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Effects of Rainfall Timing on Select Food-Crop Production in Nyando Sub-County, Kisumu County, Kenya

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Abstract: *Food security refers to a situation where all people have access to adequate, nutritious and safe food to meet their needs for a healthy and active life. However, the number of people who are food insecure globally continues to rise despite the numerous interventions that have been put in place to address the phenomenon. For example, Integrated Food Security Phase Classification report in March, 2026 revealed that about 3.3 million Kenyans faced crisis-level food insecurity driven by consecutive failed rains, high food prices and drought. It is imperative to adopt resilient food crop production systems which can cope with the reality of rainfall variability in order to ensure food security. The study aimed at assessing the effect of rainfall timing on select food-crop production in Nyando Sub-County, Kisumu County. The study used a quasi-longitudinal research design. The sample size was 384 household heads and Key Informants. Systematic random and purposive sampling techniques were used in the selection. Methods of data collection included questionnaires, interviews, focused group discussions and field observations. The quantitative data were analyzed using linear regression while qualitative data were thematically analyzed. The study findings established that about 65, 47 and 38 percent variation in the production of maize, beans and African nightshade respectively was explained by change in rainfall timing. It was concluded that rainfall timing has a significant effect on production of these crops. The study therefore recommends resilient food production systems to cope with and adapt to changing climate especially the timing of rainfall.*

Keywords: *Rainfall Variability, Rainfall Timing, Food Crop Production, Food Security and Food Insecurity.*

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1. Introduction

Climate variability and extreme weather events are the 21st Century catastrophes resulting from the increasing global population and its related effects. The impacts of climate variability (fluctuations in rainfall, temperature and wind patterns), including its influence on agricultural production and hence food security, cannot be disregarded (Odundo & Omedi, 2025). Wagesho (2016) earmarked rainfall as an important climatic factor of critical relevance in the agricultural sector in developing countries. In 2010, United Nation Framework Convention on Climate Change (UNFCCC) indicated that trends, seasonality and amounts of rainfall had changed and affected crop production in different parts of the world. Rainfall variability is measured in terms of timing, duration and magnitude: rainfall timing being the onset and arrival of rainfall within a season (Odundo, 2023; Shackleton et al., 2009). Temporal rainfall characteristics determine seasonal amount of rainfall that is reliably available for crop production and timing of farming activities (tillage and planting operations) which end up affecting crop production (Wakjira et al., 2021). Tesfaye & Seifu (2016) noted rainfall failure to support crop production as one of the effects of climate variability and change perceived by farmers. In 2015, the United Nations

Development Programme (UNDP) revered the significance of sustainable agriculture in empowering small-scale farmers, promoting gender equality, ending rural poverty, ensuring healthy lifestyles and tackling climate change.

A longitudinal study (1996-2022) done in the Slovak Republic, Europe, found May precipitation to significantly influence maize production (Bendakova et al., 2024). The study noted a significant positive impact of the interaction between time variable and May precipitation which indicated that the influence of May precipitations on maize production improved over time. These findings were in support of an earlier study that investigated the impact of climatic variables on crop yields in the Great Plains region of the United States and found that May precipitations critically influenced crop yields (Hatfield & Dold, 2018). In Kansas, the study found a higher coefficient of determination ($r^2 = 0.78$) that indicated a strong correlation between May precipitation and crop yields. The study concluded that May precipitation provided the necessary moisture for optimal crop growth, leading to higher yields.

In Africa, climate variability mostly affects agricultural output given the widespread subsistence rain-dependent agricultural practices leading to household food insecurity and livelihood loss. Ministry of Agriculture, Livestock, Fisheries and Co-operatives (MoALFC) (2021) documented that rain-dependent agriculture and livestock production practices were prone to climate variability such as delayed onset and intensification of seasonal rains. Maize production in Africa is rain-fed and extremely vulnerable to extreme weather events, including rainfall variability. As reported by Food and Agricultural Organization (FAO) (2020), Africa has low maize yields as a result of limited modern farming techniques, poor infrastructure and unpredictable weather conditions. A study done in Ethiopia found late onset of rainfall to contribute to about 1.5 percent loss of rainfed cereal crop production whereas rainfall cessation had less effect on cereal crop production (Wakjira et al., 2021). The study indicated that rainfall onset was not only limited to the period of crop growth but also during pre-planting operations such as tillage that required optimal soil moisture for soil workability.

In Kenya, Kabata et al., (2021) carried out a study on the effects of seasonal rainfall variability on smallholder farmers' maize yields in Kieni East Sub-County, Nyeri County. Results of Karl Pearson correlation found an overall decline in annual maize yields by a gradient of negative 231.9. Further, they established declines in maize yields with negative gradients of 69.19 and 162.71 during long and short rains respectively. Huho & Kosonei (2013) related lower agricultural productivity to changes in rainfall timing. The low (decrease in) maize yields coupled with increased demand poses a challenge to the country's food security (Kabata et al., 2021). Beyond a decade ago, Kenya was reported to depend on maize imports and food aid since domestic production had continuously fallen below the consumption demands of the country (Herrero et al., 2010). African nightshades are not drought-tolerant crops making water to be a limiting factor in their production (Mwai et al., 2012). Seeds may be sown either directly in the field or raised in a nursery and later on transplanted to the seedbed. Both direct sowing and transplanting should be timed at the beginning of the rainy season so as to produce stronger and larger plants, with transplanting carried out in the late afternoons or under cloudy conditions to minimize transplanting shock (Mwai, 2007; Schippers, 2002). In case transplanting is not done at the onset of rains, Schippers (2002) advised daily irrigation for the first week after transplanting and a reduced irrigation interval after seedling establishment to two-to-three times a week.

Despite the fact that many farmers in Kenya are noticing changes in the commencement and termination of rainy seasons (Simelton et al., 2013; Ogalleh et al., 2012), less attention has been paid to the start and cessation of rainfall (Nicholson, 2017). It is at this backdrop that little is known on the alleyway through which rainfall timing affects crop production in Nyando Sub-County. Existing studies in the area have focused on rainfall magnitude and duration (Odundo & Omedi, 2025; Odundo, et al., 2023). This study investigated the effect of rainfall timing on maize, beans and African Nightshade production in Nyando Sub-County of Kisumu County. Maize and beans are leading staple food crops while African Nightshade is a preferred vegetable in Kenya. Like any other zone, Nyando suffers the pangs of climate variability and there exists a dire need to ensure food security for the resident population (Odundo & Omedi, 2025). The six pillars of food security, according to Clapp et al., (2022), are: availability, access, utilization, stability, agency, and sustainability. With over 14.5 million Kenyans experiencing some form of food insecurity (NCPD, 2019), about 3.3 million Kenyans faced crisis-level food insecurity driven by consecutive failed rains, high food prices and drought as of March 2026.

An understanding of rainfall timing and its effects on maize, beans and African Nightshade production, and to an extent, other crop production, is important in enhancing socioeconomic wellbeing of farmers, realization of sustainable development goals on limiting malnutrition and achieving food security as well as the Bottom-Up Economic Transformation Agenda (BETA). This might be through climate-smart farming, including conservation agriculture, intercropping and reduced overreliance on rain-fed agriculture in Nyando County and Kenya, by extension. Maize (*Zea mays*) is an extensively-cultivated grain crop in Kenya, playing a central role in the agricultural sector and the overall economy of the country. Economically, maize is used for human consumption due to its high nutritional and calories' value, animal feed, biofuel production and raw material for alcoholic beverages (Bendakova et al., 2024; Amponsah et al., 2021). According to Karavidas et al. (2022), bean (*Phaseolus vulgaris)* is the most important legume for human consumption worldwide and an important source of vegetable protein, minerals, antioxidants, and bioactive compounds. African

Nightshade *(Solanum nigrum)* is a traditional vegetable preferred for its nutritional value, food security, medicinal, health benefits and income generation (Noella et al., 2018).

2. Literature Review

The change in the onset of rainfall is a great hindrance for growing a majority of food crops that are staple to most households in different parts of the world. According to Nedumaran (2015), the change in the arrival of rainfall had greatly affected food crop production. Brazil as a major maize producer has witnessed a change in production due to the changes in rainfall pattern and duration. A study by Wiliams & Kniveton (2010) shows a steady decline in precipitation by 10% which contributed to the low maize yield within a range of 30% to 60% in Brazil.

In the USA, a variation in the arrival of rainfall due to the emissions of gases in the atmosphere that affected the normal dates when rainfall is received in the major agricultural areas was experienced. Such changes limited the amounts of rainfall used in the growing of beans and maize thus lowering the level of household food security (Seo & Mendelsohn, 2008). A study conducted in Hebei province, China on the effect of rainfall variability on vegetable farming shows that delay of rainfall by 31 days led to 150.26kg loss of Chinese cabbage yield per hectare (Seo & Mendelsohn, 2008). Even though these studies revealed the effect of rainfall changes on crop production, there was a need to do more studies on the effect of timing of rainfall on maize, beans, and African nightshade.

Beans, African nightshade and Maize farming are famous in the majority of African countries since these crops are staple foods in most households. Africa's major maize producers like Nigeria and South Africa depend on rain for such production to be a success. As a result of the large scale, production of maize in such countries, there is a lot of generation of income for the farmers and an increase of the Gross Domestic Product (McCann, 2005). However, Africa is fast becoming food insecure due to many cases of rainfall variability that have led to a monumental decrease in the production of maize, beans and African nightshade thus resulting in importation from other countries. Nigeria as one of the major maize and African nightshade producers in Africa has experienced numerous cases of the timing of rainfall. For instance, the change in the dates of rainfall interfered with the planting days thus leading to the decline in production of such crops hence lowering the GDP by 22% within the last 5 years (Mati, 2010). Moreover, the changing rainfall amounts have increased the incidences of pests and diseases that invade most maize and beans plantations thus minimizing the quantity of maize produced. Similar situation was experienced by maize farmers in South Africa who relied greatly on rainfall for maize production. According to Dinar (2008), the reduction of rainfall between 5-10% forced farmers to look for alternatives of growing maize such as irrigation despite being quite expensive. Consequently, most households were rendered food insecure due to the massive decline in maize and beans production as these crops are valued by more than 70% of South Africans as their stable food (McCann, 2005). These studies focused on rainfall patterns on maize, African nightshade and beans growing, however, there was need to assess the effect of timing of rainfall on maize, African nightshade and beans which was the gist of this study.

Kaguongo & Food and Agriculture Organization of the United Nations (2013) also agreed that changes in rainfall patterns such as rainfall events and intensity had led to uncertainties in growing many food crops in different parts of Kenya. Maize and beans are famous among Kenyan households; in fact, they are some of the most consumed cereals in the country. On the other hand, African nightshade is also largely consumed by households in Kenya due to its nutritional value. The rain-fed crops like maize, beans and African nightshade are mainly grown in the Rift Valley, Western Kenya, parts of Eastern Province and Central Kenya. These areas constitute 50% of the total cereals and vegetables consumed in the country (Oseni & Masarirambi, 2011). However, there has been a consistent reduction in the quantity production of these crops due to changes in rainfall events. According to Mati (2010), the late arrival of rainfall interfered with the planting dates of most farmers who mainly engage in the production of these crops. For instance, planting of the African nightshade declined in several parts of western Kenya due to the late arrival of rainfall in 2014. Though Wakjira et al., (2021) held on to other factors for the decline as pest and diseases, limited capital and competition from other crops as the main cause in the decline of production of these crops, change in the timing of rainfall is considered as the main cause. This, therefore, called for the need to carry out more assessment on the effect of timing of rainfall on maize, beans, and African nightshade farming.

Mati (2010) asserted that the delay in the onset of rainfall between March and June over the last 5 years has contributed to severe loss to farmers. For instance, the tonnage of beans produced reduced for three consecutive years (2017, 2018 and 2019), leading to a decline of 4,000, 3,456 and 3,186 respectively. A similar study carried out by Cohen & Atieno (2010) on the effect of rainfall events on maize farming revealed that the late arrival of September-December 2006 rainfall was not enough to sustain maize growing in the country. As a result, several maize growing regions in Kenya like Trans Nzoia, Narok and Kakamega recorded the least harvest, a phenomenon that caused panic to the Ministry of Agriculture. According to a report by Government of Kenya (GOK) (2015), more than 1.5 million people were affected by the reduction of maize, beans and vegetable production in the country during that period. Therefore, there was need to assess the effect of timing of rainfall on maize, beans and African nightshade production in various parts of the country.

Cohen & Atieno (2010) have pointed out in their research a number of regions in Kenya that are susceptible to rainfall variability and therefore experienced reduced maize production. For instance, the drought experienced in Western Kenya from 2005 to 2009 made it difficult for the vegetables and cereal farmers in the region to obtain high yields. The changes in the dates of long rains disadvantaged the small-scale farmers in cultivating African nightshade, maize, and beans for subsistence use (Food and Agricultural Organization (FAO) (2009). This made the region to over-rely on government assistance for these crops for their subsistence.

Nyando Sub-County also experienced many cases of rainfall variability leading to floods, long droughts and reduced rainfall amounts that affected food crop farming. According to Wani & Rockström (2009), within the last 10 years, the region had experienced a change in rainfall amounts and intensity which have minimized agricultural activities. Initially, there was timely arrival of rainfall that allowed for the production of many crops; however, the late arrival of rainfall has forced farmers to opt for irrigation which was also unreliable and expensive. Many researches in the foregoing literature focused on the general influence of rainfall amounts and intensity on maize farming. This study, however, assessed the effect of timing of rainfall on maize, beans, and African nightshade production in Nyando.

3. Methodology

3.1 Study Area

Nyando Sub-County falls in the southern hemisphere. It has a longitudinal extend of 2°, from 33° 20' East to 35° 20' East of the Greenwich Meridian and a latitudinal extend of 30', from 0° 20' South to 0° 50' South of the Equator. Sandwiched between the Nandi Hills of Rift Valley and the Nyabondo Plateau of Upper Nyakach, the Sub-County is approximately 163 square kilometers with a population of 122,376 persons (KNBS, 2019). The Sub-County falls within the modified equatorial climate of the Lake Victoria Basin of the Kenyan region. Black cotton soil that stays sticky and difficult to work on during wet seasons, and dry to crack during dry seasons, is dominant.

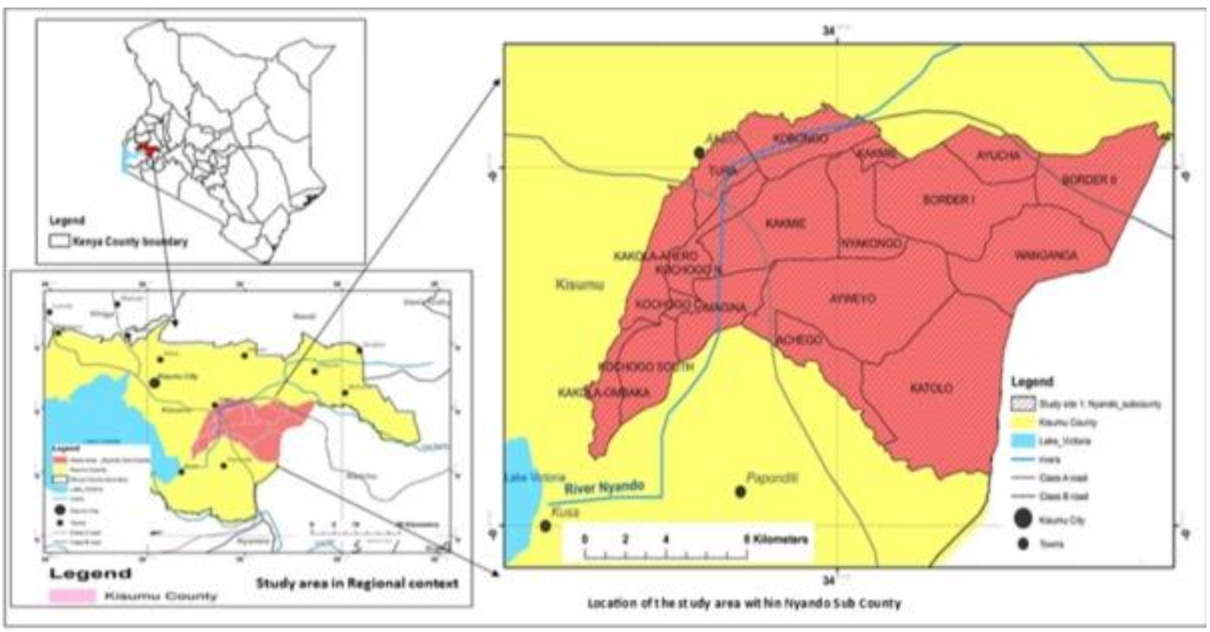

Figure 1: Study Area

3.2 Research design and instruments

A quasi-longitudinal research design was employed. Data on rainfall timing was obtained from Kisumu County Meteorological Department. Data on food crop production was obtained from household heads and Ministry of Agriculture, both at County and Sub-County levels. Research instruments included structured questionnaire for household heads, interview schedule for key informants, focus group discussion and observation checklist. The unit of data analysis was households.

3.3 Sample size and sampling procedure

A sample size of 384 was used based on Yamane's (1967) formula. Systematic random sampling was used in selecting the 384 respondents from the farming households in the study area. Purposive sampling was used in the selection of Key Informants. These included: One (1) Officer from the Ministry of Agriculture (MoA) who provided data on crops grown in the area for the period 2013-2022 and Two (2) Officers from the Kenya Meteorological Department (KMD), Kisumu County, who provided data on the timing of rainfall for the period 2013-2022.

3.4 Data Analysis

Statistical Package for Social Science (SPSS) version 22 was used in the quantitative analyses. Data on food crop yields was descriptively analyzed while data on rainfall timing was analyzed using linear regression. Qualitative data on types of food crops was analyzed by creating categories, themes and patterns relevant in explaining quantitative findings.

3.5 Ethical Considerations

Prior to the data collection exercise, permission was sought from the Maseno University Scientific and Ethics Review Committee (MUSERC) and NACOSTI for a research license permit for authority to proceed with the research. Besides, permission was sought from the local administration to conduct the research within their areas of jurisdiction. Informed consent was obtained from the respondents after an assurance that confidentiality, privacy and anonymity would be maintained. This was achieved by use of codes in the household's questionnaires instead of actual names of the respondents.

4. Results and Discussion

4.1 Farmers' perception on the nexus between rainfall timing and maize, beans and African nightshade production

Descriptive analysis was conducted to ascertain farmers' perception on rainfall arrivals during short and long rains, change in rainfall timing and crop yields during the two seasons. Moreover, rainfall timing during short rains and long rains and the crop yields during the short and long rains were also obtained. These results were as presented in Table 1.

Table 1: Summary of rainfall timing on maize, beans and African nightshade production

Good timing of long rains	Good timing of short rains	Harvest in untimely rainfall	Harvest in timely rainfall
Yes 174	Yes 164	Maize 7 Bags	Maize 12 Bags
No 203	No 217	Beans 2.8 Bags	Beans 5 Bags
Undecided 7	Undecided 3	Nightshade 285 Kg	Nightshade 350 Kg

Source: Field Data

The results in Table 1 established that the majority (203) of household heads agreed that early arrival of long rains was not good for general crop yield in the study area. It was noted that the female respondents (62%) had better timing on rainfall compared to male respondents (38%). This is because the females were more engaged in farming than male respondents and thus had better idea on the onset of short and long rains. Short rain timing was a challenge to majority of the respondents (217). The respondents with large households (3-4) had better rainfall timing than those with smaller households. The large households were in constant speculation on the onset of rains to allow them grow crops early enough to meet the family demands. With poor rainfall timing, the mean crop yield for maize, beans and African nightshade were 7 bags, 2.8 bags and 285kg respectively (Table 1). Such yields were not sufficient for large households and were forced to seek for other alternatives to feed their families. With good rainfall timing, crop yields were 12 bags, 5 bags and 350kg for maize, beans and African nightshade, respectively, per household (Table 1). There was a general consensus by the majority of the respondents that onset of long rains had changed from 2020-2022 thus explaining the decline in crop yields within those years.

In addition, the respondents' perception on rainfall timing was established by the study. The study further established the perception of respondents on onset of rainfall during short and long rains and how it influenced selected crops from 2020 to 2022. Moreover, the respondents' opinion on whether they were considering other crops due to the change in rainfall onset was established. These results were presented in Table 2.

Table 2: Perception of rainfall timing on maize, beans and African nightshade production

Change in onset of long rains (2020-2022)	Change in onset of short rains (2020-2022)	If yields of the selected crops changed (2020-2022)	Consideration of other crops	General change in the arrival of rains (2020-2022)
2020 [Yes 278], [No 111], [Undecided 1]	2020 [Yes 278], [No 111], [Undecided 1]	2020 [Yes 278], [No 111], [Undecided 1]	Yes 145	Yes 181
2021 [Yes 281], [No 96], [Undecided 7]	2021 [Yes 281], [No 96], [Undecided 7]	2021 [Yes 281], [No 96], [Undecided 7]	No 227	No 143
2022 [Yes 308], [No 70], [Undecided 6]	2022 [Yes 308], [No 70], [Undecided 6]	2022 [Yes 308], [No 70], [Undecided 6]	Undecided 12	Undecided 60

Source: Field Data

Results from Table 2 revealed the perception of household heads on rainfall timing on maize, beans and African nightshade production. Most of the household heads observed that the yield of the selected crops changed between 2020 and 2022. This was due to the climate shocks that were witnessed in different parts of the world. It is believed that global warming led to changes in the rainfall patterns. This assertion is supported by Anthropogenic Global Warming Theory that explains how global warming led to reduced hours of rainfall. Because of such uncertainties in hours of rainfall, most respondents (227) confirmed that they were slowly shifting from rain-fed agriculture to irrigation to cope with the phenomenon. In general, most respondents (181) were in agreement, 143 disagreed while the remaining respondents were undecided that there was change in the arrival of rains between 2020 and 2022. Majority (47%) of respondents who agreed that onset of rains had changed were the female since they were much engaged in food crop production than males. Male respondents (37%) who disagreed on the rainfall arrivals were more involved in cash crop farming and therefore failed to pay keen attention on the short cycle of rainfall arrivals.

4.2 Effect of rainfall timing on maize, beans and African nightshade production

4.2.1 Overall effect of rainfall timing on maize, beans and African nightshade production

Information on rainfall timing and crop yields was obtained from the primary data sources and analyzed using the simple linear regression. This was done to establish the relationship between rainfall timing and the selected food crop production. The results were as presented in Table 3.

Table 3: Results of simple linear regression analysis on the effect of rainfall timing on maize, beans and African nightshade production

Model	ar^2	df1	df2	F statistics	T	ρ	N
Maize Yield (bags/acre/annum)	.651	1	383	11.45	13.842	.000	384
Bean Yield (bags/acre/annum)	.474	1	383	16.08	-6.048	.000	384
Nightshade (kg/acre/annum	.382	1	383	8.73	-4.32	.000	384

Source: Field Data

Results of simple linear regression analysis in Table 3 indicated that there was significant effect between rainfall timing and maize yield [F (383) =11.45, $\rho < .001$, r^2 =.65], beans yield [F (383) =16.08, $\rho < .001$, r^2 = .47], and African nightshade yield [F (383) =8.73, $\rho < .001$, r^2 = .38]. Further analysis of the model showed that maize had significant positive linear association (t =13.84, $\rho < .001$), beans, and nightshade revealed a significant negative linear relationship (t = -6.05 $\rho < .001$), and (t = -4.32, $\rho < .001$) respectively. The simple linear regression results revealed that household who had good timing were likely to report improved maize yield (65%).

The right rainfall timing positively influenced maize production since the crop had enough water within the raining period thus increasing the yield. Previously, most farmers had the challenge of predicting the onset of rains thus derailing growing of crops such as maize. However, with the right prediction, maize yield increased within good margin. Better rainfall timing also positively affected both beans and African nightshade yields. Despite requiring low rainfall, good timings among the farmers were enough to encourage faster maturity of these crops. Most respondents agreed that timely rainfall allowed for the seeds to germinate faster thus leading to timely maturity. As such, about 65% of the variation in maize yield could be explained by change in rainfall timing. With the good timings, maize crop had the right amount of rainfall during the cultivation period. The information provided from the department of agriculture showed that good rainfall timing enabled maize crop to attain at least 600mm of rainfall for optimal maturity. About 47% of beans yield was affected by erratic rainfall timing. Most farmers failed to plant beans in time with the onset of rains which led to insufficient yields of the crop. The 38% change in African nightshade harvest was affected by changes in onset of rains. The change in the arrival of rainfall led to the reduction in the crop harvest since there was either extreme water logging or drying of the farms.

The results on maize yields agreed with findings of McCann (2005) in Mpumalanga province in South Africa which reported an increase in maize yield due to good rainfall timing. This is because the two areas of study experienced similar rainfall events hence similarity in findings. Therefore, better rainfall timing improved maize yields within the study area. The findings of Owino (2008) also agreed that both beans and the African nightshade showed a negative trend with rainfall timing, since beans require moderate short rains for optimal yields.

4.2.2 Effect of Rainfall Timing on Maize, Beans and African Nightshade Production during Long Rains

Linear regression was carried out to examine the effect of timing of rainfall on maize, beans and African nightshade production during long rains. This was done to establish any variation in the amounts of yields during the two rainy seasons. Results on the statistical relationship between the variables are presented in Table 4 below.

Table 4: Effect of rainfall timing on maize, beans and African nightshade production during long rains

Model	ar^2	df1	df2	F statistics	T	ρ	N
Maize Yield (bags/acre/annum)	.582	1	383	23.21	12.663	.000	384
Bean Yield (bags/acre/annum)	.481	1	383	17.33	-5.332	.000	384
Nightshade (kg/acre/annum	.514	1	383	16.41	-7.518	.053	384

Source: Field Data

Results of simple linear regression analysis in Table 4 indicated that there was significant relationship between rainfall timing (long rains) and maize yield [F (383) =23.21, $\rho < .001$, $r^2 = .58$], beans yield [F (383) =17.33, $\rho < .001$, $r^2 = .48$], and African Nightshade yield [F (383) =16.41, $\rho < .001$, $r^2 = .51$]. Further analysis of the model showed that maize had significant positive linear association (t = 12.66, $\rho < .001$), beans and nightshade revealed a significant negative linear relationship (t =-5.33 $\rho < .001$) and (t =-7.52, $\rho < .001$), respectively. About 58% of the variation in maize yield could be explained by change in rainfall timing in long rains seasons, 48% of beans yield was affected by variability in rainfall timing during long rains, while 51% change in nightshade harvest was possibly affected by changes in rainfall timing during long rains seasons.

Maize yield indicated a strong positive linear association with right rainfall timing for long crop cycle. This is because maize takes longer duration before it matures therefore proper timing allowed it to get enough rainfall with the growing period. Most respondents agreed that timing of the long rains was a challenge therefore, the few times that they managed to predict the onset of rainfall led to an increase in the maize yields. Female respondents (62%) had better timing on rainfall onset than the males (38%) since they were more involved in food crop production. The female respondents had a vast idea on the extent of rainfall variability thus had to try as much as possible to predict rainfall arrivals. Beans and African nightshade on the other hand portrayed negative linear relationship in the same season. Beans and African Nightshade crops were popular among the widowed respondents (31.4%) as they perceived the two crops to be less capital intensive. This finding was concretized by a response from a focus group discussion which revealed:

> "*I have had a lot of challenges in food crop production like maize and a few other vegetables. My major challenge is coping up with the production of capital intensive maize crop. Some people would think that once the rains are there then maize grow automatically. However, you must have good capital to help in land preparation as well as paying the workers in the farm. I am therefore forced to concentrate on beans and African nightshade production that require less capital*".

Poor timing of rainfall had little impact on beans and African nightshade yields since both crops take a relatively shorter time to reach maturity compared to maize crop.

The results on maize yields were different from the findings in Matabeleland, Zimbabwe by Williams and Kniveton (2011) which reported constant maize yield as a result of good rainfall timing. This is because unlike Matabeleland which has longer rainfall distributions, Nyando has a relatively shorter rainfall distribution, therefore early rainfall timing ensured that maize crops had enough moisture for their maturity. This led to increase in the maize yield due to good rainfall timing. The findings on beans differed with that of Leal et al. (2015) that reported an increase in yields of beans as a result of predicting the onset of rains. The findings assert that right timing of rainfall ensured that beans matured within the rainfall weeks thus increasing the yields. However, in Nyando most respondents were found to be growing different varieties of beans that responded differently to rainfall timing. The findings of Edmonds and Chweya (2018) agreed that African nightshade yields increased with good rainfall timing during long rains seasons. This is because the vegetable takes shorter time to reach maturity. Therefore, right rainfall timing increased its yield.

4.2.3 Effect of Rainfall Timing on Maize, Beans and African Nightshade Production During Short Rains

Further analysis was conducted on the effect of rainfall timing on maize, beans and African nightshade production during short rains. This was using linear regression and the results are as presented in Table 5.

Table 5: Effect of rainfall timing on maize, beans and African Nightshade production during short rains

Model	ar^2	df1	df2	F statistics	T	ρ	N
Maize Yield (bags/acre/annum)	.581	.65	383	22.68	10.74	.020	384
Bean Yield (bags/acre/annum)	.432	.47	383	11.74	-6.039	.009	384
Nightshade (kg/acre/annum	.341	.38	383	18.13	-5.099	.059	384

Source: Field Data

Results of simple linear regression analysis in Table 5 indicated that there was significant effect between rainfall timing in short rains and maize yield [F (383) =22.68, $\rho < .05$, $r^2 = .58$] and beans yield [F (383) =11.74, $\rho = .01$, $r^2 = .43$]. However, African nightshade yield [F (383) =18.13,

$\rho < .1$, $r^2 = .34$] was insignificantly predicted. Further analysis of the model showed that maize had significant positive linear association ($t = 10.74$, $\rho < .05$) while beans and Nightshade revealed a significant negative linear relationship: ($t = -6.04$, $\rho < .01$) and ($t = -5.1$, $\rho < .1$), respectively.

From the findings, maize crop yield improved with good rainfall timing during short rain cycle. Short rains had to be accurately timed for better maize yield. Most respondents therefore agreed that they had to speculate the onset of rains to allow them get good maize harvest during the short rains. Similar trend was observed with beans and nightshade yields. In 2020, about 72% of the respondents with the majority being females failed to predict the rainfall onset therefore reducing maize yield by 58%. The study area was worst hit in 2022 when more than 80% of the farmers could not tell when the short rains would arrive thus affecting food crop production. Therefore, the 58% variation in maize yield was explained by change in rainfall timing in short rains seasons between the years 2020 to 2022. Even though beans require low rainfall, its production was slightly affected by changes in rainfall arrival. Despite the late rainfall arrival, the farmers who planted late managed to harvest beans within the 4-5 weeks that the short rains lasted. However, the bean yield greatly declined in 2022 when short rains delayed for about 4 weeks. During the short rains, farmers' attitude changed towards farming since they could not predict the yields. In a nutshell, the declined beans production was not only attributed to late rainfall arrival but also on the negative attitude of farmers on the expected yields.

Untimely arrival of the short rains affected the quality of African nightshade produced. The 34% variation in African nightshade production was not only caused by changes in rainfall timing but also due to diseases that thrive well during the short rains. Moreover, most respondents confirmed that during the short rains, there was great attack by pests (birds) on the crops. This means that a number of farmers opted out of farming not only due to untimely rainfall arrival but also due to many incidences of pest invasion. Despite the great impact caused by late rainfall arrivals and the crop diseases, most respondents confirmed the delay of the short rains forced them to use other alternative techniques like irrigation to boost the crop yields. The irrigation technique enabled them to realize better yields that met the high market demands during the short rains.

The results on maize contrasted the findings in Bahati Sub-County by Arunga et al., (2012) which reported a reduction on maize yield as a result of good rainfall timing. This is because the anticipated low rains in the second season led to poor timing decisions among the households of Nyando in terms of maize production (Omondi 2018). The result of beans yields is similar to the findings by Edmonds & Chweya (2018) that noted a weak negative correlation between the yield and rainfall timing during the short rains seasons. Earlier findings on Nightshade yield by Katungi et al., (2009) indicated that the vegetable was drought-resistant and did well under irrigation and was on high demand during the dry season.

5. Conclusion and Recommendations

5.1 Conclusion

The study established that rainfall timing is statistically significant in assessing the selected crops' yields. Simple linear regression analysis indicated that there was significant effect of rainfall timing on maize yield ($F=11.45$, $\rho < .001$, $r^2 = 0.65$), beans yield ($F=16.08$, $p< 0.01$, $r^2 = 0.47$), and African nightshade ($F=8.73$, $p< 0.001$, $r^2 = 0.38$). About 65 percent, 47 percent and 38 percent of the variations in maize, beans and African nightshade yields respectively was explained by change in rainfall timing. There was significant effect of rainfall timing during long rains and maize yields ($F=23.21$, $p< 0.001$, $r^2 = 0.58$), beans yield ($F=17.33$, $p< 0.001$, $r^2 = 0.48$) and African nightshade ($F=16.41$, $p< 0.001$, $r^2 = 0.51$). Further, there was significant effect between rainfall timing during short rains and maize yields ($F=22.68$, $p< 0.001$, $r^2 = 0.58$), beans yield ($F=11.74$, $p = 0.059$, $r^2 = 0.43$), and African Nightshade ($F=18.13$, $p < 0.051$, $r^2 = 0.34$). Clearly, rainfall timing affected the production of these crops.

5.2 Recommendations

Based on the research findings, the study recommends the following:

1. Adapting food production systems to cope with and adapt to changing climate especially the timing of rainfall. This can be well-guided by having localized weather-prediction models, investing in region-specific research and implementing adaptive technologies tailored to local conditions.
2. Farmers need to respond to the changing growing conditions by altering their production techniques. This is an imperative since variation in rainfall timing affects soil moisture balance, and when combined with other climate change variables of temperature and wind patterns, definitely impacts crop production.

References

Amponsah, R., Kong, X., & Abendin, S. (2021). The impact of maize trade on the development of the maize industry in Ghana. *Open Journal of Business and Management*, *9*: 1906-1931.

Arunga, E. E., Ochuodho, J. O., Kinyua, M. G., & Owuoche, J. O. (2012). Characterization of Uromyces appendiculatus isolates collected from snap bean growing areas in Kenya.

Bendakova, V., Nagy, H., Turcekova, N., Adamickova, I., & Bielik, P. (2024). Assessing the climate change impacts on maize production in the Slovak Republic and their relevance to sustainability: a case study. *Sustainability, 16, 5573*.

Cohen, D. W., & Atieno, O. E. S. (2010). *Siaya: The historical anthropology of an African landscape*. London: J. Currey.

Chweya, J. A. (2018). *Black nightshades: Solanum nigrum L. and related species*. Rome: IPGRI.

Clapp, J., Moseley, W., G., Burlingame, B., & Termine, P. (2022). Viewpoint: The case for a six-dimensional food security framework. *Food Policy 106 (2022) 102164*.

Dinar, A. (2008). *Climate change and agriculture in Africa: Impact assessment and adaptation strategies*. London: Earthscan.

Edmonds, J. M., & Chweya, J. A. (2018). *Black nightshades: Solanum nigrum L. and related species*. Rome: IPGRI.

Food and Agricultural Organization. (2009). The state of insecurity in the world 2009. Food and Agriculture Organization of the United Nations, Rome, 58 pp.

Food and Agricultural organization (FAO) (2020). FAOSTAT Maize Statistics.

Government of Kenya (2015). *Economic Review of Agriculture*. Ministry of Agriculture, Livestock and Fisheries. Nairobi: GPO, 62(62).

Hatfield, J. L., & Dold, C. (2018). Agroclimatology and wheat production: copping with climate change. *Front. Plant Sci. 20 (224)*.

Herrero, M., Ringler, C., Van de Steeg, J., Thornton, P., Zhu, T., Bryan, E., Omolo, A., Koo, J., &Notenbaert, A. (2010). Climate Variability and Climate Change and their Impacts on Kenya's Agricultural sector. *International Livestock Research Institute (ILRI), Nairobi, Kenya*.

Huho, J. M. and Kosonei, R. C. (2013). *The opportunities and challenges for mitigating climate change through drought adaptive strategies: the case of Laikipia County, Kenya*. SAVAP

International Fund for Agricultural Development (IFAD). (2011). Document County Programme Evaluation, Rome, IFAD, Nairobi.

Kabata, L. N., Makokha, G. L., & Obiero, K. (2021). Seasonal rainfall variability effects of smallholder farmers' maize yields in Kieni East sub-County, Nyeri County, Kenya. J*ournal of Arts and Humanities, 10(10)*: 12-29.

Kaguongo, W., & Food and Agriculture Organization of the United Nations. (2013). *A policymakers' guide to crop diversification: The case of the potato in Kenya*. Rome: Food and Agriculture Organization of the United Nations.

Karavidas, I., Ntatsi, G., Vougeleka, V., Karkanis, A., Ntanasi, T., Saitanis, C., Agathokleous, E.,Ropokis, A., Sabatino. L., Tran, F., Iannetta, P. P. M., & Savvas, D. (2022). Agronomic practices to increase the yield and quality of Common Bean (*Phaseolus vulgaris*): A systematic review. *Agronomy, 12 (271)*.

Katungi, E., Farrow, A., Chianu, J., Sperling, L., & Beebe, S. (2009). Common bean in Eastern and Southern Africa: a situation and outlook analysis. *International Centre for Tropical Agriculture*, *61*, 1-44.

KNBS. (2019). *Population and Housing Census*. Nairobi: GPO.

Leal, F. W., Esilaba, A. O., Rao, K. P. C., & Sridhar, G. (2015). *Adapting African Agriculture to Climate Change: Transforming Rural Livelihoods*.

Mati, B. M. (2010). The effect of climate change on maize production in the semi-humid–semi-arid areas of Kenya. *Journal of Arid Environments*, *46*(4), 333-344.

McCann, J. (2005). *Maize and grace: Africa's encounter with a New World crop, 1500-2000*. Cambridge, Mass: Harvard University Press.

MoALFC. (2021). *Kenya County Climate Risk Profile: Kitui County*. Ministry of Agriculture, Livestock, Fisheries and Co-operatives (MoALFC). Nairobi: GPO.

Mwai, G. N., Ojiewo, C. O., Masinde, P. W., & Aging, S. G. (2012). Good agricultural practices for African Nightshade production in sub-Saharan Africa. In: Nono-Womdim, R., Ojiewo, C., Abang, M., & Oluoch, M. O. (Eds.), "Good agricultural practices for African indigenous vegetables. Proceedings of a Technical Consultation Workshop held in Arusha Tanzania, 7-8 December 2009". *International Society for Horticultural Sciences, Belgium*.

Mwai, G. N. (2007). Morphological and Molecular Characterization and Yield Evaluation of Vegetable African Nightshades (Solanum L. Section Solanum) under Varying Cultural Practices. *Unpublished PhD Thesis, Maseno University, Maseno, Kenya*.

National Council for Population and Development (NCPD). (2019). Food security and nutrition in Kenya: the role of population. *Position Paper, Issue 2*.

Nedumaran, S. (2015). *Climate change challenges and adaptations at farm- - case studies from Asia*.

Nicholson, S. E. (2017). Climate and climate variability of rainfall over Eastern Africa. *Rev. Geophys*: 55 (3): 590-635.

Noella, E., Abukutsa-Onyango, M. O., & Wesonga, J. (2018). Production, processing and storage techniques of African Nightshade (Solanum spp.) seeds and their correlation with farmers' characteristics in western Kenya. *African Journal of Food, Agriculture, Nutrition and Development; 18(2)*: 13338-13351.

Odundo, T. & Omedi, G. (2025). Influence of rainfall magnitude on Maize, Beans and African Nightshade production in Nyando sub-County of Kisumu County, Kenya. *International Journal of Research and Innovation in Social Sciences, IX(V)*: 6508-6517.

Odundo, T. (2023). Effect of rainfall variability on selected food crop production in Nyando sub-County, Kisumu County, Kenya. *Unpublished Masters Thesis, Maseno University*, Kenya.

Odundo, T., Mutavi, I., & Obuoyo, J. (2023). The effect of rainfall duration on Maize, Beans and African Nightshade production in Nyando sub-County of Kisumu County, Kenya. *International Journal of Innovative Science and Research Technology, Volume 8, Issue 7*: 346-355.

Ogalleh, S., Vogl, C., Eitzinger, J., & Hauser, M. (2012). Local Perceptions and Responses to Climate Change and Variability: The Case of Laikipia District, Kenya. *Sustainability 4*: 3302-3325.

Omondi, S. (2018). *Urban-based agriculture and poultry production: The case of Kisumu and Thika in Kenya* (No. 23). Lund University.

Owino, R. A. (2008). *Ethnobotany and Mineral Contents of Indigenous Vegetables of Kisumu District in Kenya* (Doctoral dissertation, University of Nairobi).

Oseni, T. O., & Masarirambi, M. T. (2011). Effect of climate change on maize (*Zea mays*) production and food security in Swaziland. *change*, *2*(3).

Seo, S. N., & Mendelsohn, R. (2008). An analysis of crop choice: Adapting to climate change in South American farms. *Ecological economics*, *67*(1), 109-116.

Schippers, R. R. (2002). African indigenous vegetables: an overview of the cultivated species. 2nd revised edition on CD-Rom. *Natural Resources Institute International, University of Greenwich and Horticultural Development Services.* UK: LLP, Chatham.

Shackleton, C. M., Pasquini, M., & Drescher, A. W. (2009). *African indigenous vegetables in urban agriculture*. London: Earthscan.

Simelton, E., Quinn, C. H., Batisani, N., Dougill, A. J., Dyer, J. C., Fraser, E. D. G., Mkwambisi, D., Sallu, S., & Stringer, L. C. (2013). Is rainfall really changing? Farmer's perceptions, meteorological data, and policy implications. *Climate and Development 5*: 123-138.

Tesfaye, W., & Seifu, L. (2016). Climate change perception and choice of adaptation strategies: empirical evidence from smallholder farmers in east Ethiopia. *Int. J. Clim. Chang. Strateg. Manag. 8*: 253–270.

Wagesho, N. (2016). Analysis of Rainfall Variability and Farmers' Perception towards it in Agrarian Community of Southern Ethiopia. *Journal of Environment and Earth Science 6(4)*:99-107.

Wakjira, M. T., Peleg, N., Anghileri, D., Molnar, D., Alamirew, T., Six, J. & Molnar, P. (2021). Rainfall seasonality and timing: implications for cereal production in Ethiopia. *Agricultural and Forest Meteorology*, 310.

Williams, C. J. R., & Kniveton, D. R. (2011). *African climate and climate change: Physical, social, and political perspectives*. Dordrecht: Springer.

Yamane, T. (1967). Statistics: An Introductory Analysis,2nd Edition, New York. Harper and Row.