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Research Article

Seasonal Annual Variability of Rainfall in Endebess Sub-County Between 2008-2018

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Abstract: Climate change is attributed indirectly or directly to anthropogenic activities that has led to subsequent changes in the global atmospheric composition and hence the observed climate variability over period of time. Maize crop is very sensitive to climatic change conditions such as rainfalls patterns and onset. These changes have potentially compromised agricultural production systems and hence having a negative effect on the food supply in the country, it is therefore imperative to understand the effect of seasonal annual variability of rainfall among the small-scale farmers in Endebess Sub-County, Trans Nzoia County, Kenya between 2008- 2018. The study was based on 150 maize farmers in wards namely; Chepchoina, Matumbei and Endebess. Primary data was obtained from randomly selected farmers through questionnaires, while secondary data on rainfalls and maize production yields was collected from Kitale Meteorological Departments and Endebess Sub-County Ministry of Agriculture offices respectively between 2008-2018. The data collected was analyzed using Statistical Package for Social Sciences version 22 and Precipitations Concentration Index (PCI) values. The study findings on analysis of annual rainfall between 2008–2018 in PCI was 9.3 and seasonal variability was PCI 16 which means uniform distributions of rainfalls between the years. However, the finding found that there was a positive relationship between rainfall and maize yields r = 0.625 while annual rainfall variable index is significant to seasonal months' variability. This study recommends that both National Government and County Government of Trans Nzoia should create awareness on climate change and adaptations measures to rainfall variability in the study area.
Keywords: Rainfall, climate change, maize production.

Introduction

Climate change is rapidly emerging as a globally critical development problem affecting agriculture sector and food security. It is considered as one of the greatest threats to attainment of Millennium Development Goals (MDGs) globally an unperfected increase in greenhouses emission that is caused by anthropogenic activities (Stocker *et al.*, 2013) which has led to an increase in global temperature by 0.85^0C (0.65^0C-1.6^0C from 1880-2012) (Pachauri *et al.,* 2014).

In the sub-Saharan Africa, Agriculture plays a very important role that contributes towards livelihood and economic development across the continent. On average, agriculture contributes about 15 percent of the total GDP (FAO, 2016). However, Sub-Saharan is vulnerable to climate change and 70 percent of the population depends on rain fed agriculture for their livelihood. Small holder farms account to 80 percent of the cultivated land in the Sub-Saharan Africa. According to IPCC (2007), the climate change projected have severely compromised agriculture production and food accessibility. In Kenya, Agricultural production remains to be the back bone of economic growth. It is the single most important sector in the economy contributing approximately 25 percent of the

National Labor Forces (Republic of Kenya, 2015). Over 80 percent of the Kenya population live in the rural areas and derive their livelihoods directly or indirectly from Agriculture.

Beside the importance of agriculture, the performance of the sector of the whole economy faces many worrisome challenges from rainfall variability that affect the sector by influencing emergencies and distributions of crop pests and livestock disease, exacerbating the frequency and distributions of adverse weather conditions, reducing water supplies for irrigation and enhancing severely of soil erosion processes (IPCC, 2001).

In Africa, agriculture sector constitutes a large share in the economic development, with the mixtures of both subsistence and commercial productions. Crop production is vulnerable to rainfall variability and potential impacts of climate changes because of factors such as wide spread of poverty, recurrent droughts, and inequitable land distributions. Rainfall records, historically, from the early 1900s to mid-1980s show that Africa average precipitation has decreased since 1968 and has been fluctuating around lower mean (UNEP, 2010).

The rainfall variability in the past have been acknowledged by a large part of scientific institutions that pose the greatest phenomenon challenges to agriculture and food security in the Sub-Saharan African (SSA). This is because the region is vulnerable to climate variations due to its location and the low adaptive capacity (Alkemade *et al.*, 2009; Shah *et al.*, 2008).

The climate change report provides evidence that food production systems have been potentially compromised by climate variability (IPCC, 2007). This means that agro-ecological zones for agricultural world would be negatively affected by climatic variations and yield potential of many high-profile crops produced in the zones particularly along the margin of semi-arid and coastal are expected to decrease and it would further adversely affect crop security and exacerbate malnutrition in the region (FAO, 2008).

Weather variation refers to changes in the state of climate that can be identified by changes in the means and variability of the properties that persists for an extended period. These are the changes in climate over time due to natural variability as a result of anthropogenic activity which increases the earth temperature due to the release of the gases to the atmosphere such as CO_2, CH_4, CFC, NO_2 and O_2 into the atmosphere (IPCC, 2007).

Purpose of the Study

The main purpose of this study was to assess the effect of rainfall variability on maize crop productions in Endebess Sub-County.

Literature Review

Effects of rainfall variability on maize production

Agricultural production is very sensitive to weather variability and weather extreme events such as floods, drought and severe storms (IFPRI, 2009). Climate change has negative effect to agriculture production and has direct impact to maize farmers who depend most on rain fed agriculture for the production. This is because small scale farmers are the main contributors of domestic food security in the country, hence, the rain fed agriculture have been limited means of copying with the adverse weather variability (Nganga, 2006). The major elements of the climate that affects crop growth are intensity and durations of rainfall, the relationship between the annual rainfalls and potential evapotranspiration and the year to variation in rainfalls (Kabubo Mariara and Karanja (2007).

According to Ayoade *et al.*, (2004), water plays a vital role in the growth of plant productions. It provides the medium in which food and nutrients are carried out through plant. Ezedimma (1996), reported that water precipitation is the main constituency of physiological plant tissues and reagent of photosynthesis. Water is required for all metabolic reactors in the plant. Agriculture sector relies heavily on predictable rainfall and temperature. Crops suffer significantly most following the climatic vagaries variations and thus affecting the livelihood of most smallholders' farmers who depend mainly on rain fed agriculture and the natural resources for their livelihood (IPCC, 2012).

Sarker *et al.*, (2012) and Kabubo Mariara and Karanja (2007), climate change in Kenya has induced irregularities in the rainfall amounts and frequency of extreme precipitation trends and frequents of erratic, dry spell extremes events such as floods, droughts and heat waves. The increased frequency of these episodes is projected to influence the crop production yields in the region (IPCC, 2008). The agriculture activities and development is particularly vulnerable to intricate of weather extremes not only because it depends on the rain fed but more so farming activities are subsistent oriented for food productions.

Maize production in Endebess Sub-County is mainly small-scale farming and other crops grown are wheat, sugar cane, sunflowers, beans and commercial farming user system (GOK, 2009). These small-scale maize farmers face the challenges from weather adversities, increasing poverty level and shortage of water availability (World Bank, 2009). Endebess Sub-County is highly potential rich in alluvial soil for farming with high population density of 106 persons per km^2 (GOK, 2009). This has increased land fragmentation and reduction of maize production yields per hectare of land. The maize production involved, is dominantly the small-scale farmers which is already vulnerable to the rainfall variability effects (Ongoma *et al.*, 2015) that continues giving the same crop system on small portion of land over the sequences of the years that lead to soil erosion and loss of soil fertility.

Rainfall variability does not only affect the maize production (*Zea-mays*), but also other cash crops grown within the region such as wheat, sunflower, sugar cane (Haerero *et al.*, 2010). Thus, the increasing variability in Endebess Sub-County is vulnerable to crop development and subsequent yields that depends on the rainfall amount, intensity and distributions within growing seasons. The variations of precipitation have effects on the quality and quantity of products. According to Kabubo-Mariara and Karanja (2007), conducted research on the impacts of climate changes on crop on agriculture. The finding of this study was to contextualize the impacts on crop modelling simulation, run the biophysical adaptation to water and temperature stress. They assume that farmers are not aware of the adaptation strategies provided. This study tried to reduce the gap by providing intervention measures to address the problems that are related to rainfall variability that the small-scale farmers could be facing (Tshuma and Mathuthu, 2014).

According to Moyo *et al.*, (2012), rainfall and temperature have significant effects on agricultural production. However, rainfall is the main input climatic factor that determined the crop yield distribution of crops. Makenzi *et al.*, (2013), agricultural activities schedules follow the rainfall amount, especially in the tropical region. Huho *et al.*, (2012), the Sub-Saharan Africa depends on rain fed agriculture which provides food for its population and represents a major of economic growth, follows precipitation patterns closely (UNEP, 2008). Therefore, scarcity of water as well as weather extremes have impact on crop productions (IPCC, 2007).

The seasonal rainfall is marked by hanged onset of long rain season, declining number of rain days and increasing intensities altering the farming calendar with the negative effects on maize yield production. The impacts of climate variations on small scale farming had become the subject of debate among the policy makers and agricultural officers in the county (Harris *et al.*, 2014).

Despite the largely detrimental impact of rainfall variability on human system and naturals, (Mugalavai *et al.*, 2008), there is little known about the small-scale farmers on the challenges facing on agriculture practices. Therefore, there is still little attention focused on the specific crop and effects of climatic variability especially rainfall variability regarding to maize production. This study sought to examine the effects of rainfall variability on maize crop production in Endebess Sub-County. This knowledge on small scale farmers perceived effects of rainfall variability on maize has potentially helped the planning of mitigation and adaptation measures for various spheres of the society that are likely to be vulnerable to changing climatic vagaries (Van Ruijven *et al.*, 2014), to meet the present and future farming needs in specific agro-ecological zones in Kenya whose livelihood sources depend on rainfall performance.

Materials and Methods

The study adopted longitudinal and correlative research design using both qualitative and quantitative approaches. The target population was Endebess Sub-County had 2000 farmers registered in the Sub-County (Sub county Agriculture office by 2018). Small scale maize farmers were preferred more so because they major in the maize crop production. A sample of 150 was selected from the study population for data collection purposes. The study administered questionnaires to collect information from maize farmers in the ground field. The study obtained secondary data on maize yields, rainfall amounts from the Ministry of Agriculture office at Endebess Sub-County, Kitale Meteorological Departments in respective offices between 2008 and 2018. Other data included the shape of study, site extracted from the County Map of Trans Nzoia were used. Validity of instrument was determined by circulating the research tool to the supervisor and other experts in the field of research to evaluate the item objectivity of the questionnaires that were used in the study. The study used test-retest method to determine reliability of the instrument. The analysis of data utilized both descriptive and inferential statistics and results presented in the form of a table percentages, charts and graphs.

Findings of the Study

Seasonal rainfall variability in Endebess Sub County between 2008-2018

To achieve the objective (one), the respondents were interviewed to indicate whether they had noticed the trend of seasons and annual rainfalls changes in the last ten years. Their responses were indicated in the figure 1.

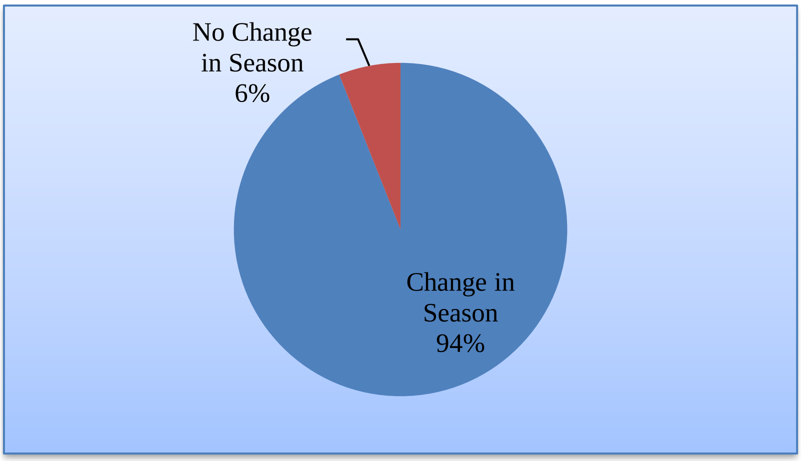

Figure 1. Seasonal rainfall variability in Endebess Sub-County between 2008-2018.

The result presented in figure 1 above, shows an overwhelming majority of the respondent, 138 (94%) supported the finding that there were changes in patterns in the last ten years in terms of durations, either prolong or short season as compared to 6.2% respondents who differed with the opinion. The change in the seasons and annuals rainfalls is attributed by changes in climate due to global warming effects (IPCC, 2014).

Seasonal and annual rainfall patterns

The study sought to use secondary data. Endebess Sub-County provided the results indicating the total rainfall volume of 13248.8mm recorded on 1189 rain days within the period of 10 years as from 2008 to 2018. The annual rainfall ranged from 980mm to 1607mm. The seasonal rainfall amounts to approximately 90% of total annual rainfall recorded as indicated in figure 2 (annual and 4.4 numbers of rain days (2008–2018). The total rainfall volume that exceed the mean of 1204.3mm is 1411.7mm (2010), 1268.4mm (2012); 1207.3mm (2014); 1607.0mm (2016) and 1365.5mm (2018); this translate to 52% of rainfall recorded in the studied period and 48% recorded rainfall fall below the mean, 1111.6mm (2008); 1000mm (2009), 1154.3mm (2011); 998.7mm (2013); 980.0mm (2015) and 1142.5mm (2017).

These results indicate that there is a higher variation of rainfall that is recorded below normal level and thus leading to annual decrease. This trend is in line with (Omoyo *et al.*, 2015). The seasonal rainfall ranges from 123.2mm to 1804.2mm per year. The months of January, February and December recorded the lowest amount of rainfalls in the last ten years as shown in figure 4 (Monthly seasonal rainfalls distribution).

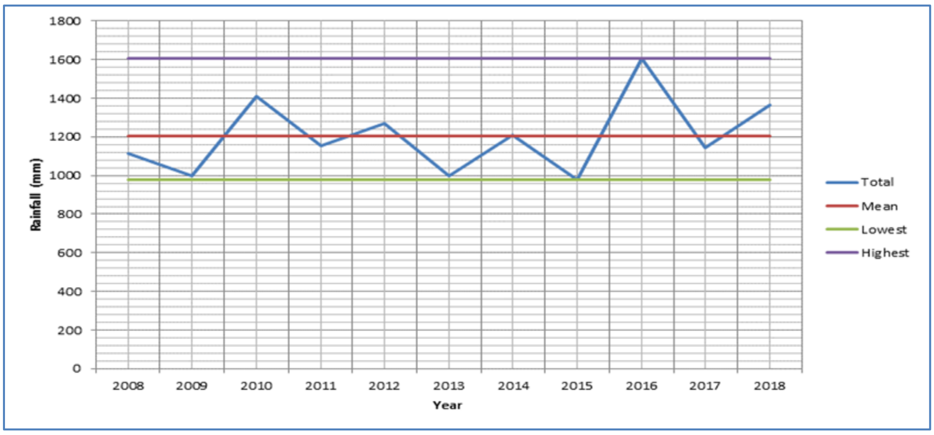

Figure 2. Annual Rainfall between 2008–2018 (Total, mean, Lowest & highest)

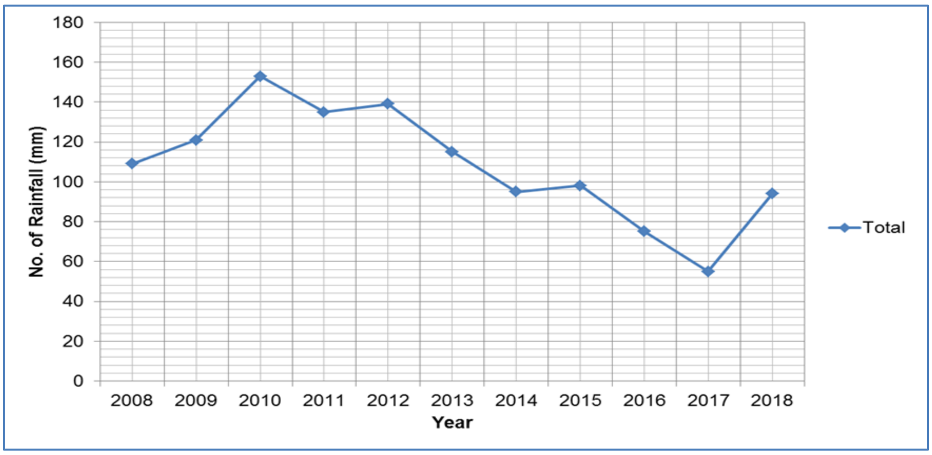

Figure 3. Number of rain days (mm) against the years (2008–2018)

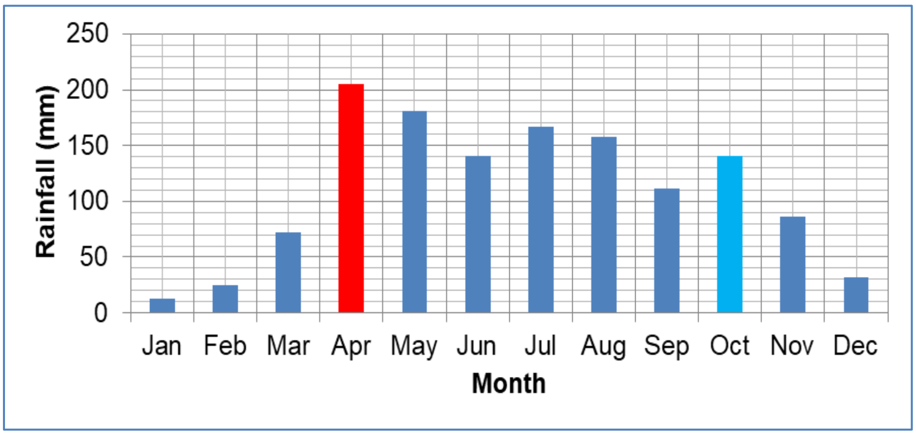

Figure 4. Monthly Rainfall distribution between 2008–2018

This is because the months of January and February are dry months, which on maize calendar usually are land preparation before the planting season and before the onset of long rain in March. This dry spell period in January and February provides a conducive environment for soil aeration and enhances the maize growth.

The month of April is the peak month for long rain seasons. This month recorded the highest rainfall amount in all seasons of the study. This influence of high rainfall is attributed by the bimodal patterns of rainfalls which begin on March to May that coincide with Ongoma, *et al.*, (2015). The study area experienced both long rain and short rain seasons. The long rain season was a reliable season which supports the maize planting. However, excess water during the seasons can pose danger of water logging in the farms and damage the maize seed during the germination process.

According to Rugumayo, (2013), the month of April usually records the highest rainfall beyond the mean as shown in figure 4 (monthly seasons distributions), thus having the risk of water logging. The rainfall distribution in the months of May, June, September and November declined while the months of July, August and October increased. The increased rainfall in short season is not useful to maize production, but causes the harmful effects like damage of maize and spoilage of maize grains. The findings indicate that rain was very erratic during the 2015 period and could pose danger of dry spell which could not support maize productions. July experienced erratic rainfall and posed danger on maize at a critical stage of anthesis and grain filling causing yield loss that coincided with the findings of Ahmed *et al.*, (2015). Short seasons during the period registered the highest rainfall in three months of 375mm against 330mm of rainfall recorded in long rain season. The increase of rainfall in OND short season is attributed to the effects of El Nino and global warming effects coupled with Meso scale factors such as land uses, anthropogenic emission of greenhouse gases, and cover reduction. This is in line with the findings of Gichangi *et al*., (2015) who study the assessment of climate variability and changes is semi-arid Eastern Kenya, the findings indicate that rainfall variations are attributed to changes in weather elements. However, the rainfall pattern in 2016 season, the trend was decreasing as from April, May, June, August, September, October and November posing danger of erratic rainfall and hence dry spell was to influence the variations from year to year as using the precipitation index median of annual rainfalls is 1154mm.

Annual and seasonal rainfall distributions and variability in Endebess Sub-County

The annual and seasonal rainfall distribution variability adopted the statistical measures of rainfall variability respectively. This is the mean standard deviations of seasonal and annual co-efficient variations PCI and seasonal relative variability index.

Table 1. Analysis of Annual rainfalls and seasons as from 2008–2018

Indicator/Time	Annuals	Seasonal
Total rainfalls volume	13,246.8mm	935.7mm
Means	1,204.3mm	133.7mm
Minimum	980mm	86.7mm
Maximum	1,607mm	205.1mm
Standard deviations (SD)	186.9mm	44.6mm
Co-efficient Variations (CV)	15.5%	33.3%
Precipitation Concentrations Index (PCI)	9.3	16
Source: Rainfall data from Endebess / Kitale Meteorological Office, 2020		

The findings in table 1 reveal that, the coefficient of annual and season rainfall as 15.5% and 33.3% respectively. The annual variability across the years was moderate, while the seasonal was highly variable. The Precipitation Concentrations Index (PCI), in annual rainfalls was uniformly distributed across the years to years, while the seasons Precipitation Concentrations Index (PCI) seasonal was 16 indicating irregular distribution of rainfalls in the months. This means that some months in the seasons experienced lowest rainfalls or erratic rainfalls and other months experienced dry spell periods. These findings coincide with Oliver (1980) and Michiels *et al.*, (1992) who studied the climate classifications formulas in Precipitation Concentration Index (PCI) values in Spain between 1946-2005 and classifications tools has been used in world in analysis of climate.

Table 2. Annual seasonal variability index

Years	Amounts of Rainfalls (mm)	Annual Variations (Index Mean x = 1204.3)
2008	1111.6	-7.69
2009	1000	-16.96
2010	1411.7	+17.22
2011	1154.3	-4.15
2012	1268.4	+5.32
2013	998.4	-17.1
2014	1207.3	+0.25
2015	980	-18.6
2016	1607	+33.4
2017	1142.5	-5.13
2018	1365.5	+13.14

Table 3. Seasonal Variability Index

Month	Amounts of Rainfalls (mm)	Monthly Variations (Index Mean x = 110.7)
January	12.3	-88.9
February	25.0	-77.42
March	71.9	-35.05
April	205.1	+85.3
May	180.4	+62.96
June	140.2	+26.65
July	166.9	+50.77
August	157.3	+41.8
September	111.2	+0.45
October	140.2	+26.6
November	86.7	-21.6
December	31.5	+71.5

Table 2 and 3 rainfall variability in annual rainfall range between +33.4 in 2006 and -18.6 in 2015 respectively. While the seasonal variability rainfall ranges between the months of April +85.3 and -88.9 in January. Therefore, the implication of the variability index means that the 2006 annual rainfall variability was low and the year 2015 rainfall variability was high due to low amount of rainfall in the 10 years' period. However, the seasonal month variation was low in April and high variability in January which experienced erratic rainfall and hence dry spell. The annual rainfall distribution decreased in volume as from 2013, 2014 and 2015 as shown in figure 5 (Annual rainfalls trend) and also the number of rainy days in the seasons reduced in June and July. There was an increase of rainy days therefore, the month of June is considered to be a critical stage of maize plant production. Pollinations, tasseling and sinking are very important process which water crisis during this period will lead to low yield. This finding is in line with those of Basir *et al.,*(2018) who studied the effects of rainfall variability on maize varieties grown in changing climate, a case study small holders farming in Zimbabwe, their findings indicated that critical maize growth stage often coincided with mid-season of dry spells, and water stress during this period resulted to 100% losses of the yield and during the month of June farmers are advised to change the planting calendar from March to April where maize planted will not coincide with dry spell period. However, the excess water in the month of July and May causes water logging in the farms and may weaken the standing maize stem hence leading to stunted growth. According to Rugumayo *et al.*, (2012), farmers are advised to plant resistant varieties of maize which can withstand harsh conditions especially dry spells and water logging.

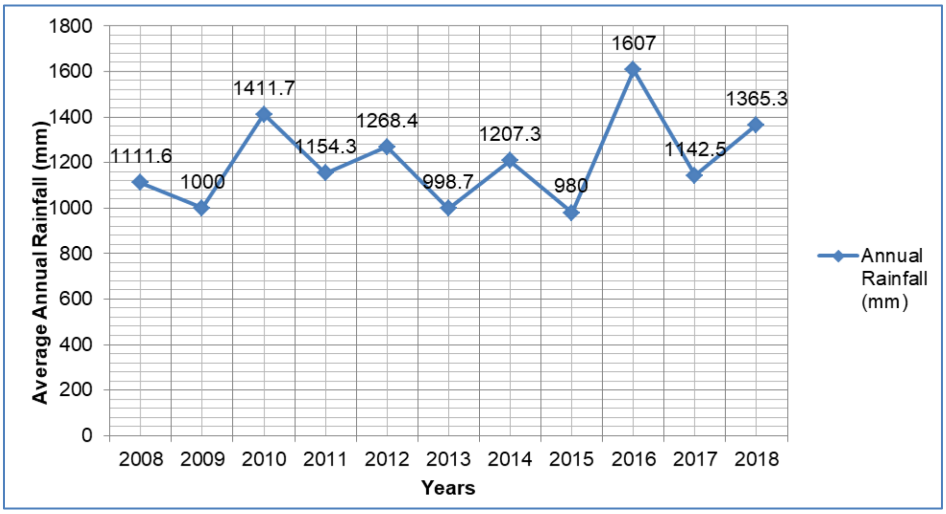

Figure 5. Rainfall variability and trends in Endebess Sub-County between 2008-2018 (Source: Kitale Meteorological Office from 2008-2018)

From the secondary data on rainfall collected during the study period as show above. Figure 6 (annual rainfalls and monthly rainfalls) show the total rainfall volume in the 10 years as recorded in the study period was 13246.8mm and the mean average rainfall was 1204.3mm. The rainfalls range was between 980mm to 1607mm. The highest rainfall was recorded between 2010, and 2016. Other years that also recorded high rainfall were between 2014 and 2018. The lowest average mean rainfall was recorded in the following years, 2008, 2009, 2013, and 2017.

The variations of annual rainfall amount in 2015 as received in the study period was attributed to the effects of El Niño which is caused by global warming and anthropogenic emission of greenhouse gases that lead to climate change and rainfall variability. This was in agreement with Ogwang *et al.*, (2015) findings. 51.8% of the rainfall received in the study area was above the mean average rainfall and 48.2% of the rainfall received was below the average mean. This finding shows that more years in the study area recorded rainfall above normal average.

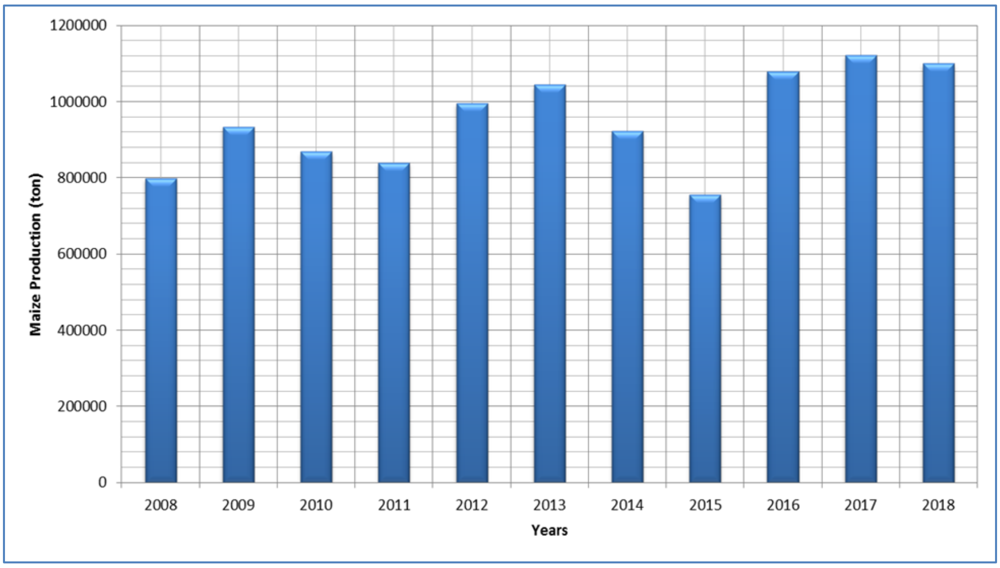

Figure 6. Maize Production Data (90kg) between 2008–2018 (Source: Ministry of Agriculture, Endebess Sub-County (2020))

From figure 6 Maize Production data between 2008–2018 shows that there was fluctuation in Maize yield production in the study period. Maize production decreasing trend was experienced in the following years of study; 2010, 2011, 2014 and 2015 which was below the mean of maize production. Maize production showed increased trends in the following period; 2009, 2012, 2013, 2016, 2017 and 2018. The highest maize yield was recorded in 2017 and the lowest yield recorded in 2015. The variability of maize yield production is attributed to the favorable and unfavorable rainfall received during the affected years in the study area. The lowest maize yield in 2015 was due to erratic rainfalls that led to decreased yields. While on the other hand, the highest yield recorded in 2017 was due to favorable rainfall amounts that favored maize production in the study area.

Table 4. The correlation between rainfalls amount and cropped area

Year	Rainfall (mm)	Maize (Tonnes)	Hectares	Achieved Ha./Tonne
2008	1111.6	799	**751**	1063.6418
2009	1000	934	**875**	1067.5714
2010	1411.7	369	**990**	877.71717
2011	1154.3	839	**851**	986.24559
2012	1268.4	996	**1300**	766.40385
2013	998.7	1044	**905**	1153.4807
2014	1207.3	923	**1258**	733.70429
2015	980	756	**1010**	748.87129
2016	1607	1079	**2476**	435.72213
2017	1142.5	1123	**1450**	774
2018	1365.3	1100	**1504**	731.08378

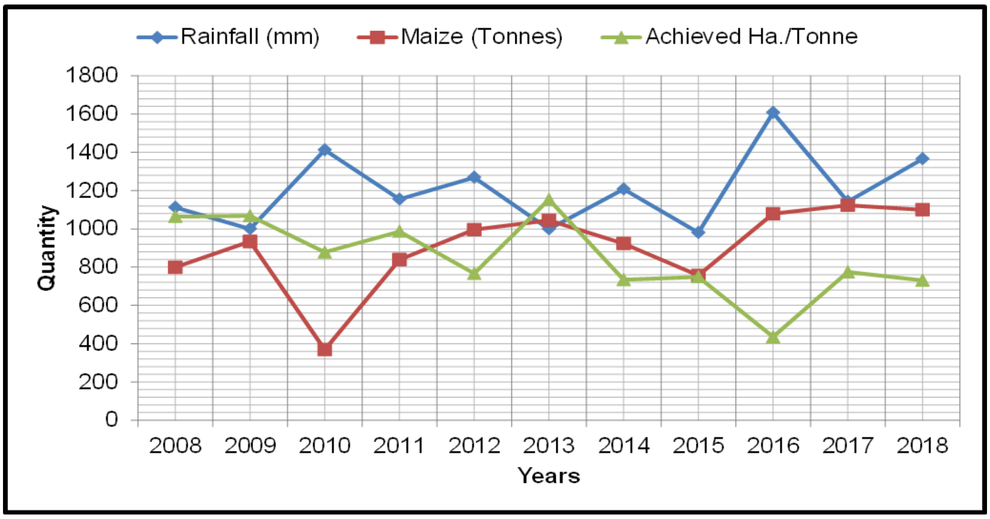

Figure 7. Correlation between rainfalls amount, cropped area and Maize yield

Table 5. Statistical Analysis of Rainfalls amounts, 2008–2018

Variables	Mean	Min	Max	Standard Deviations (SD)	Co-efficient Variations (CV)
Maize production yield in 90kg/bags	951,058	7,956,360	1,112,500	53,216.4	5.6%
Rainfalls amounts (mm)	1,204.3	980	1,607	186.7	15.5%
Cropped Area (Hectares)	1215.5	751	2,476	319.7	26.3%
Achieved (Ha. /Kg) yield	849	436	1154	35.7	4.2%

Correlations of maize production (tons), rainfall amount and yields per hectare

Table 5 shows that maize yield is positively related to annual rainfall recorded during the study period. The trends of maize production corresponded with trends of annual rainfall recorded. When rainfall declined, so did maize yield. There was reduction in rainfalls at 257mm and also maize yield at 29.6 tones while the similar results were on served when rainfall was at 227.3mm and corresponding maize yield of 166.6 tones. However, rainfall trend and maize yields increase was observed in the year 2016, where 627mm rainfall amounts corresponded to 322.5 tones. This positive relation existing in maize yields and annual rainfall strongly agreed with earlier findings by Rasul *et al.*, (2013).

On the other hand, the cropped area is also positively related to rainfall volumes as recorded in the study period in eleven years. For instance, in 2016, the cropped area was 2,476 Ha. This was in line with total annual rainfall volumes recorded as 1607mm. Then other periods showed the similar results such as in 2017 and 2018, where the cropped area positively related to the amounts of rainfall.

This finding shows that, large area of land and high maize yield production was experienced as indicated in 2016, 2017 and 2018 and the smaller area cropped had reduced as indicated in the 2008 and 2011. While the high rainfall volumes annually were well correlated to maize production.

The decline in maize yields in the periods of 2010, 2011, 2014 and 2015 was attributed to cases of rainfall variability due to delayed planting dates and other factors such as inputs and crop management practices.

Table 5 above shows variation in rainfall amount as the major cause of maize yield variability. The mean rainfall volume and the maize yield production were 1204.3mm and 951.1 tons (951058 kg /bags) respectively. On the same note, co-efficient Variations (CV) of rainfall 15.5% and maize 5.6% the standard deviations is 186.7mm and 53.2 tons respectively. However, the cropped land volume was 9,338.4Ha, standard deviations 319.7 and 26.3% as Coefficient Variations (CV) indicate these findings that rain was highly variable and affected the cropped land area and hence led to decline on maize yield.

The positive relationship between rainfall amounts and maize yield had demonstrated that farmers in the study area were vulnerable to risks associated with rainfall variability and thus adaptive measures to mitigate the problem as this finding was agreement with the argument by Bewket (2009).

Conclusions

In accordance to the study findings, it is evident that the analysis of annual rainfalls shows that there was uniform distribution of rainfall across the years. Concentration of annual rainfall was uniform (PCI 9.3), where rainfall was uniform at approximately 90% of the year. Although the seasonal rainfall was poorly distributed across the seasons of the months experiencing erratic rainfall. The concentration of seasonal rainfall PCI was 16 meaning irregular distribution of rainfall. This implies that rainfall was inadequate to support maize production in rain-fed agricultural farming.

Recommendations

The government and other stakeholders in the global climate change should revisit their action. They should work closely to strengthen capacity building on agricultural sector as whole in the study area. Strong forces should be put in place in the assessments of the effects of climate change and rainfall variability and put potential policy to cope with the effects of rainfall variations. This approach can be done through the integrated approach. System where both the County and National government create awareness on climate change and innovations skills that will enhance the adaptation measures.

Conflicts of interest: There is no conflict of interest of any kind.

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