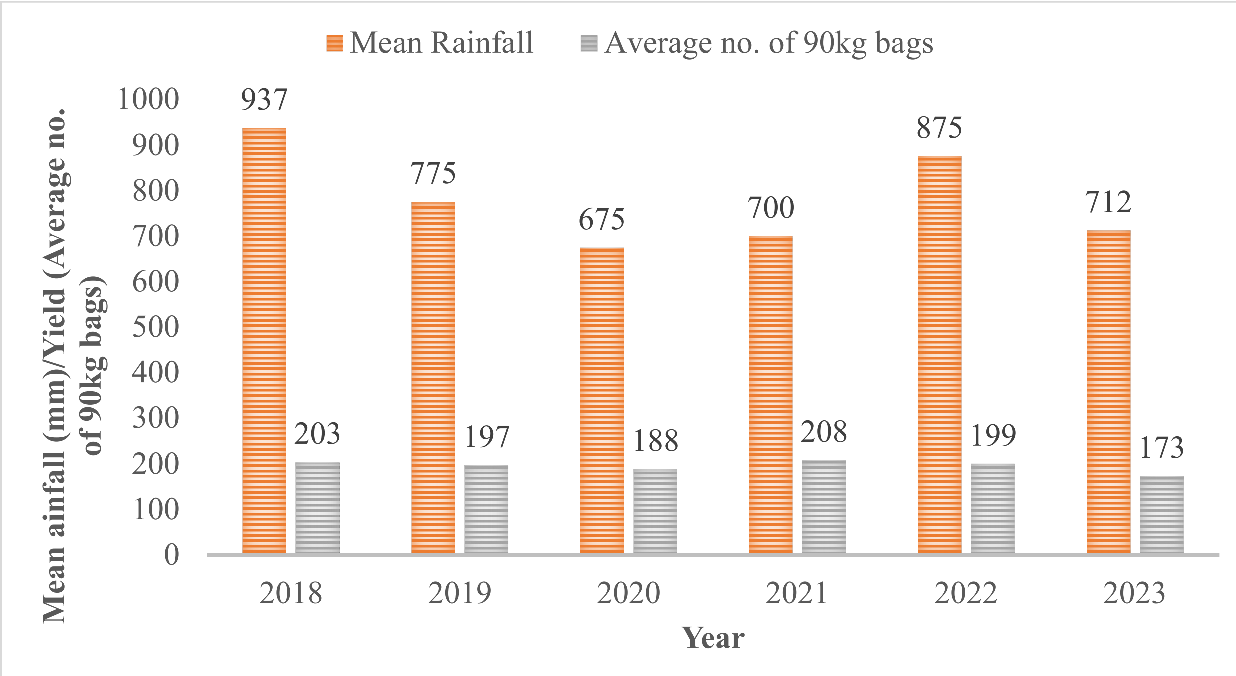

Figure 6: A comparison of Maize yield and total annual weather between 2018 – 2023

Figure 6 clearly shows that mean rainfall is directly proportional to maize production, suggesting that increased rainfall generally leads to higher maize yields. However, in 2020 and 2021, maize production was higher despite lower rainfall patterns. The yields per year were correlated with annual weather totals of the 5-year period from 2018 – 2023, using Pearson correlation moment to establish the influence of weather variability on maize yields (Table 3).

Table 3: Correlation between Maize production (yield) and annual weather from 2018- 2023

		Mean %	Percentage maize yield
% mean	Pearson Correlation	1	0.845*
	Sig (2-tailed)		0.05
	N	5	5
% Maize yield	Pearson Correlation	0.845	
	Sig (2-tailed)	0.05	
	N	5	5

The results indicated a strong positive significant relationship between weather anomalies and maize yield during each growing season ($r = 0.845$, $p = 0.05$). This analysis suggests that as favourable weather conditions increase, maize yields also increase and conversely, as weather conditions worsen, maize yields decrease. Farmers are highly vulnerable to weather variability due to the strong correlation between maize production and weather patterns. Similar findings were reported by Alberto (2013), who observed a significant relationship between seasonal weather and the yields of cassava, sweet potatoes and sorghum. Makokha et al. (2017) further explored the effects of climate variability on maize yields in Western Kenya, discovering that increased rainfall directly enhanced maize yields, while extreme conditions such as drought or excessive rain reduced productivity. Migori County has two planting seasons, with the dominant season being the long rain season, which accommodates all maize varieties, including late and early maturing types.

Conclusion

The results indicated that the rainfall and temperature variability experienced in Migori County were sufficient to impact maize production from 2011 to 2023. This analysis also highlights a robust significant relationship where favourable weather conditions are related to high maize yields; weather anomalies directly influence agricultural productivity. Rainfall and temperature fluctuations were determined through this analysis to be among the key factors contributing to maize production; erratic weather conditions have led to low yields in specific years. These changes make the smallholder farmers of Migori County particularly vulnerable, given the heavy dependence on rain-fed agriculture. Support should be directed toward farmers in adopting climate-resilient agricultural practices, such as the use of drought-tolerant varieties of maize, besides adopting proper water conservation techniques to mitigate the impacts brought by unpredictable rainfall and temperature changes.

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