ASSESSMENT OF RAINFALL VARIABILITY AND MAIZE CROP FARMING IN NYANDARUA COUNTY, KENYA

[1]Muriithi D.I., [2]Wambua B.N., and [2]Omoke K.J.

[1]PhD Candidate, University of Nairobi, Department of Geography, Population and Environmental Studies, P.O. BOX 30197-00100 NAIROBI, KENYA

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ABSTRACT

Crop farming is crucial to the livelihoods of communities living in the rural areas of Kenya. The sector largely depends on climatic variables such as rainfall for optimum crop output. This article presents the analysis, interpretation and discussion of the research findings based on the objective of assessing the climate variability of mean annual rainfall and its impact on crop farming (maize output) in Nyandarua County. To achieve this objective, the researcher sought to analyse rainfall amount and fluctuations in Nyandarua County for 21 years and correlate the variable with crop output (maize) over the same period. The variability of rainfall and maize output was analysed using descriptive statistics of mean, standard deviation and coefficient of variance. Simple line trends and scatter graphs were used to show this variation. The inferential statistics of regression and correlation analysis were used to establish the relationship between the rainfall factor and the selected crop output. The null hypothesis associated to this objective was tested using results of the correlation and regression analysis. Evidence of the study indicated that the annual average rainfall had increased from 1999 to 2006. However, the last fifteen years preceding the study, the mean annual rainfall had significantly fluctuated between the peaks of 117 mm and off peaks of 67 mm. The utmost variation in the rainfall amount was experienced between the years 2013 and 2007. Referring to the 21-year period of annual crop output records, the output of maize greatly fluctuated between 2019 and 1999 with an average tonnes of 29,145.76. Rainfall variability was concluded to have greatly influenced the changes in maize output (r=0.688). The regression line for rainfall variability and maize output produced a slope that was described by the equation $y=463x - 11100 + έ$. The regression value (R2 = 0.47189 showed that 47.19% of the fluctuation in maize output was as a result of the disparity in rainfall amount and distribution. In conclusion, results of the study implied that rainfall amount and distribution was highly erratic and unpredictable. Therefore this scenario exhibited much uncertainty to the small scale farmers in the region. For better planning of the effect of climate variability, the study recommended that policymakers and other relevant stakeholders should come up with awareness programs through the provision of useful information that assimilate the small holder farmer indigenous knowledge and perception and its effects on their livelihoods with the accurate meteorological scientific data.

Keywords: Rainfall variability; logistic regression model; crop variability; adaptation strategies;

1. INTRODUCTION

Climate variability is the discrepancies in the averages, totals, and other data, like the standard error and coefficient of variation, of climate variables, like rainfall and temperature, recorded over a shorter time period, like ten to twenty years (Luers and Moser, 2006). Variations in manmade factors or intrinsic natural processes of the climate system may be the cause of climate variability (Selvaraju and Baas, 2007). Climate variation, particularly owing to rainfall and temperature, is likely to reduce the production of the County's main crops. Small-scale farmers have used a variety of adaptive tactics to preserve and enhance essential crop yield in response to this detrimental impact. For these reasons, it's critical to comprehend how fluctuations in temperature and rainfall affect crop farming, to examine the adaptation techniques used in response to various climatic changes, and to evaluate the factors that influence the use of these techniques in crop farming. Globally, 24% of the gross world product is produced by agriculture, particularly agricultural production (Slater et al., 2007). About 60% of Africa's labour force makes their living through crop farming, which also contributes to 17% of the continent's overall GNP and 40% of its overseas earnings (Harsch, 2004).

The economy of Kenya is heavily dependent on rain-fed agriculture, particularly through the production of crops that are particularly vulnerable to climate change (Mendelsohn et al., 2007). Since 2000, the average annual rainfall in Africa has been on a downward trend of 7mm (WHO, 2018). More than ten times as much rainfall is being lost as compared to the Caribbean plus Latin America. Food security in Africa, where approximately 90% of agriculture depends on rainfall, is seriously threatened by the unpredictability and decline in rainfall (WHO, 2018). According to a 2011 report by IPCC, 25–42% of Africa's agricultural habitat may have become unusable by 2020, which would result in a decrease in food crops. Climate change is expected to lower cereal output in Nyandarua Region, Kenya, by roughly 16%, and to cause the loss of cultivable land by 11% within two decades (GoK, 2010).

According to preliminary statistics as from Kenya Meteorological Department, the intensity and pattern of the country's Nyandarua County's rainfall have changed and are now exceedingly unreliable and unpredictable. The Agriculture Ministry and County government data also showed that some crops' agricultural output had been dropping. Additionally, Nyandarua County's cultivable land area had been declining, going from 80,331 hectares by 2012 down to 60,917 ha of land in 2016. Crop farming, which depends on climatic elements and is the primary economic sector and source of income in Nyandarua County, must be studied in connection to the area of cultivable land, crop yield, and meteorological variables such as temperature and rainfall. These variables' changing tendencies could result in decreased agricultural income for the county, the loss of livelihood for small-scale farmers, and a rise in food insecurity for Nyandarua County population.

The area of study

At the central Kenya, Nyandarua County lies between the counties of Laikipia in the north, Murang'a in the east, Kiambu to the south and Nakuru to the west. Nyandarua County with a surface area of 3,245km^2 lies on latitudinal extent of 0°8' to the North and $0^0 50^1$ to the south. The county's longitudes are between 35°13' East and 36°42' West (Muraya et al. 2016). The five sub-counties that make Nyandarua County are Ndaragwa, Ol'kalou, Ol'joroOrok, Kinangop and Kipipiri. Ndaragwa is the smallest while Kinangop is the largest with six divisions and 16 locations.

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The region experiences two bimodal rainfall seasons with long rains from March to May with a maximum of 1600mm and short rains happening from September to December with a maximum of 700mm (Omwoyo and Akivaga, 2015). The county is one of the food baskets in Kenya where major food crops such as maize, vegetables, Irish potatoes and wheat are grown. These food crops contribute to a substantial source of income for most households because they are not all used for subsistence (Kaguongo, et al., 2007).

Referring to the figure 1 below, high precipitation of between 1500 to 1750mm on the other hand was experienced around the area bordering Murang'a and Nyeri to the East. The high rainfall is as a result of nearness to the massive Aberdare forest and effect of the wind ward side of Mt. Kenya. Areas such as South Kinangop, Tulaga, Ndunyu Njeru, Miharati and Ndondori are very rich in food crops output especially the vegetables and Irish potatoes.

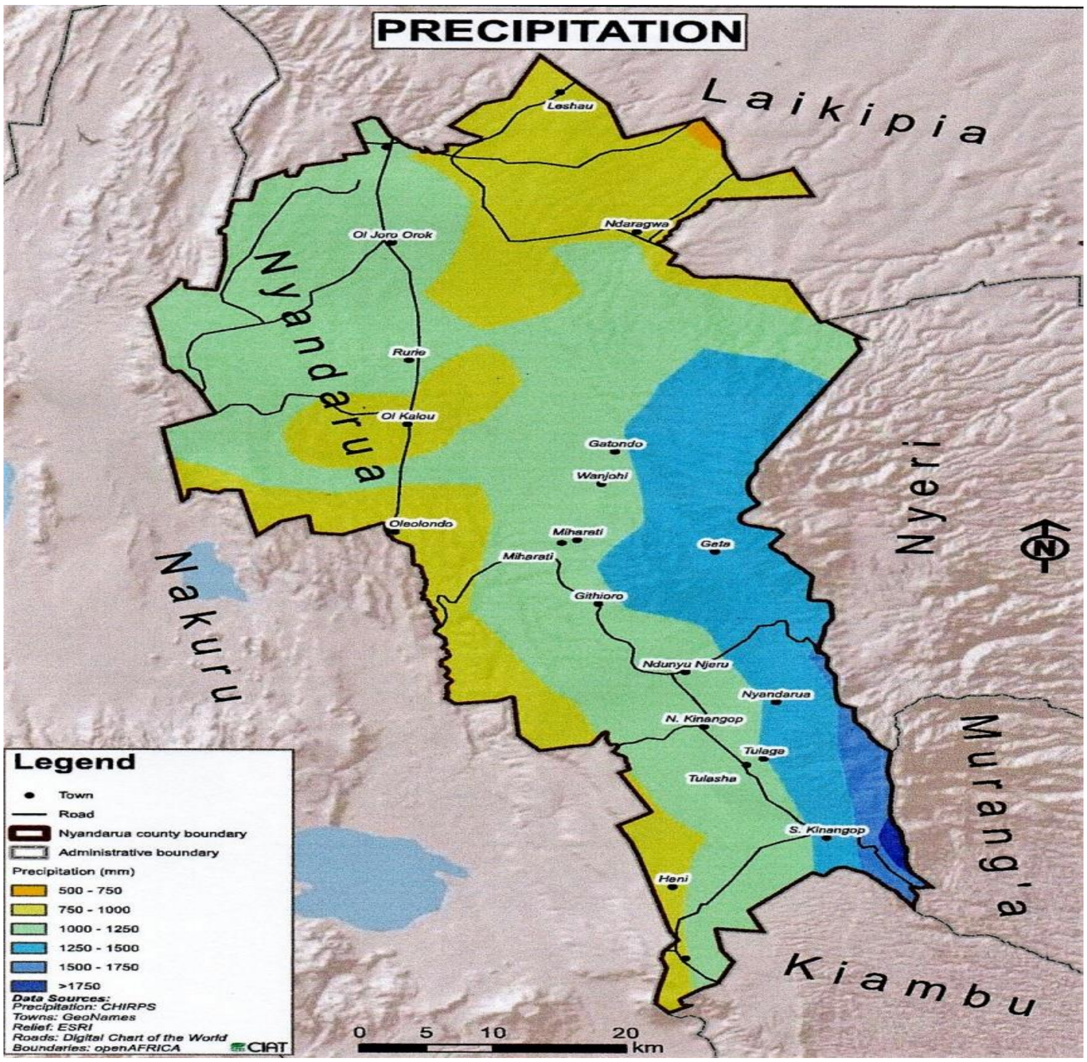

Figure 1: Precipitation in Nyandarua
Source: County Climate Risk Profile in Kenya 2017

Trend in crop output

The area bordering Nakuru County from the North to the South received less precipitation of 500-700mm. Likewise, the area to the North which includes Leshau and Ndaragwa has bordered Laikipia County which is a bit dry. The arid and semi-arid conditions of the lee ward side of Mt Kenya have encroached substantial part of Nyandarua County especially to the North. Most parts of Ndaragwa Sub County have completely dried up evidenced by insufficient rainfall. This has contributed to failure of crops and drying up of rivers. The county government has proposed to the national government to declare Ndaragwa constituency an arid and semi-arid region and a hard ship area. This will increase the accessibility of funds to improve the marginal areas in terms of social and physical infrastructure and human capital development.

Nyandarua County has enjoyed a favourable climatic condition supporting agriculture for many years. Small scale farmers have therefore depended on rainfall for various agricultural activities. The agricultural production has remained stable for many years. However from late 1990s the variations in crop out portrayed a declining trend. This erratic variation in crop output has to a larger extent been contributed to by changes in rainfall quantity and patterns. Temperatures have been extreme on both sides. The days are too hot and at nights too cold leading to frost bite especially in Irish potatoes and thus lowering the crop output. Crop farming being rain dependent in the study area has been negatively affected by deviations in rainfall patterns. Farmers have changed the planting calendar with uncertainties, crops have failed to germinate, crops have withered at the flowering stage and pests and diseases have increased. These effects have resulted to dramatic change in agricultural output. Other agronomical factors such as reduced soil fertility and poor methods of farming have also affected crop farming in this county. The high cost input for example certified seeds, chemicals and fertilizers have worsened the current situation of agriculture in the region. Many farmers cannot access affordable credit facilities and reliable agricultural extension services. A lot of research on this matter is needed in this area to avert the declining trend of crop output.

2. MATERIALS AND METHODS

The study utilized a descriptive survey methodology to observe and analyse the variation of rainfall and maize crop output. This design allowed the researcher to draw conclusions and inferences from the sample population where the independent and dependent variables were not under the researcher's control. The climate and crop output secondary data was obtained from secondary sources in the ministry of environment, ministry of agriculture and the county government departments. The variations of these variables were assessed using measures of central tendency, standard deviations and coefficient of variance. The impact of variations in rainfall amount to the maize output was analyzed using correlation and regression statistical methods. These relationships were also collaborated with the answers obtained from the open ended questionnaires. The Microsoft offices excel and the version 17 of the statistical package software for social sciences made it easy to carry out these complex inferential analyses.

Coefficient of variance and Mean Standard deviation

The average annual rainfall is the mean of the totals of monthly rainfall for respective years divided by the twelve months.

i) $$\textit{Annual Mean Rainfall} = \frac{\sum \textit{Monthly Total Rainfall}}{(\textit{Twelve Months})}$$

The average annual rainfall over the years was established by constructing a simple linear regression model. Using the regression equation, the magnitude of change was determined by the slope of the respective linear equation. The assessment of variations in rainfall amount may have been affected by seasonality and several missed monthly readings. Because of this inconsistency, the coefficient of variance (CoV) was figured out for annual mean rainfall in the entire period of investigation and then correlated with maize output figures in tonnes using the Pearson Correlation Coefficient model. The coefficient of variance was calculated by dividing the standard deviation with the mean annual rainfall as shown in the formula (ii) below.

ii) $$\textit{Coefficient of variance} = \frac{\textit{Standard deviation}}{\textit{mean annual rainfall}}$$

The standard deviation compares data sets with the same mean but of different range by measuring the spread of the particular data from mean value (Karanja et al., 2013). The standard deviation for the rainfall variable was obtained by getting the mean annual rainfall which was then subtracted from each monthly rainfall amount. The summation of these results were then added for n months and then divided by twelve months. The square root of this value gave the standard deviation.

The standard deviation formula used is given below.

iii) $$\textit{Standard Deviation } (s) = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})}{n-1}}$$

Where: √ = Square root

∑ = Sum total of individual values of $(x_i - \bar{x})$ for i - n (i.e. January to February)
x_i = Total number of variable x

$\bar{x}$ = Mean of variable x

n = 12 months (Total number of observations/values)

Pearson Correlation Coefficient(r)
The individual climatic variable of rainfall and its relationship with output in tonnes for maize crop in the entire period of observation was measured by the Pearson correlation coefficient. This analysis technique identified the direction and magnitude of how the independent variable may have influenced the selected crop output variance. The Pearson's correlation coefficient (r) is the association between two variables (one dependent and one independent). This statistical technique is used to determine the correlation between the rainfall variation and amount variable and the maize output in tonnes for the same period of observation.

The following correlation coefficient formula was used in the study.

iv) $$r = \frac{\sum_{i=1}^{N}(x_i - \bar{x})(y_i - \bar{y})}{\left[\sum_{i=1}^{N}(x_i - \bar{x})^2 (y_i - \bar{y})^2\right]^{1/2}}$$

Where: $\sum$= Summation of

N = Total number of observations

$\bar{x}$=Mean of variable x

x_i=Total number of variable x

$\bar{y}$= Mean of variable y

y_i= Total number of variable y

r= The Pearson's correlation coefficient (r)

3. FINDINGS AND DISCUSSION

Mean annual rainfall trend in Nyandarua County (1999-2019)

The maximum and minimum total annual rainfall was recorded at 1,572 mm and 672 mm respectively. The descriptive statistics results indicated that the twenty one year mean annual rainfall was 1042.8 mm with a standard deviation of 229.9. The mean annual range was 75 while the variance was 367.12.

Table 1: Rainfall Descriptive in mm

Descriptive Statistics	Total annual rainfall	Mean annual rainfall
Mean	1,042.80	86.9
Standard Deviation	229.92	19.16
Maximum	1,572.00	131.0
Minimum	672.00	56.0
Variance	52,864.70	367.12
N	21	21

Source: 2020 Research

The study's findings also showed an increase in annual mean rainfall from 1999 to 2006, as seen in table 4.7. The mean annual rainfall did, however, vary significantly between the years 2007 and 2019 between peaks of 117.4 mm and off peaks of 67.1 mm. The research area had undergone a steady increase in mean annual rainfall during the previous three years (2017–2019). However, between 1999 and 2019, there were a few years with extremely low mean annual rainfall, which had an influence on Nyandarua County's agriculture production. These periods of low precipitation included those of 2000 (56.0 mm), 2009 (59.1 mm), and 1999. (65.5mm). Additionally, the scatter graph below shows that the period from 2007 to 2013 saw the greatest variation in rainfall amounts based on physical observations. These findings of the average annual rainfall between the years 2002 and 2007 backed with Jaetzold et al. (2007) claim that central Kenya's rainfall pattern and intensity were marginally erratic and unpredictable. However, between 1999 and 2019, there were a few years with extremely low mean annual rainfall, which had an influence on Nyandarua County's agriculture production. These periods of low precipitation included those of 2000 (56.0 mm), 2009 (59.1 mm), and 1999. (65.5mm). Additionally, the scatter graph below shows that the period from 2007 to 2013 saw the greatest variation in rainfall amounts based on physical observations. These findings of the average annual rainfall between the years 2002 and 2007 backed with Jaetzold et al. (2007) claim that central Kenya's rainfall pattern and intensity were marginally erratic and unpredictable.

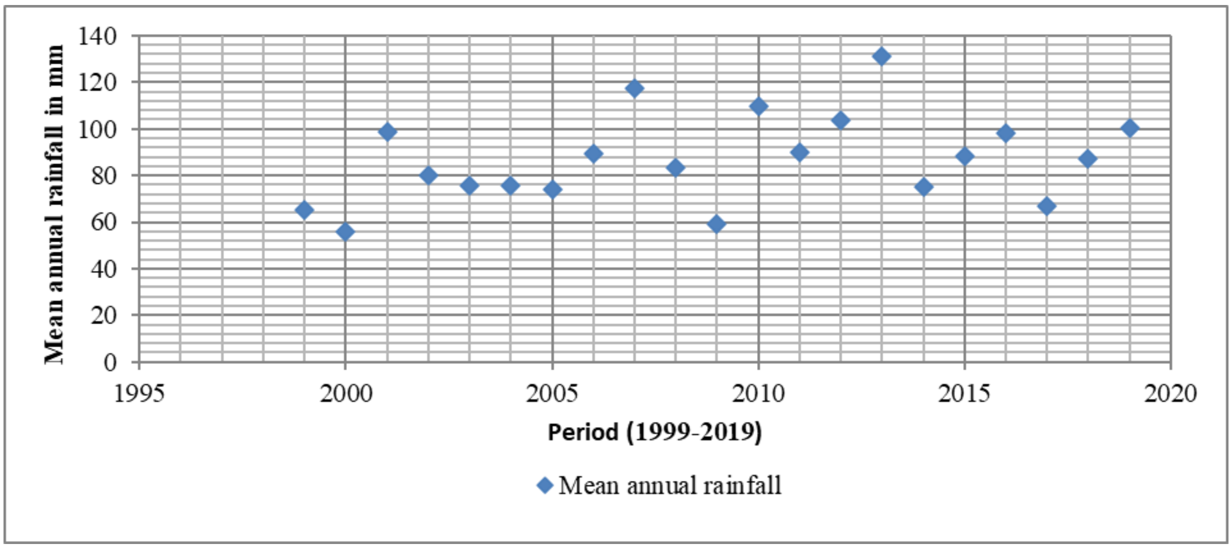

Figure 2: shows a scatter graph of the average annual rainfall trend (1999-2019)

Source: 2020 Research

Changes and trends in Nyandarua County's maize production

The data provided by the County government of Nyandarua showed that between 1999 and 2019, maize output averaged 29,145.76 tonnes, with a maximum output of 54,951 tonnes recorded in the year 2011 and a minimum output of 10,343 tonnes recorded in the year 2000. This information was based on 21-year annual crop output analyses. The production of maize fell significantly between the years 2013 (53,575 tonnes) and 2014 (10,343 tonnes). The highest annual rainfall total was similarly 131 mm in 2013, which was followed by a sharp decline in 2014. (74.9 mm). This connection suggests that there was a link between the output of maize and the amount of rainfall during these two times. A complex analysis, however, showed that the maximum maize output of 54,951 tonnes occurred in 2011, when the amount of rainfall totalled

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1080 mm with just a mean of 90 mm. considering the other periods, 2011 wasn't the best, but it was the year with the biggest output of maize. This result demonstrated that highest rainfall did not always imply maximum crop yield. Perhaps the most efficient use of appropriate adaptation tactics could be attributed to for the highest productivity of maize. Adam et al. (2020) findings, which showed that climatic conditions cannot support high yields of crops alone in the absence of suitable adaptation methods, also made reference to this finding. Additionally, despite a decrease in rainfall, the small-scale farmers' adaption tactics during this time may have been successful in increasing crop output. This conclusion necessitates a careful evaluation of the adaptation mechanisms used by small-scale farmers to maintain crop productivity despite the observed climatic volatility.

There were significant changes in maize production throughout a 21-year period, according to the scatter graph for this variable. Due to this output volatility, it was necessary to look into potential causes, such as the adaptation tactics currently being used, and to propose potential changes in order to keep maize output stable.

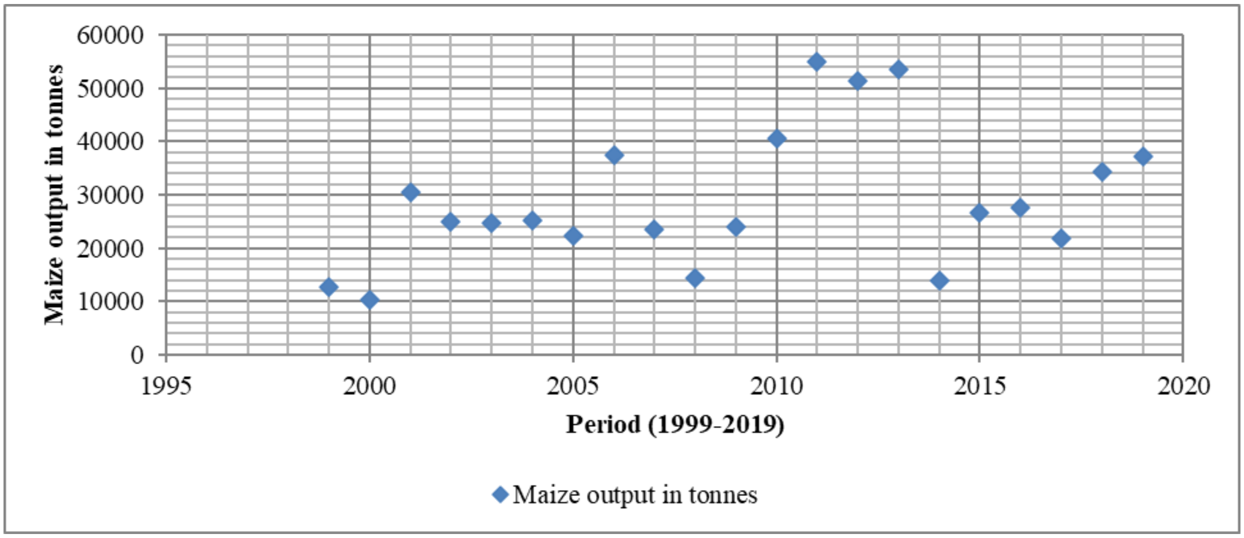

Figure 3: A scatter diagram displaying the change in the tonnage of maize production (1999-2019)
Source: 2020 Research

Correlation between rainfall fluctuation and maize output

In order to determine the association between rainfall variability and crop yield, the researcher used secondary rainfall and crop output data that were obtained from the KMD and county agricultural departments (Maize). This association was measured using the inferential statistics of Pearson correlation. The correlation coefficient (r), which was used to gauge how closely the two variables were related, was the analysis's outcome. On a scale from 0 to 1, the relationship's strength was evaluated. To put it in another way, a Pearson correlation value close to 1 indicates that there was a substantial relationship between the two variables and that the changes in one variable were closely correlated with changes in the other.

A weak connection between the two variables was present if Pearson's correlation value was near to 0. If the Pearson's correlation value was negative, it indicated a negative association and that it was likely that a positive change in one variable would result in a negative change in the other. The student t-test statistic was employed to determine whether the connection was significant at 0.05 significance levels. The null hypothesis was rejected if the obtained correlation value was greater than the p value of 0.05. The null hypothesis failed rejection if the estimated correlation value was lower than the p-value.

Table 2 shows the Pearson correlation coefficients with rainfall patterns and the yield of the chosen maize crop.

Correlations		Annual Mean Rainfall in mm
Tonnes of maize produced.	Pearson Correlation	**.687****
	Sig. (2-tailed)	.001
	N	21

****. The 0.05 level of significance for correlation (2-tailed)**
Source: Author's 2020 calculations

Variability in rainfall and specific crop yield

Comparative line graph analysis of these two groupings of variables identified some observable correlations between them. For instance, between the years 1999 and 2000, a drop in the average annual rainfall was linked to a drop in maize production. A considerable increase in the mean annual rainfall between 2000 and 2001 coincided with a significant increase in maize production. The average yearly rainfall between 2002 and 2005 was comparatively consistent, as was the yield of the maize crop. The mean annual rainfall decreased significantly from 131 millimetres to 74.9 millimetres during the years 2013 and 2014, as did the amount of maize produced, which fell from 53,575 tonnes down to 14,017 tonnes during the same period. The rainfall amount had significantly increased over the three years before the study. As a result, there was a notable rise in agricultural output, particularly for maize. However, a deeper examination of the comparative figures revealed that maize had a considerably stronger relationship with rainfall variability than did other crops. To determine what causes this association, more study may be done.

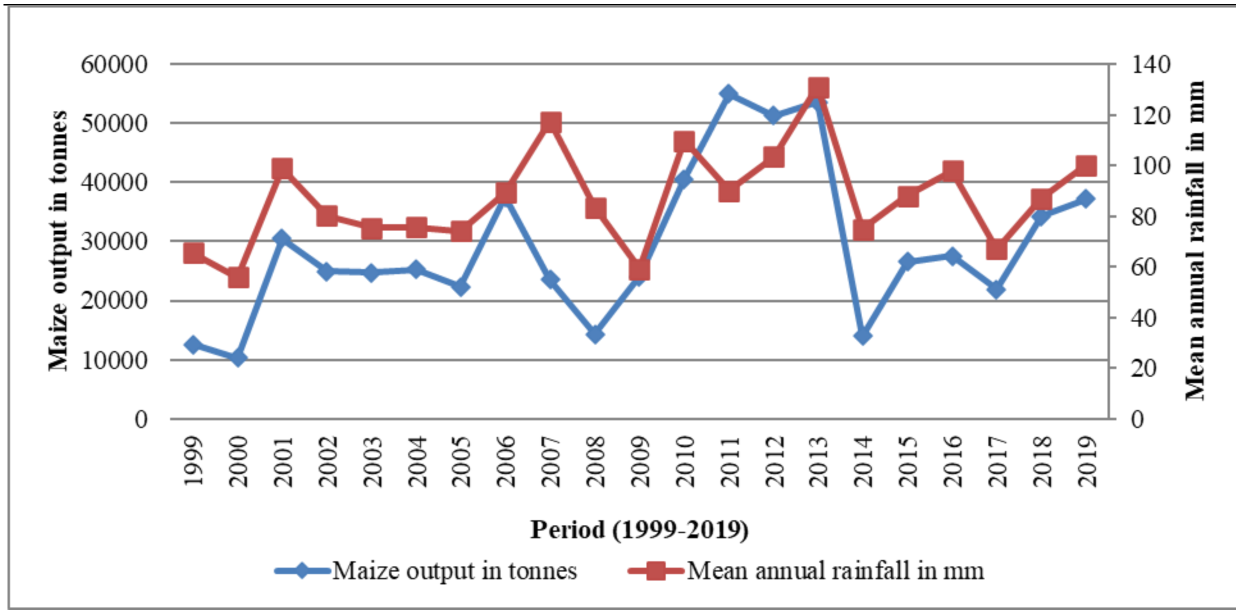

Figure 4: A comparison line graph demonstrating the patterns in the average annual rainfall and the tonnes of maize production
Source: 2020 Research

In several of the 21 years depicted in the above graph, there was a positive association between the amount of rainfall and the yield of the maize crop. However, other agronomic factors, including a rise in the size of cultivable land, or possibly a decrease in pests and diseases, or even a decrease in post-harvest losses, could have contributed to the inverse relationship between rainwater and maize production in the years of 2007 and 2011, where rain increase did not correspond with a rise in maize output. Kenya Seed Company (2013) claims that successful maize production relies on both favourable climatic circumstances and other agronomic elements that have been tempered by appropriate adaptation tactics. In this situation, rainfall could not be enough to ensure optimal maize output.

Again for 21 years (1999-2019), a Pearson correlation relating extreme rainfall and maize production was conducted. The value of r=0.687 for the Pearson's correlation coefficient between both the two variables was discovered. This Pearson correlation coefficient was near to 1 and greater than the p-value of 0.05, indicating a significant positive link between the two parameters. This was understood to suggest that variations in rainfall had a significant impact on changes in maize production during a 21-year period. The null hypothesis (H0), that annual rainfall had not greatly affected crop farming (maize yield) was thus refuted.

Views of the respondent regarding the most recent change in rainfall

The researcher was interested in learning how small-scale farmers perceived and understood climate variability in relation to rainfall intensity. In order to do this, the researcher asked two closed-ended questions on the questionnaire: (1) whether participants had observed any changes in rainfall during the previous years preceding the study, and (2) how the amount of rainfall had changed over the previous 10 years. Ninety-three percent of respondents stated they had seen variations in rainfall in the few years prior to the poll, while only six percent said they hadn't. Out of the 300 responders, 214 (71.3%) noticed that the amount of rainfall had reduced, according to further study, around 68 participants (22.7%), saw an increase in rainfall, whereas 18 respondents (6%) saw no change in rainfall. The majority of the respondents made this observation, which was at odds with the secondary data's actual conclusion that yearly mean rainfall had risen over the three years before the survey. Further analysis of the survey results revealed that 251 (90%) of the 300 respondents agreed with the assertion that rainfall had recently become extremely erratic and challenging to anticipate. However, 6% of respondents disagreed with this assertion, and 4% were unsure.

The inferential analysis of the secondary annual rainfall from the Kenyan meteorological agency, which also demonstrated the same trend, matched these results. The Nyandarua County Masterplan (2018) states that the county experiences two bimodal rainfall seasons; having short rains from September through December with maximum rainfall of 700 mm and longer rains from March to May with a maximum rainfall of 1600 mm. In recent years, prolonged downpours have pushed back the commencement date until April or early May. Crop planting, harvesting, and crop output have all been significantly impacted by this climatic trend. Farmers have changed the start time for preparation of the land and the dates for planting in response to this situation. A decrease in rainfall could have a negative impact on agricultural production, according to Hassan et al. (2008). Since approximately 90% of Africa's agriculture depends on rain, the unpredictability and decline in rainfall represent a serious danger to food security.

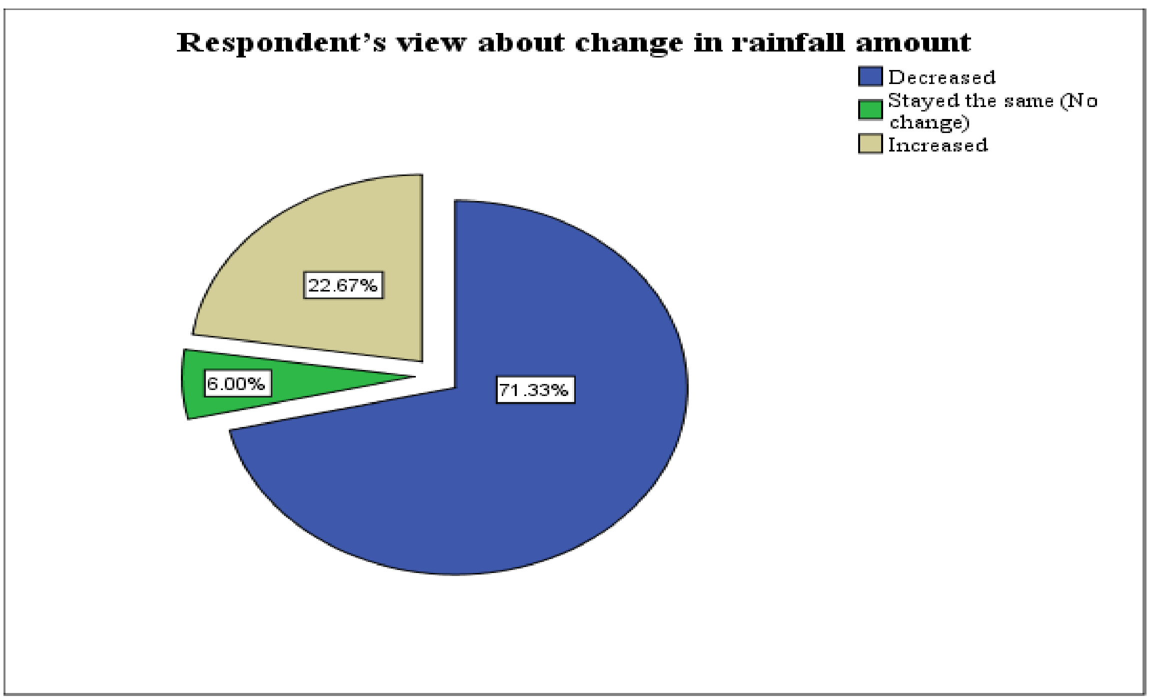

Figure 5: Reactions from respondents to the most recent shift in rainfall amounts
Source: 2020 Research

Respondent's perception of the variation in major crop output

The researcher aimed to examine how small-scale farmers felt about perceived variations in crop yield during the previous years with regard to variations in major crop output. According to the questionnaire's analysis, the majority of small-scale farmers (89.7%) preferred maize, beans, and Irish potatoes as their main crops. However, it was discovered that the County also grew a variety of other crops, but not by many small-scale farmers. These crops included fruits, sorghum, green peas, millet, French beans, kales, cabbages, and wheat.

When asked to characterize the changes in agricultural production or output over the previous ten years, the respondents gave a 77.7% response that they had not noticed any changes or that the output had stayed the same. However, 10.3% thought crop output had grown while 12% thought crop output had decreased. This wide range of responses suggested that farmers might not have kept good records of the amount of agricultural output per harvest, which would have prevented them from accurately determining changes in crop output.

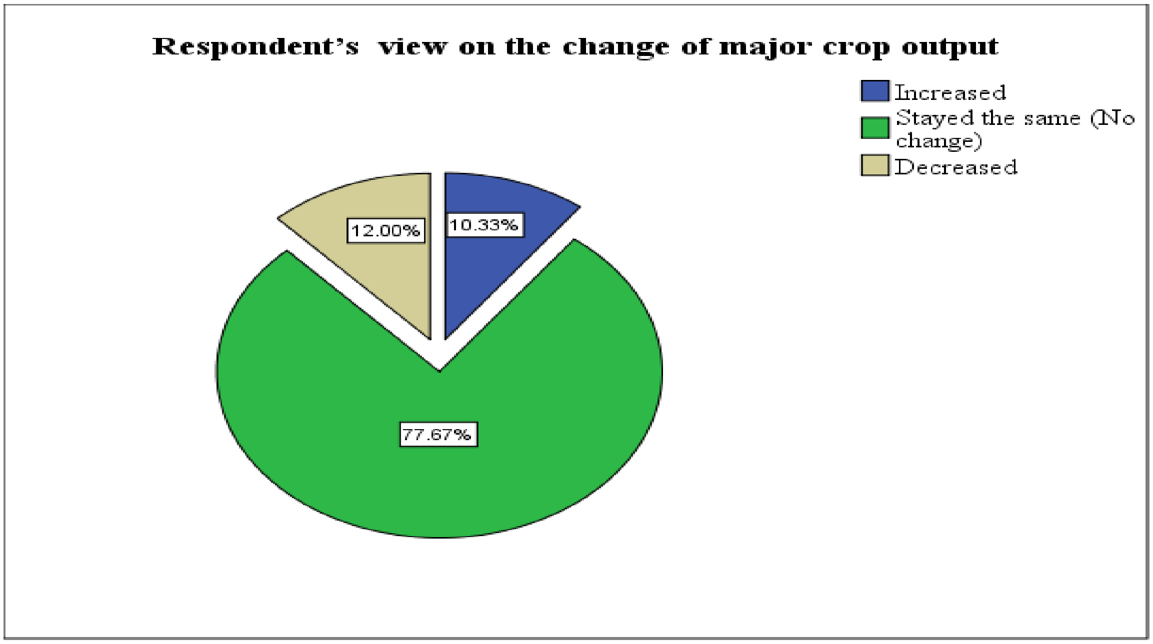

Figure 6 Respondents' perceptions of the changes in major crop yield
Source: 2020 Research

4. DISCUSSION OF RESULTS

Nyandarua County has in fact undergone climate variability. For the past 21 years, fluctuations in the mean annual rainfall have served as a manifestation of this unpredictability (1999 to 2019). The participant's opinion of the variations in the chosen meteorological variable works in conjunction with the secondary data concerning changes in rainfall. 93% of respondents said they had noticed variations in rainfall in the years before the research. A reduction in rainfall was noted by 71.3%. According to Mendelsohn (2010), Kenya's economy is heavily reliant on rain-fed agriculture, particularly the growing of crops that are especially vulnerable to climate change.

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Table 3: Nyandarua County Weather Variables (Rainfall and Temperature) (1999-2000)

Year	Annual Average Minimum Temperature in ^{0}c	Annual Average Maximum Temperature in ^{0}c	Annual Average Rainfall in mm
1999	9.4	23.4	65.5
2000	10.6	24.6	56.0
2001	11.4	23.7	98.9
2002	11.6	23.9	80.1
2003	7.7	21.0	75.5
2004	7.5	21.6	75.6
2005	7.6	22.1	74.2
2006	7.9	21.6	89.3
2007	8.3	21.0	117.4
2008	7.6	21.6	83.4
2009	7.6	22.7	59.1
2010	8.7	21.4	109.9
2011	7.7	22.0	90.0
2012	8.3	21.9	103.5
2013	8.1	21.6	131.0
2014	7.9	22.1	74.9
2015	8.5	20.4	88.1
2016	8.1	22.1	98.0
2017	8.0	23.0	67.1
2018	8.0	22.1	87.1
2019	8.4	22.7	100.3

Kenya Meteorological Department is the source (2020)

The most significant staple crop in Kenya is maize, which is grown in practically all agro - ecological regions of the nation. In the nation, maize is both a commercial commodity and a food security crop, particularly in the rift valley as well as some areas of western and central Kenya (Schroeder et al., 2013). According to the poll, the majority of participants (89.7%) preferred to plant Irish potatoes, maize, and beans. This shows that among the small farmers in Nyandarua County, crop farming was the primary economic activity and a significant source of both food and revenue.

The analysis also shows that there has been a significant variance in maize production over the past 20 years, from 1999 to 2019. In fact, a significant decline in maize production between 2013 and 2014 was observed. Declining maize yield, according to Seo et al. (2010), should be handled carefully. This is due to the fact that as the population has grown, so has the demand for food. Additionally, the area that can be farmed has been shrinking, which has reduced the amount of maize produced. According to the report, Irish potato and maize production have experienced regular peaks then off peaks during the past 21 years. The peaks could be attributed to favourable meteorological conditions required for crop growth, successful adaption of improved varieties and allied technologies, and to some extent an expansion in the areas under cultivation. Likewise, the declines in production seen in some years may have been caused by a variety of factors, including unfavourable weather conditions, shrinking land areas, an increase in diseases and pests, soil degradation and dwindling soil fertility, high input costs, and significant post-harvest setbacks (Ingram et al 2011).

Final Thoughts and Policy Suggestions

There are certain correlations between the amount of rainfall and maize production. With an average annual rainfall of only 56 mm, the year 2000 was judged to have the least quantity of rainfall. Similarly, maize had its lowest production that year (10,343 tonnes). The highest annual average rainfall occurred in 2012 and 2013, with 103 mm and 131 mm, respectively. The largest output was also recorded by maize (51,300 and 53,575 tonnes, respectively).

Maize crop damaged by hailstones

Cabbage crop damaged by hailstones

Plate 1: The detrimental impact of torrential rain on crops in 2019

Source: 2020 Research

The trends curve and scatter plot of the variability of rainfall showed that these meteorological variables varied noticeably. These plots and trend lines also demonstrated that the variables remained highly unpredictable, which had an impact on how well-prepared farmers were for farming. In general, these findings concurred with questionnaire responses that were analyzed, showing that 55.7 percent of respondents saw climate-related issues as the main causes of the drop in agricultural output. Similar findings were reported by Mendelsohn et al. (2010), who found that many local farmers across eleven African nations thought that the temperature had risen but rainfall intensity had decreased.

5. CONCLUSION

Based on the aforementioned findings, it was determined that the climatic component taken into account in this study, namely mean annual rainfall, had an impact on the output of the maize crop during a 21-year period (1999-2019). In this instance, the hypothesis 1 that rainfall in Nyandarua County had no substantial impact on crop cultivation (maize output) was rejected. It was clear from the discussion of the results that rainfall was a significant predictor of crop output, particularly maize for Nyandarua County. Overall, the study's findings showed that the climatic parameters taken into consideration could not explain at least 50 percent of total of the variability in maize output.

Conflict of Interests

The authors of this work have affirmed that they do not have any competing interests.

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Contributions from Authors

Author 1 worked on this project while being supervised and guided by writers 2. Author 1 carried out the research, carried out the statistical analysis, and wrote the manuscript draft of the publication.

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Availability of information and resources

The primary and secondary data utilized in this article were part of the author's ongoing PhD in Geography and Environmental Studies thesis at the University of Nairobi, which was partially fulfilling the requirements for that degree.

REFERENCES

Adam, H., Mumuni, E., & Abubakari, A. (2020). Factors Influencing Adaptation Strategies to Cope with Climate Variability: A Study of Maize Farmers in Mion District of Northern Ghana. *UDS International Journal of Development*, *7*(1), 296–306. Retrieved from https://www.udsijd.org/index.php/udsijd/article/download/440/197

Government of the Republic of Kenya. (2018). *National climate change action plan 2018-2022*. Retrieved from Ministry of Environment and Forestry website: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwjIr5vJtq32AhWGNewKHWr5C2EQFnoECAYQAw&url=http%3A%2F%2Fwww.environment.go.ke%2Fwp-content%2Fuploads%2F2020%2F03%2FNCCAP_2018-2022_ExecutiveSummary-Compressed-1.pdf&usg=AOvVaw1GyD84soQi7FyKDSEX2uYf

Harsch, E. (2015). Agriculture: Africa's "engine for growth" | Africa Renewal. Retrieved from Un.org website: https://www.un.org/africarenewal/magazine/january-2004/agriculture-africas-engine-growth

Hassan, R. M., & Nhemachena, C. (2008). Determinants of African farmers' strategies for adapting to climate change: Multinomial choice analysis. *African Journal of Agricultural and Resource Economics*, *02*(1). Retrieved from https://econpapers.repec.org/article/agsafjare/56969.htm

Ingram, J. (2011). A food systems approach to researching food security and its interactions with global environmental change. *Food Security*, *3*(4), 417–431. https://doi.org/10.1007/s12571-011-0149-9

Ingram, J. S. I., Gregory, P. J., & Izac, A.-M. . (2008). The role of agronomic research in climate change and food security policy. *Agriculture, Ecosystems & Environment*, *126*(1-2), 4–12. https://doi.org/10.1016/j.agee.2008.01.009

Intergovernmental Panel on Climate Change (IPCC). (2001). *Climate Change 2001: Impacts, Adaptation and Vulnerability. A Contribution of the Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change* (J. J. McCarthy, O. F. Canziani, N. A. Leary, D. J. Dokken, & K. S. White, Eds.). UK: Cambridge University Press.

IPCC. (2007). *Climate change 2007: impacts, adaptation and vulnerability: Contribution of Working Group II to the fourth assessment report of the Intergovernmental Panel on Climate Change* (M. L. Parry & Working Group II, Eds.). Cambridge, United Kingdom and New York, USA: Cambridge University Press.

Jäetzold R., Schmidt, H., Hornetz, B., & Shisanya, C. (2007). *Farm management handbook of Kenya Vol. 2 Natural conditions and farm management information B Central Kenya : (Rift Valley and central provinces)* (2nd ed., Vol. 2). Nairobi: Ministry of Agriculture and GTZ.

Kaguongo, W., Gildemacher, P. R., Demo, P., & Wagoire, W. W. (2007). *Farmer practices and adoption of improved potato varieties in Kenya and Uganda (No. Social Sciences working paper 2008-5)*. https://doi.org/http://dx.doi.org/10.13140/2.1.2155.7449

Karanja, A. M. (2013). *Analysis of rainfall variability on Irish Potato production in Ol jorok Division, Nyandarua County* (Unpublished Thesis). Kenyatta University.

Kenya Seed Company Limited. (2013). – Top Quality Seed. Zea Mays. Retrieved March 20, 2013, from Kenya Seed Company Limited website: http://www.kenyaseed.com/index.php?option=comcontent&view=article&id=243&Itemid=220

Kurukulasuriya, P., & Mendelsohn, R. O. (2007, August 1). Crop Selection: Adapting to Climage Change in Africa. Retrieved March 1, 2022, from papers.ssrn.com website: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1005546

Limo, W. K. (2013). *Factors influencing climate change adaptation among tea farmers in Chebut catchment area, Nandi central district, Kenya* (Unpublished MA Thesis). Univeristy of Nairobi.

Luers, A. L., & Moser, S. C. (2006). *Preparing for the Impacts of Climate Change in California: Advancing the Debate on Adaptation*. Sacramento: California Energy Commission, Public Interest Energy Research Program and the California Environmental Protection Agency.

Mburu, B. K. (2013). *Effects of Climate Variability and Change on dry-land agriculture and the adaptation strategies by small-scale farmers in Yatta District, Kenya* (Unpublished PhD Thesis). Kenyatta University.

Mendelsohn, R. (2010). Climate change impacts on agriculture. In *Handbook of agricultural economics. Agricultural Development*. Amsterdam: Elsevier.

Muraya, L. W. (2016). *The comprehensive secondary school Atlas for Kenya*. Nairobi: Longhorn Publishers.

Mutunga, E. J., Charles, K. N., & Patricia, M. (2017). *Smallholder Farmers Perceptions and Adaptations to Climate Change and Variability in Kitui County, Kenya*. Retrieved from http://repository.seku.ac.ke/handle/123456789/3447

Omwoyo, F., & Akivaga. (2005). *Comprehensive geography of form two students in Kenya*. Kampala, Uganda: Longhorn Publishers (U) Ltd.

Pachauri, R., Meyer, L., Hallegatte, S., Hegerl, G., Van Ypersele, J.-P., Brinkman, S., … Van Boxmeer, F. (2015). Climate Change 2014 Synthesis Report. In *Katharine J. Mach (USA)*. Retrieved from Gian-Kasper Plattner website: https://www.ipcc.ch/site/assets/uploads/2018/02/SYR_AR5_FINAL_full.pdf

Schroeder, C., Onyango, T. K., Nar, R. B., Jick, N. A., Parzies, H. K., & Gemenet, D. C. (2013). Potentials of hybrid maize varieties for small-holder farmers in Kenya: a review based on Swot analysis. *African Journal of Food, Agriculture, Nutrition and Development*, *13*(2), 7562–7586.

Selvaraju, R., & Baas, S. (2007). *Climate variability and change: adaptation to drought in Bangladesh : a resource book and training guide* (Asian Disaster Preparedness Center & Food And Agriculture Organization Of The United Nations, Eds.). Rome: Asian Disaster Preparedness Center, Food And Agriculture Organization Of The United Nations.

Seo, S. N., & Mendelsohn, R. O. (2007). Climate Change Adaptation in Africa: A Microeconomic Analysis of Livestock Choice. *World Bank Policy Research Working Paper*, *4277*. Retrieved from http://papers.ssrn.com/sol3/papers.cfm?abstract_id=999487

Slater, R., Peskett, L., Ludi, E., & Brown, D. (2007). Climate change, agricultural policy and poverty reduction: How much do we know. *Natural Resource Perspectives 109 Policy Conclusions*. Retrieved from https://sarpn.org/documents/d0002852/Climate_agriculture_poverty_ODI_Sept2007.pdf

WHO. (2018, February 19). Millennium Development Goals (MDGs). Retrieved from World Health Organization website: https://www.who.int/news-room/fact-sheets/detail/millennium-development-goals-(mdgs)