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Seasonal Rainfall Variability Effects on Smallholder Farmers' Maize Yields in Kieni East Sub-County, Nyeri County, Kenya

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ABSTRACT

Agricultural production in Kenya is rainfall dependent, thus long -term and short-term rainfall variability affects crop productivity. The primary goal of the agriculture sector in the country is to achieve national food security. This paper therefore analyzes seasonal rainfall variability effects on smallholder farmers' maize yields in Kieni East sub-County between years 2009-2018. Rainfall data was collected from existing meteorological stations in the study area while maize yields data was obtained from the Ministry of Agriculture (MoA), Nyeri County. Data analysis entailed use of trend analysis and Karl Pearson correlation at 1% levels of significance. Results of the study showed a decline in the annual maize yields in tons as indicated by a negative gradient of -231.9. During both the long and short rains there was also a decline in maize yields with a negative gradient of -69.19 and -162.71 respectively. The study concluded that at 1% levels of significance there was a strong positive correlation between rainfall and maize yields in the study area. It is recommended that the research findings be used by the Ministry of Agriculture (MoA) to formulate policies that focus on rainfall variability and its effects on smallholder maize farming so as to improve the yields.

Keywords: Seasonality, Rainfall Variability, Smallholder Farmers, Maize Yields.

1. Introduction

Studies in rainfall evolution in many areas show that climate change translates into altered weather conditions such as rainfall variations and extreme events (WMO, 2013). Climate extremes are anticipated to grow more frequent and severe as a result of global warming, according to (IPCC, 2012). Crop productivity is reduced by more variable rainfall patterns and unpredictable high temperature periods (Kumar *et al*., 2012). Maize (Zea Mays) is a cereal crop that may be cultivated in a variety of Agro-Ecological Zones. It is, after wheat, the world's second most significant food crop. Maize is farmed in various places of the world in both long and short rainy seasons, and matures in 90-190 days

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depending on the seed variety (Schroeder *et al*., 2013). Rainfall variability will reduce global production of essential crops like maize, wheat, and rice (Lobell *et al*., 2011; Sage et al., 2015).

Rainfall in Africa is extremely varied, and it is influenced by both climate change and human activity (Muchuru & Nhamo, 2019). Climate change is expected to increase climate variability, as well as the frequency and severity of extreme weather events in Africa and other parts of the world (Thornton et al., 2011; Coumou & Rahmstorf, 2012; IPCC, 2012). Variability in rainfall is observed in both seasonal and annual trends, influencing various household livelihoods. Due to its critical relevance in supporting life on, notably in the sector of agriculture, rainfall is one of the most important climatic factors in developing countries (Wagesho, 2016). According to FAO (2009) maize production in Africa is rain-fed, and it is extremely vulnerable to extreme weather events like rainfall variability.

SSA has been identified as one of the most sensitive to the effects of climate change (Bryan et al., 2013; IPCC, 2014). Crop yields in Southern and Western Africa could decline by 18-45% by the end of the century, with an overall mean decline of 24% in most of Sub-Saharan Africa, according to Waha *et al*. (2013), based on three general circulation models (GCMs: MPI-ECHAM5, UKMO-HadCM3, and NCAR-CCSM3) using the SRES A2 emission scenario. Rain-fed agriculture, particularly in tropical and semi-arid climates, is characterized by poor crop yields that are significantly below potential yields attainable in the area, as well as significant on-farm water losses. Rain-fed cereal yields in tropical and semi-arid Sub–Saharan Africa, for example, have been reported to be around 1 ton ha-1 (Rockstrom, 2001), compared to potential yields of 3-5 tons ha-1 in the region (Barron, 2004). This substantial disparity demonstrates that there is a significant opportunity to boost rain-fed agriculture crop yields.

Maize is an important cereal food crop in East Africa, with 7.3 million hectares grown each year, accounting for 21% of arable land and 41% of cereal land (Erenstein *et al*., 2011). Heavy rainstorms are projected to grow more prevalent in Eastern Africa, posing a threat to crop output (Herrero *et al*., 2010). East Africa could lose 40% of its maize yield by the end of the 21st century due to a drop in existing farming acreage (Lobell *et al*., 2011),a decline attributed to limited seasonal length, heat stress, diseases and weeds prevalence (Ziska *et al*., 2011).

In Kenya, climate is the most important predictive element in rain-fed agricultural systems, and its impact is considerably higher in the Arid and Semi-Arid Lands (Herrero *et al*., 2010). The amount, timing, and distribution of rain have all changed, resulting in lower agricultural productivity (Huho & Kosonei, 2013). Despite rising rainfall variability in Kenya, rain-fed small-scale agriculture still accounts for 75% of the country's agricultural production (Herrero *et al*., 2010). The country's food security is challenged by a decrease in maize yield coupled with an increase in demand. Since the year 2000, Kenya has depended on maize imports and food aid because domestic production has continuously fallen short of the country's consumption demands (Herrero *et al*., 2010). According to FAO (2013), maize is farmed on an estimated 1.5 million hectares in the country each year, yielding approximately 26 million bags of maize. This is less than the 34 million bags of maize that is predicted to be consumed in the country each year (Kang'ethe, 2011).

Monthly rainfall variability is somewhat more noticeable in the drier zones of Kenya's central highlands, where maize farming is the staple food and accounts for 90% of the population where Kieni East sub-County is located, and is mostly rain-fed. Rainfall occurs 4-7 rainy months (Jaetzold *et al*., 2007), but with high seasonal variations (Micheni *et al*., 2004). Prolonged cold seasons, increased frost incidences (typically coupled with dry spells), extended rainy seasons, and, in some locations, such as Kieni East, prolonged drought (MoALF, 2016), are further signs of climate extremes. As a result, these changes in precipitation patterns are expected to have a negative influence on maize yield. The rainfall patterns in Nyeri County have altered, with amounts declining every 3-4 years (Karienye *et al*., 2012). Maize yield in 90kg bags were 61,531,000 in the year 2015, 13,028,000 in 2016, 18,114,000 in 2017, and 12,866,000 in 2018, according to a joint report by Kenya Food Security Steering Group (KFSSG) and Nyeri County Steering Group (Nyeri County, February, 2018), indicating variability, attributable in part to climatic hazards such as rainfall variability. In the year 2013, floods resulted in a 15% reduction in agricultural areas in the Kiamathaga in the sub-County, as well as an equal loss in maize yields (Orre *et al*., 2013).This study therefore sought to analyze the effects of seasonal rainfall variability on smallholder farmers' maize yields in Kieni East sub-County in Nyeri County, Kenya, between the years 2009 and 2018. The maize crop therefore was chosen because of its importance in the local diet of people in central Kenya, notably in Kieni East sub-County, where the majority of farmers are smallholder farmers who rely on rain-fed agriculture, as well as its extensive cultivation throughout the country. Rainfall data was collected from existing meteorological stations in the study area while maize yields data was obtained from the Ministry of Agriculture (MoA), Nyeri County. Data analysis entailed use of trend analysis and Karl Pearson correlation at 1% levels of significance. Results of the study showed a decline in the annual maize yields in tons as indicated by a negative gradient of -231.9. During both the long and short rains there was also a decline in maize yields with a negative gradient of -69.19 and -162.71 respectively. The study concluded that at 1% levels of significance there was a strong positive correlation between rainfall and maize yields in the study area. It is recommended that the research findings be used by the Ministry of Agriculture (MoA) to formulate policies that focus on rainfall variability and its effects on smallholder maize farming so as to improve the yields.

Understanding rainfall variability and its characteristics is critical to enhancing the socio-economic well-being of smallholder maize farmers and enhance the realization of the vision 2030 goal together with the Big Four Agenda on food security in the sub-County, Nyeri County, and in the country in general. The outcomes of the research will be used by the MoA, other policy-makers and stakeholders to develop policies that address rainfall variability. The information will be used by smallholder maize farmers to evaluate their adaptive tactics and develop successful techniques for dealing with extreme rainfall variability. The findings will also serve as a foundation for ongoing learning and the selection of farmer innovations that are likely to improve smallholder farmers' adaptive strategies.

2. Literature review

2.1 Inter and intra-seasonal rainfall variability

Climate change is expected to increase climate variability, as well as the frequency and intensity of extreme weather events in Africa and elsewhere (Muller *et al*., 2011; Thornton *et al*., 2011; Coumou & Rahmstorf, 2012). Furthermore, several studies on precipitation and temperature change have discovered that the African continent is now warmer than it was 100 years ago, with increased inter-annual and intra-seasonal variability in rainfall (Cooper & Coe, 2011; Rosell, 2011). However, when it comes to climate change and extreme events, Africa is lacking in expertise (Herrero *et al*., 2010). Rain-fed agriculture is likely to be increasingly impeded in many parts of Africa as a result of increased climate-related threats. Temperatures in Sub-Saharan Africa (SSA) are predicted to rise, as are changes in rainfall intensity and distribution, as well as an increase in the occurrences of extreme weather events, such as droughts and floods, pests, weeds, and disease epidemics (FAO, 2015; Connolly-Boutin & Smit, 2015).

According to Niang *et al*. (2014), climate variability is projected to enhance precipitation fluctuations in East Africa. Farmers in this region have always had to contend with a great deal of variability in rainfall, both within and between seasons, and their farming practices have never remained consistent (Cooper & Coe, 2011). Climate change is already causing changes in precipitation patterns and more frequent and irregular extreme events such as floods and droughts in Kenya (Badege *et al*., 2013). Studies show that many farmers in Kenya and Uganda are noticing climate changes such as changes in the commencement and termination of rainy seasons, increased rainfall variability, and decreasing rainfall (Osbahr *et al*., 2011; Ogalleh *et al*., 2012; Simelton *et al*., 2013). Scientists in East Africa however have paid less attention to start and cessation than to seasonal totals (Nicholson, 2017), although Camberlin and Okoola (2003) and Mugalavai *et al*. (2008) investigated the start and end of rainfall in Kenya and linked it to atmospheric, oceanic, and local factors (winds, water body, vegetation cover and topography). The onset of the long rains has been linked to equatorial zonal winds across Kenya and Tanzania (Camberlin & Okoola, 2003).

According to Huho and Mugalavai (2010), the great majority of Kenya is classified as ASALs, which include the Kieni East sub-County. According to Omwoyo *et al*. (2015), Kenya's arid and semi-arid counties experience significant climate variability, which has major implications for maize yields and food security, and climate change-related agricultural constraints range from pronounced seasonality of rainfall to severe and recurrent droughts. As a result of these findings, Barron *et al*. (2003) recommend characterizing rainfall variability at a local level as a first step in on-farm management.

According to a study by Bryan *et al*. (2011), farmers are more concerned about growing variability and seasonal differences, which limits their ability to predict rainfall patterns and plan their farming activities accordingly. The study of variables such as rainfall amount, rainy days, growing season duration, and frequency of dry spells, as well as within-season and inter-season rainfall variability, has piqued interest in the past and continues to do so now. Furthermore, most GCMs may not have been able to simulate the specific effects of rapid warming in the Indian Ocean on circulation and precipitation patterns due to the high uncertainty in climate forecasts for the East African region (Funk *et al*., 2008). Due to inhibited convection across tropical Eastern Africa in recent decades, this trend has resulted in lower rainfall from March to June, a phenomenon that is expected to continue for some time yet is not or poorly documented by most GCMs (Williams & Funk, 2011). This knowledge gap necessitated this study to examine and provide data on inter- and intra-seasonal rainfall variability in Kieni East sub-County, Nyeri County, Kenya, between the years of 1988 and 2018.

2.2 Effects of rainfall variability on maize farming

The agricultural sector is severely influenced by changing climatic circumstances, as accumulating evidence reveals (Lobell *et al.,* 2011; Khanal & Mishra, 2017), and the severity of which is anticipated to increase in the near future, with poorer countries being the most affected (IPCC, 2012, 2014). Climate models have been used in some studies to project future climatic situations in order to advise policymakers about what to expect and possibly put policies in place to address the changes that are expected to occur (Urban *et al*., 2012). Long-term climate change has a huge impact on world food production. Weather anomalies and rapid onset of extremes (dry spells, droughts, and floods) have a negative impact on crop yields through pest and disease outbreaks (Gornall *et al*., 2010), changes in soil fertility (Clair & Lynch, 2010), moisture content, and, most importantly, water quality and resources (Malek, 2018). Furthermore, climate-related impacts, according to the IPCC (2014), will increase the likelihood of food insecurity and food system disruption. Drought and heat effects on crops have been studied extensively using both empirical (Glotter & Elliot, 2017) and model-based methods (Lobell *et al*., 2013; Troy *et al*., 2015; Zipper *et al*., 2016). Despite accessible field and experimental evidence, extreme rainfall has received little attention (Shaw & Meyer, 2015).

Climate variability has been cited as a major factor in rural subsistence people's low crop yields (Kamau *et al*., 2011). Climate change is seen as one of the primary concerns hampering Africa's efforts to achieve food security, due to the continent's reliance on rain-fed agriculture and smallholder farmers' limited ability to adapt to climate change and variability (IPCC, 2014; Phirri *et al*., 2016). In Sub-Saharan Africa (SSA), a predominantly agricultural-based economy, small-scale farmers account for 75% of agricultural production and 75% of employment (Salami *et al*., 2010).

According to Muga, (2010) increased crop variability (deviation from the mean) is also a major concern for farmers in Eastern Africa. Maize farming is rain-fed in East Africa, and it is grown at a variety of latitudes, altitudes, moisture regimes, slopes, and soil types (Livingstone *et al*., 2011). Drought at the flowering stage prevents pollination and severely reduces yield (Schroeder *et al*., 2013). Warm ENSO occurrences, also known as El Nino occurrences, result in exceptionally heavy precipitation in parts of equatorial East Africa, causing flooding and reduced agricultural productivity. Small-scale family farms grow maize mostly for domestic consumption and local markets (Erenstein *et al*., 2011). Large-scale spatial variability is explained by differences in rainfall and soil characteristics (HarvestChoice, 2010; Smale et al., 2011; Yengoh, 2012), whereas small-scale variability is influenced by farm management decisions such as sowing dates, weeding, pests, diseases, fertilizer application, and tilling method. Furthermore, biophysical factors such as rainfall, soil characteristics, elevation, and floods are blamed for small-scale variability (Sacks *et al*., 2010; Vyas et al., 2013; Nathan, 2014). The inter-annual fluctuation of rainfall and temperature, which results in recurrent droughts in the region, is a key determinant of maize yield temporal variability (Magehema *et al*., 2014). This wide range of yields emphasizes the importance of assessing and monitoring yields throughout the growing season. When the amount of water lost in the soil exceeds the amount absorbed, maize yields may be reduced. When a large amount of water is lost, the maize crop will be unable to absorb nutrients from the soil, resulting in the plant's weakness and vulnerability to pests and diseases. The result is either a total crop loss or a reduction in maize output (Sheng *et al*., 2014). East Africa has larger inter-annual rainfall variability than other tropical regions with similar average climatic conditions (Camberlin, 2010). In addition to inter-annual variability, intra-season variability can affect crop output (Cooper *et al*., 2008). Rainfall is significant in farming because it is a signal of long-term changes in the climatic system. The pattern of rainfall, on the other hand, is more important to farmers (Falaki *et al*., 2013). The different roles played by intra-seasonal and inter-annual rainfall variability on crop production fluctuations in the tropics in general, and East Africa in particular, remains poorly understood.

Due to rainfall variability, Kenya is projected to continue to lose output of important commodities such as maize across the country (Herrero *et al.,* 2010). Rainfall variability, according to Herrero *et al*., (2010), decreases the output of not only staple food crops like maize, but also other significant crops like tea, sugarcane, and wheat. It is for this reason that this region must be prioritized in terms of research. In Kenya, studies of the influence of climate change on crop productivity have focused on the implications of climatic means (Bilham, 2011; Cheserek, *et al*., 2015), rather than individual climate variables like as rainfall. In some locations, rainfall variability, especially the severity and frequency of extreme events, is predicted to increase, and such changes are anticipated to have a greater negative effect on crop yields than changes in climate alone (Rowhani *et al*., 2011). The existence of a considerable knowledge gap in this field necessitated this study.

3. Data and methodology

3.1 Description of the study area

The research was carried out in Nyeri County's Kieni East sub-County. Narumoru/Kiamathaga, Kabaru, Thegu, and Gakawa are the four wards that make up the sub-county. It has a population of 96,500 persons and 29,012 households (KNBS, 2010). It is expansive, covering an area of 817.1 km2 (GoK, 2013). The sub-County is located between latitude 00 00' and 0024' S and longitude 370 00' and 370 12' E. According to the study area map Fig 01, it borders Meru central sub-County to the north, Mathira sub-County and Nyeri municipality to the south, Mt. Kenya to the east, and Kieni west sub-County to the west. The size of the land per household varies by sub-County, but averages 2 hectares (Jaetzold *et al*., 2007), thus the majority of the farms are small scale and land ownership is primarily freehold. Rainfall patterns dictate the growing seasons, with two different rainfall seasons happening between March and May (MAM) and October to December (OND), with average annual rainfall ranging from 500mm to 850mm (MoALF, 2016). Tropical-Alpine, Upper Highlands, Lower Highlands, and Upper Midlands are the four primary agro-ecological zones identified by Jaetzold and Schmidt (2007). It should be noted that these agro-ecological zones are mainly based on climatic data with limited considerations on soil condition; hence hardly any coffee and tea are grown in Kieni (Wamicha, 1993). The altitude rises between 1500m at Kiganjo, which is the lowest area, and 2400m at Kabaru forest reserve. The driest areas are Kiganjo and Naromoru within the agro-climatic zones V and VI respectively. The major soils include the fibric histosols, humic andosols, humic nitosols, luvic phaenozems as well as vertisols, fluvisols and gleysols (Sombroek *et al*., 1982). Maize is the most commonly grown food crop, and it is regarded as a crucial staple food by the population, accounting for about 80% of the food supply in the form of coarse grain and flour. Other crops grown include beans, potatoes, and wheat. Beans are the second most important food crop after maize, and they are traded throughout livelihood zones. Potatoes are grown all year

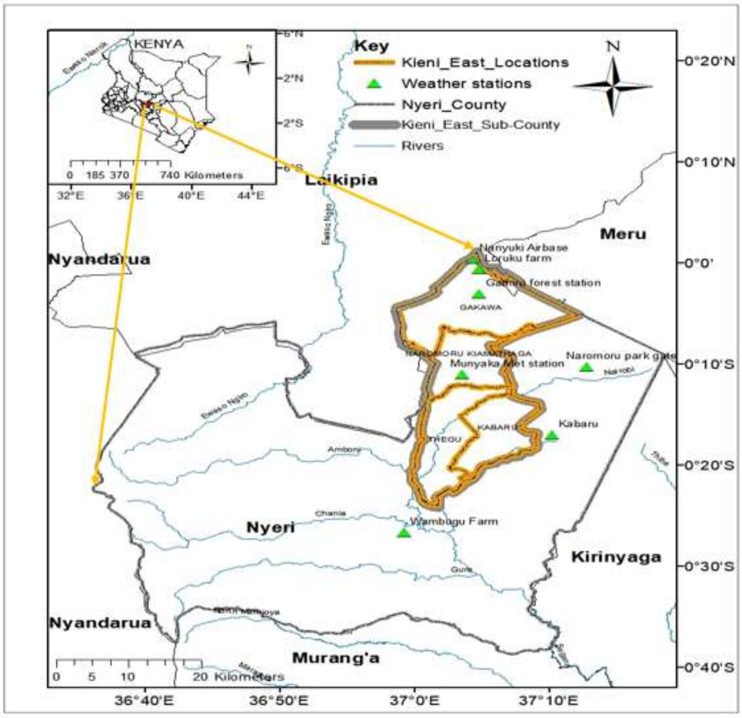

Figure 1. Map of the study area.

under rain-fed conditions for both commercial and subsistence needs, accounting for 60% and 40% of total production, respectively. Wheat is grown for both household use and income, although it is currently suffering from moisture stress throughout the blooming and booting periods. Irrigated horticulture is primarily practiced in the upper mixed farming areas that border Mt Kenya, and because water sources have been flowing at or below base levels, most plots are experiencing moisture stress, prompting most farmers to switch to more stress tolerant crops such as kale and spinach from cabbages.

3.2 Research design

A mixed research design was used in this study. The goal of using qualitative and quantitative approaches in a mixed research design was to broaden and heighten the study's knowledge and validity (Schoonenboom & Johnson, 2017). Furthermore, studies that use both techniques have been shown to be more inclusive than studies that only use one (Creswell & Plano, 2011). Primary and secondary data were used to compile this report. Household structured questionnaires and in-depth interviews were used to collect primary data. There were both open-ended and closed-ended questions on the surveys. The open-ended questions were chosen to sensitively handle bias-prone areas including farmers' views of rainfall variability. Closed-ended questions were used to measure rainfall variability. Secondary data on rainfall and maize yields was gathered from both published and unpublished publications. This strategy ensured that enough data and information was gathered. The information gathered helped to explain the impact of rainfall variability on maize yields in Nyeri County's Kieni East sub-County.

3.3 Sampling procedures and sample size

The researcher purposively targeted smallholder farmers in Kieni East sub-County with 29,012 households consisting of smallholder maize farmers from the Kieni East sub-county in Nyeri County as illustrated in Table 01; since most farmers are actively involved in maize farming as it is their major staple food. Using the Nassiuma (2000) formula, which employs a coefficient of variation (c) in the range of 21 percent to 30 percent and a standard error (e) in the range of 2% to 5%, the estimated sample size was 223 smallholder maize farmers from the target population. The sample was wide enough to justify the results being generalized for Kieni East sub-County, hence a 30% coefficient of variation was adopted as the upper limit. A standard error of 2% was used to ensure that there was little error. To cover all of the wards and stratify the samples, the study used stratified random sampling. An independent random sample size equivalent to the size of each stratum was taken from each stratum. Nassiuma's (2000) formula was used to calculate the sample size for each stratum, and the sample was made up of households. Proportional allocation was used to determine the number of farmers from each ward who participated in the study. Table 01 shows the proportionate distribution of respondents, and after the interval was set, the actual respondents were chosen from the wards using systematic random selection. Personnel for in-depth interviews were picked and included the Kenya Meteorological Department, MOA, local administration, and extension agricultural officials through a process of purposive sampling.

The formula for the sample size was; $n= NC^2/C^2+ (N-1)\ e^2$. n= the sample size, N= the households size (29,012), C= the coefficient of variation (30%), e= the margin of error (2%).

$$= \frac{29012x0.3^2}{0.3^2 + (29012 - 1)0.02^2} = 223$$

Table 1.

Sample size distribution.

	Households (N)	Sample (n)	%
Narumoro/kiamathaga	9976	9976/29012*223=77	77/223*100= 35
Kabaru	6205	6205/29012*223=48	48/223*100= 21
Thegu	4734	4734/29012*223=36	36/223*100= 16
Gakawa	8097	8097/29012*223=62	62/223*100= 28
Total	29012	223	100

Source: KNBS, (2010)

3.4 Data collection and analysis

Data was collected from secondary sources from the Kabaru, Munyaka, Naromoru Met stations, Gathiuru Forest station and Loruku farm rainfall station where monthly and annual rainfall data was captured in Kieni East Sub- County. Maize yields data was obtained from the Ministry of Agriculture, Livestock and Fisheries, Nyeri County from the Nyeri County Annual Progress Report and other county reports. Trend analysis for both rainfall and maize was done for the period between 2009 and 2018, as well as calculating the variability index, means and standard deviation. Descriptive analysis was used to summarize the findings in graphs and tables. The paper also used Karl Pearson correlation analysis to test the validity of the research hypotheses at 1 % levels of significance.

3.5 Limitations of the Study

One of the study's limitations was the maize farmers' reluctance to offer precise information on total yields from their farms. Data on rainfall and maize yields were similarly difficult to come by. Only data from one of the five county's rainfall stations (Loruku farm) was used. The availability of complete data, i.e. more than 10% as recommended by the World Meteorological Organization (WMO), for 30 years, a timeframe adequate for a climatological analysis (Atheru, 1999) and relevant to the current study, influenced station selection. Because there was no available recorded data from the Ministry of Agriculture, Livestock, and Fisheries in the County for the earlier years in the sub-County, maize yields were analyzed for 10 years from 2009 to 2018. Other factors influencing maize yields, such as pest and disease infestation, poor farming practices, and socioeconomic concerns, are considered to be absent in this study, while accepting that maize yields are influenced by non-climatic factors. Due to data limitations, the study focused solely on one climatic element, rainfall, while excluding others and acknowledging that water, warmth, light, and air fit within the four fundamental criteria for plant growth. The study also concentrated on the maize crop, eliminating other food crops grown in the area, because the Kieni East sub-County is mostly a maize-growing area as a staple crop. Despite these flaws, the study's integrated design (questionnaire, interview, and analysis of rainfall variability) provided checks and balances that resulted in more informed responses and less subjectivity.

4. Results and discussion

4.1 Annual rainfall and maize yield data

Annual rainfall and maize yield patterns, as shown in Fig. 02 illustrate that variations in rainfall lead to variations in maize yields. Figure 02 shows a decline in the trend lines with negative gradients of -33.709 and -231.9 for rainfall and maize yields respectively. The average annual rainfall was 780.07mm, a standard deviation of 158.97mm, and annual rainfall variability ranging from -260.47mm in the year 2000 to 528mm in 1997, according to the study. The peak years for annual rainfall were 2010 and 2015, and the peak years for maize yield were also 2010 and 2015. The yearly rainfall decreased in 2011, 2012, 2016, and 2018, while the maize yield decreased in the same years. The correlation between annual rainfall and annual maize yields was at 20%. These results are consistent with those of Ali *et al*. (2017), who discovered that rainfall variability had a significant impact on maize yield. Blanc (2011) and Bhandari (2013) found that precipitation increase leads to increased maize yield. Sowunmi and Akimola (2010) also found that maize can be cultivated in many places of Nigeria with enough water. Water scarcity, however, causes yield loss throughout critical stages of maize development (grain filling and anthesis) (Basir *et al*., 2018). This is why crop varieties that correlate to the length of the growing season in the sub-County are so important. One of the main reasons why smallholder farmers in Africa are struggling is because of declining yields and droughts. ASALS do not appear to be adopting improved farming practices as observed by Nyandiko *et al*. (2012).

Results on Table 02 show the Correlation between the annual rainfall and the annual maize yield. The p-value = 0.004 is less than 0.01. This implies that at 1 % levels of significance there is a strong positive correlation between the annual rainfall and the annual maize yield in Kieni East Sub-County in Nyeri County.

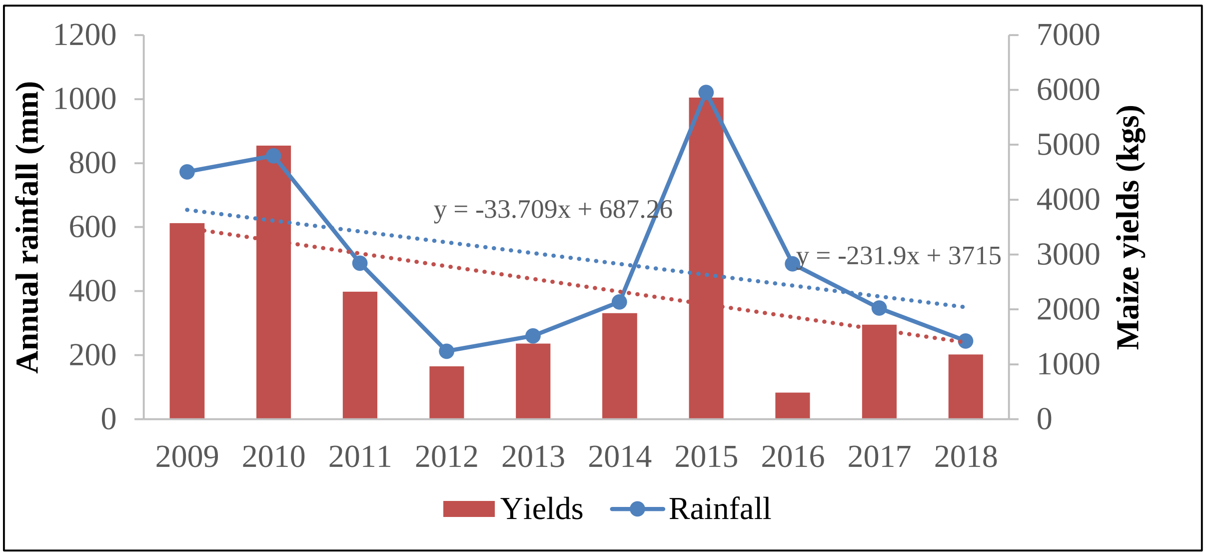

Figure 2. Annual rainfall and annual maize yields trends.

Table 2.
Correlation of annual rainfall and annual maize yield.

		Annual Rainfall	Annual Maize Yield
Annual Rainfall	Pearson Correlation	1	0.821**
	p-Value		0.004
	N	10	10
Annual Maize Yield	Pearson Correlation	0.821**	1
	p-Value	0.004	
	N	10	10

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

4.2 Seasonal rainfall and maize yields during the long rains season

Variation in rainfall amounts induced variations in maize yield, according to the findings in Fig. 03 on rainfall and maize yield trends during the long rains. The figure depicting a decrease in the trend lines with negative gradients of -21.412 and -69.192 for rainfall and maize yields, respectively, demonstrates this clearly. The peak years for long rains were 2010 and 2015, which coincided with the peak years for maize yield. Both trends, however, experienced a downturn in 2011, 2012, 2013, 2016, and 2018. Between 1988 and 2018, the average rainfall amount during the season was 260.86mm, with a standard deviation of 85.89mm. With fluctuations ranging from -133.46mm in 2016 to 178.14mm in 2003, the trend line suggested a decline in rainfall. The correlation between rainfall and maize yields was at 32%. This is in accordance with Sage *et al.* (2015), who predicted that higher rainfall variability would affect maize yields. These results also agree with Jokastah *et al.* (2013) who noted that most smallholder farmers in semi-arid and the sub-humid regions of Kenya had witnessed a reduction of crop production attributed to either low rainfall or erratic rainfall patterns coupled with other factors such as hailstones, floods and longer than normal rainfall. Studies also done by Araya & Stroosnijer (2011) established that short growing periods were among the causes of crop failure. Shorter growing seasons due to a delayed start of rainfall hampers soil preparation and exposes crops to increased terminal moisture stress during grain filling, reducing crop yields. With the perception that OND is the main season, it is also possible that farmers inKieni East sub-County reduce the area under maifarming during MAM, which probably reduces the overall annual maize yields than they would otherwise be. Farmers therefore need to be sensitized on the need to maximally utilize the two rainy seasons in maize farming.

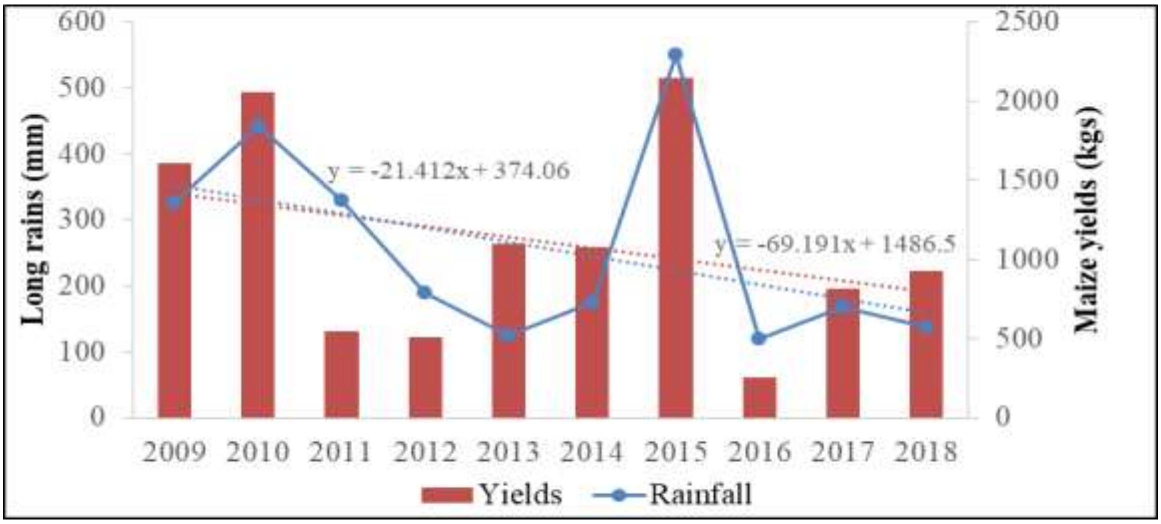

Figure 3. Rainfall and maize yields trends during the long rains.

Results on Table 03 show the Correlation between the rainfall and the maize yield during long rains. The p-value = 0.009 is less than 0.01. This implies that at 1 % levels of significance there exists a strong positive relationship between rainfall and maize yield during long rains in Kieni East Sub-County in Nyeri County.

Table 3.

Correlation of rainfall amount and maize yield during long rains.

		Long Rains	Maize Yield Annual
Long Rains	Pearson Correlation	1	0.634**
	p-Value		0.009
	N	10	10
Maize Yield	Pearson Correlation	0.634**	1
	p-Value	0.009	
	N	10	10

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

4.3 Seasonal rainfall and maize yields data during the short rain season

During the short rains, variations in rainfall caused variations in maize yield, as seen in Figure 04.The figure clearly show a decrease in the trend lines for rainfall and maize yields, with negative gradients of -10.384 and -162.71, respectively. Similarly, these curves peaked in the same years, 2010, and 2015 and dips in 2011, 2012, and 2016. The variability of short rains was observed to range from -154.05mm in 2008 to 452.25mm in 1997, with the average rainfall during the season being 276.55mm and a standard deviation of 126.09mm. Correlation between rainfall and maize yields was 46%. Adamgbe and Ujoh (2013) established that extreme climatic events and climate factors influencing crop production due to changing and erratic climate conditions like fluctuating rainfall, unpredictable floods have an adverse effect on maize crops especially in the ASALs. The study makes a finding that if maize is properly evaluated as to how it adjusts itself to the changes brought about by climate then it is likely that proper adaptive measures will be formulated. Water levels above those required by the crop have a detrimental impact on yields. A study carried out in Laikipia East district (Huho *et al*., 2012) supports this observation. It was found out that annual rainfall amounts increased between the years 1976-2005, but this did not lead to good agricultural production. This was attributed to the changing rainfall patterns that disrupted farming activities. Furthermore, increased rainfall intensities can cause increased soil erosion and losses of nutrients from arable soils thus impacting crop production. Rowhani et al. (2011) also observed that an increase in inter-seasonal precipitation reduces maize yield. Yengo et al. (2010) stated that higher rainfall intensities during the main rain growing season could increase the rate of erosion and loss of nutrients from arable soils, thereby reducing soil fertility and consequently impacting crop productivity. Geerts and Raes (2012) further stated that a significant increase of total seasonal precipitation is not important in rain-fed maize farming. What matters in crop phenology development is the rainfall distribution. These results also concur with Eludoyin et al. (2017) that too early rainfall, late rainfall, prolonged dryness after initial rainfall, excessive rainfall among others were the common weather-related causes of low crop yields. Amissa –Arthur et al. (2002) alluded that parts of Eastern Kenya receive more rain during this season and it constitutes the main growing season in the drier parts of Sub-Saharan Africa and the Great Horn of Africa for crops such as maize, sorghum, green grams and finger millet. Kieni East is one of the drier parts of Central Kenya. Mugalavai et al. (2008) argued that for the short rains, early onset translates into a longer growing season. This could explain the higher yields in the OND season, making it the major crop growing season in the study area. According to Nicholson (2017), the short rains in East Africa are well known to have a higher predictability being largely driven by variations in the Indian Ocean Dipole and ENSO. With the rainfall peaking mainly in November, there is need for farmers to plant early since the rainfall cessation begins in December so as to optimize rainfall received at the early stages of the season.

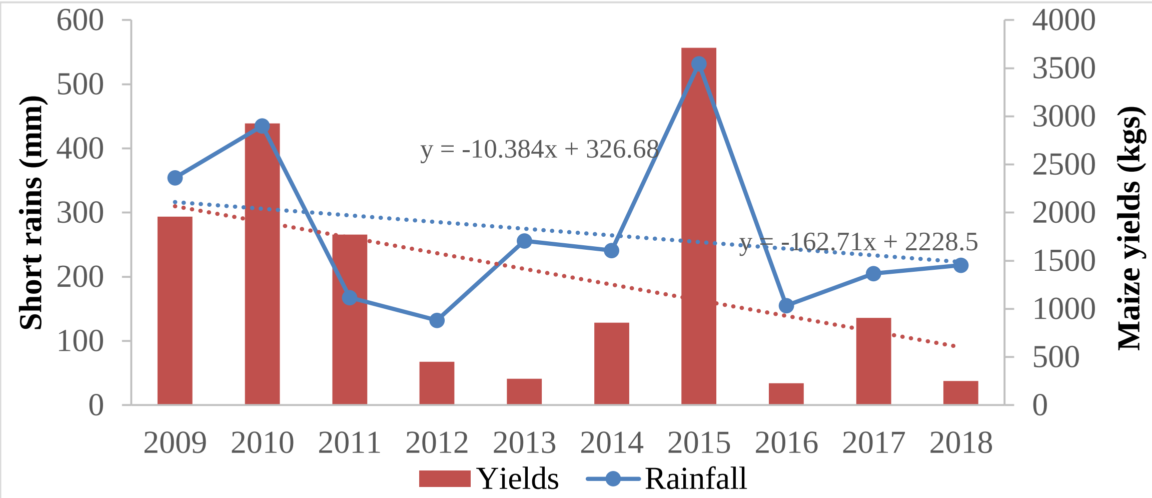

Figure 4. Rainfall and maize yields trends during the short rains.

R

esults on Table 04 show the Correlation between the rainfall and the maize yield during short rains. The p-value = 0.000 is less than 0.01. This implies that at 1 % levels of significance there exists a strong positive relationship between the rainfall and the maize yield during short rains in Kieni East Sub-County in Nyeri County

Table 4.

Correlation of rainfall amount and maize yield during short rains.

		Short Rains	Maize Yield Annual
Short Rains	Pearson Correlation	1	0.918**
	p-Value		0.000
	N	10	10
Maize Yield	Pearson Correlation	0.918**	1
	p-Value	0.000	
	N	10	10

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

Variability in timing of the rains has a significant impact on agriculture and early warning of onset and cessation, is a regular request from user needs assessments in semi-arid East Africa (Owusu *et al*., 2017) as it would allow farmers to better manage potential risks to their planting and harvesting activities. The date of onset of rainfall is highly important for agriculture. A delay of the onset implies a shortened crop growing period leading to low crop yields (Mugalavai *et al*., 2008). The onset month for the long rains in Kieni East Sub-County in Nyeri County varied from March to April. According to Figure 05, March recorded 21 times (67.7%) while April was recorded in 9 times (32.3%). According to figures 06 and 07, the peak season occurred in April (71.2%) and cessation between May (54.5%), June (32.5%) and

July (12.9%). False starts of the rainy season cause replanting and increase the cost of maize farming. Therefore start of seasons need to be monitored to reduce the risk of crop failure in the sub-County. Camberlin and Okoola (2003) observed a 25-30% maize yield reduction in Kenya due to a 20 day delay of the main rainfall season. It is important that the smallholder maize farmers plant prior to or upon onset, especially during the MAM season, failure to which a significant amount of rainfall will be missed and therefore affect maize yields. This makes the growing of early maturing maize seeds and drought mitigation strategies like rainwater harvesting important in Kieni East sub-County. An early cessation implies a short crop growing season leading to low crop yields. This concurs with the findings by Oruonye et al. (2014) that a reliable estimation of the onset and cessation dates of the rain crop could help maximize rainwater use by farmers.

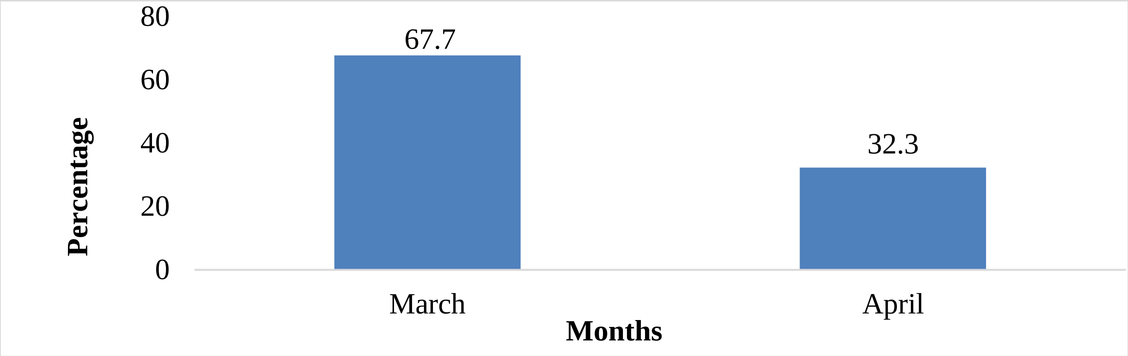

Figure 5. Onset month for the long rains season.

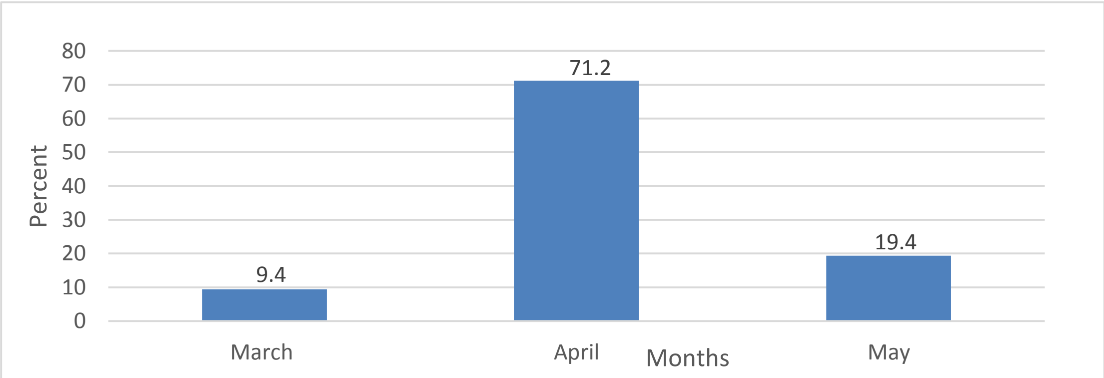

Figure 6. Peak month for the long rains in Kieni East Sub-County.

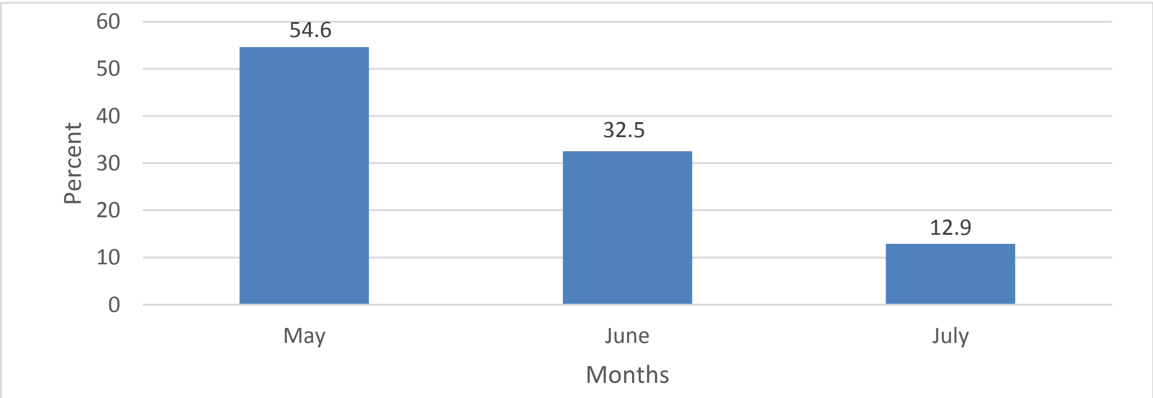

Figure 7. Cessation month for the long rains in Kieni East sub-County.

The onset month for the short rains in Kieni East sub-County in Nyeri County varied from September to October. The results in Figure 08 indicate that September recorded 93.5% while October had 6.5% of the total amounts received at the onset. It results to a longer crop growing season since the rainfall peaks in November as indicated by Fig.09, with the cessation being between December (71%), January (22.6%) and February (6.4%) as indicated by Fig. 010. These results found that seasonal change is a challenge in the sub-County and therefore farmers needed to be updated and advised so as to plant in time. Effective use of weather forecast information like on the onset date and cessation can significantly optimize rainfall and lead to improved maize yields in the sub-County. Araya and Stroosnijer (2011) established that short growing periods were among the causes of crop failure. Optimum maize production calls for good timing of the planting dates. By planting late, farmers avoid the potential false starts which may occur early in the season. This ensures that crops do not suffer moisture stress in the initial and crucial stages of development (Chivenge et al., 2015). This would make the planting of short cycle maize varieties, rainwater harvesting and irrigation as adaptation strategies very important in Kieni East sub-County.

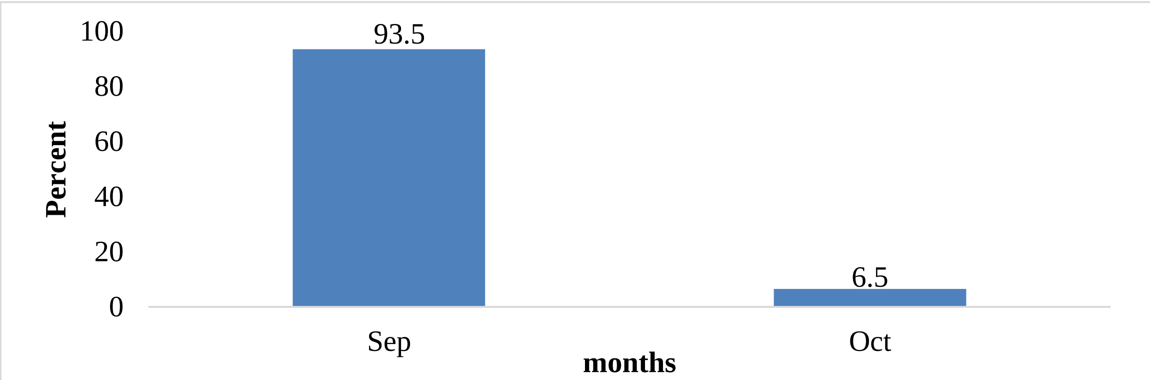

Figure 8. Onset month for the short rains in Kieni East Sub-County.

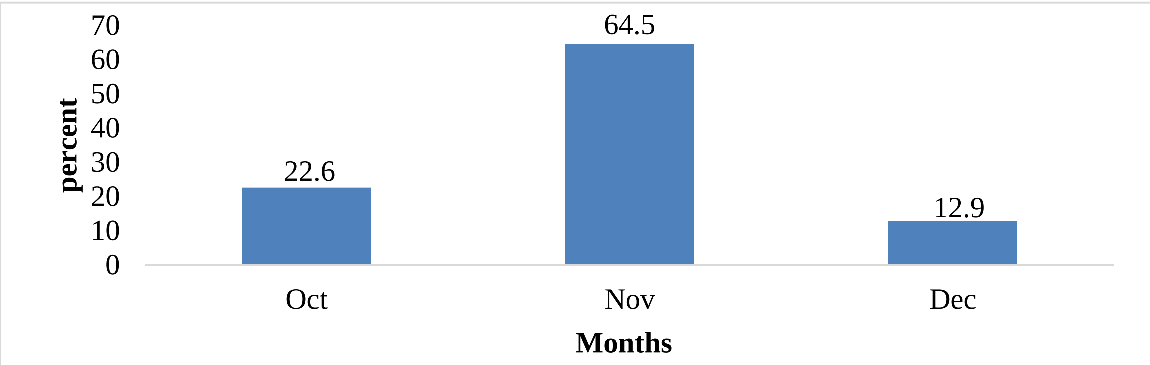

Figure 9. Peak month for the short rains in Kieni East Sub-County.

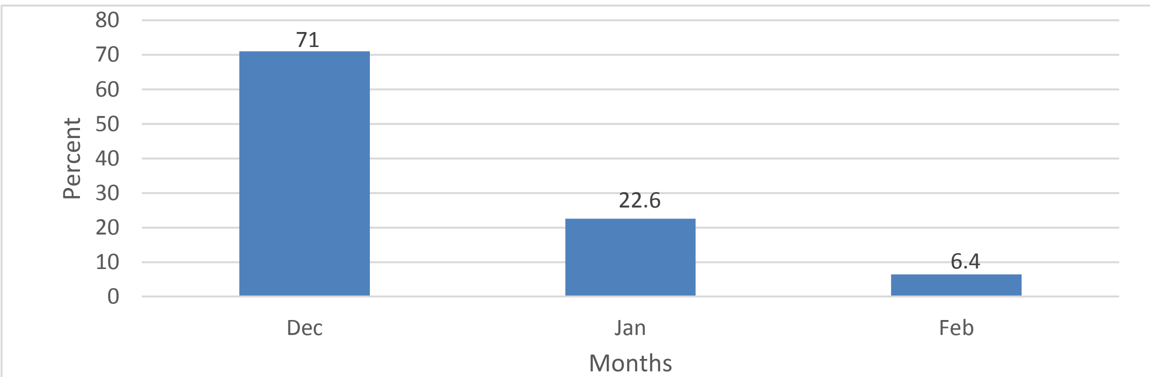

Figure 10. Cessation month for the short rains in Kieni East Sub-County.

5. Conclusion and policy implications

5.1 Conclusion

The study's main aim was to investigate the effects of seasonal rainfall variability on maize yields in Kenya's Kieni East sub-County, Nyeri County between the years 1988 and 2018. The study indicates that annual rainfall amounts had dropped throughout the previous period, with an average annual rainfall of 780.07mm, a standard deviation of 158.97mm, and annual rainfall variability ranging from -260.47mm in the year 2000 to 528mm in 1997, according to the study. During the long rains, the study's findings demonstrated a drop in rainfall amounts. From 1988 to 2018, the average rainfall amount during the long rains was 260.86mm, with a standard deviation of 85.89mm. With fluctuations ranging from -133.46mm in 2016 to 178.14mm in 2003, the trend line suggested a decline in rainfall. The study's findings revealed that rainfall levels increased during the short rains, with an average of 276.55mm and a standard deviation of 126.09mm. The variability of short rains was observed to range from -154.05mm in 2008 to 452.25mm in 1997, indicating that there was random variability.

This study clearly shows that there was a decline in the annual maize yields in tons as indicated by a negative gradient (-231.9) in Kieni East sub-County, with the peak years being 2015 and 2010, and the dips being 2016 and 2012. During the long rains, maize yields declined along a negative gradient (-69.19), with peak years in 2015 and 2010 and dips in 2016 and 2012. The short rains resulted in a negative gradient (-162.71) in maize yields, with peaks in 2015 and 2010 and dips in 2016 and 2012. This is true evidence that seasonal rainfall variability has an effect on maize yields by smallholder farmers in the Kieni East sub-County. The maize yield was shown to be correlated with rainfall amount: $r(10) = 0.821$, p-value = 0.004 with rainfall amount during long rains, $r(10) = 0.634$, p-value = 0.009 with rainfall amount during short rains, and $r(10) = 0.918$, p-value = 0.000 with rainfall amount during short rains. This implies that at 1 % levels of significance there exists a strong positive relationship between the rainfall and the maize yield in Kieni East sub-County in Nyeri County.

5.2 Policy implications and recommendations

The following recommendations are suggested to maize farmers, Ministry of Agriculture (MoA), stakeholders, policy makers and researchers in Kieni East sub-County, based on the findings of the study;

The study recommends that the Kenya Meteorological department (Nyeri) should liaise with the agricultural extension officers to provide timely and reliable forecast predictions to the farmers through the short messaging services (SMS) on the onset and cessation of the seasonal rains so as to optimize on the crop growing season and improve maize yields in the study area.

Farmers should plant prior to or upon onset, especially during MAM season, failure to which a significant amount of rainfall will be missed and therefore affect maize yields. Farmers should utilize the OND season mainly for maize farming since the rainfall onset is in September and the cessation extends up to February thus making it the major crop growing season. The MAM season can then be utilized for the short cycle maize varieties so as to increase annual yields, as well as growing other crops such as beans that have short growing cycles so as to cushion them from the effects of rainfall variability.

The policy makers and other stakeholders should use the research findings to formulate policies that focus on rainfall variability and its effects on smallholder maize farming based on the correlation between annual and seasonal rainfall and maize yields in the study area so as to improve on maize yields.

In view of the high correlation between seasonal rainfall and maize yields, adoption of maize varieties that are drought resistant should be bred for farmers in Kieni East sub-County by the relevant policy makers and stakeholders.

Farmers need to be sensitized on soil conservation and management measures to prevent loss of soil nutrients when there is excessive seasonal rainfall and on more effective and sustainable water harvesting measures for use during the dry season.

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