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EFFECTS OF CLIMATE VARIABILITY ON AGRICULTURAL PRODUCTION IN BUGESERA DISTRICT OF RWANDA: A CASE OF MAIZE

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ABSTRACT

The study aims to investigate the effects of climate variability on agricultural production in Bugesera District, Rwanda for a period of 2012 up 2022.The objectives of the study are to analyze the historical trends and patterns of temperature and rainfall variability in Bugesera District from 2012 to 2022, to analyze agricultural production fluctuation over the same period, and to determine the relationship between climate variability and agricultural production. The research used quantitative research design. It was quantitative, by focusing on collecting numerical data to answer research questions and establish statistical relationships between climate variability and agricultural production of maize in Bugesera District. The researcher analyzed historical trends and patterns of temperature and rainfall variability in Bugesera District from 2012 to 2022, as well as agricultural production fluctuations over the same period from different institutions databases. The findings of the study have important implications for policy makers and farmers in Bugesera District and other regions facing similar challenges. According to the findings presented in table 4.2, the regression analysis indicated a strong positive relationship between the predictors of the model, which are rainfall variability and temperature variability, and the dependent variable, which is agricultural production in Bugesera district, with a correlation coefficient (R) of 0.716. This means that the predictors have a correlation of 71.6% with the dependent variable. Additionally, the study found that the combination of rainfall variability and temperature variability together accounted for 51.2% (R^2 = 0.512) of the agricultural production in Bugesera district. Despite the availability of new agricultural technologies in the study sites, a reduction in maize yield was observed in the current study. The primary reason for the decline was linked to harsh weather conditions, particularly unpredictable rains and dry periods. The decrease in maize production resulted in food insecurity, which was characterized by inadequate quantities and poor quality of food, ultimately leading to malnutrition. In order to attain sustainable maize production and enhance food security, it is crucial to provide more support for adaptation and resilience strategies such as watershed management, utilization of drought-resistant and early-maturing maize varieties, establishment of community food reserves, formation of savings and credit groups, development of improved irrigation infrastructure, creation of diversified sources of income, and promotion of enhanced maize value chains.

Key Words: *Rainfall patterns, Temperature, Agricultural production, Bugesera District*

1. INTRODUCTION

The increase in greenhouse gas (GHG) concentrations in the atmosphere caused by human activities, such as carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O), has been linked to global climate change and variability, as stated by Fuller and David (2017. There is a probability of over 99% that land areas will experience warmer temperatures with fewer cold days and nights. It is highly likely that regions will experience more frequent heat waves, heavy precipitation events, drought, tropical cyclones, and extreme high sea levels. (Ayalew, Lalego, & Kaske, 2019) In developing countries, climate variability is potentially impacting economic activities rather than communities living in prosperous nations because poor countries economic activities are sensitive to climate and it is important to address this climate variability for long-term success of development assistance (Smith, et al., 2017).

The production of crops is likely to decrease in the long run due to rising temperatures, mainly because there will be fewer reliable days for growing crops.

The Intergovernmental Panel on Climate Change (IPCC) has projected a 5% reduction in maize yields by 2050 in Sub-Saharan Africa. Similar to other developing nations, agriculture in Rwanda is highly susceptible and vulnerable to the potential unfavorable effects of climate change. This sector is confronted with a range of risks and obstacles that could have significant consequences on agricultural stakeholders, investments, and supply chain development in Rwanda.

Additionally, changes in precipitation patterns are expected to cause short-term crop failures and long-term declines in production. (Adebanjo, Okogun, & Opiribo, 2021). Climate variability can indirectly lead to an increase in population and growth of pests, weeds, insects, and diseases, thereby complicating and increasing the cost of crop management. Therefore, crop production is negatively affected (Gbetibouo & Ringler, 2019). As a result of climate variability, countries like Rwanda that heavily rely on rain-fed agriculture are more likely to experience significant effects since variations in rainfall patterns have the potential to restrict crop production (Ngabitsinze, Mukashema, Ikirezi, & Niyitanga, 2011) Moreover, it is anticipated that more than 170 million individuals across the globe will encounter food insecurity by 2080 (Twecam, Wang, Xu, & Mohamed, 2022).

A study by Chen et al. (2018) found that climate variability has significant impacts on the rice production in China the most important crop in the country. The study found that changes in temperature and precipitation patterns have led to a decline in rice yields in many regions of China, and that this decline is likely to continue in the future. The study also found that farmers have adopted a variety of adaptation strategies, including changes in crop variety and crop management practices, but their effectiveness is limited by lack of resources and information.

In Africa, there exists a robust connection between climate change, agriculture, and food security, given that numerous African nations heavily depend on climate for their agricultural output. Climate change's impact on agricultural production in these countries creates a situation where there is insufficient food to cater to the population's needs. Consequently, most nations resort to trading to bridge the food deficit. However, when this gap is not closed, a country becomes food insecure (Africa, 2017).

In Kenya, a study by Mucheru and Karanja (2016) investigated the effects of climate variability on the rice production and marketing system in the central region of the country. They found that changes in precipitation patterns and temperature were affecting rice production and contributing to price volatility in the local market.

The impact of climate variability on maize production in Siha District, Tanzania was analyzed using descriptive and inferential statistics. The study examined future climate variability scenarios and found that temperature has significantly increased while rainfall has significantly reduced. This could shorten the length of the growing season and have significant impacts on the agro ecological zones (Nzaro, 2020). The year-to-year crop production in Rwanda is significantly influenced by the country's climate variability, which remains one of the crucial factors, even in high-tech agricultural regions (Mikova, Makupa, & Kayumba, 2015). Maize production has fluctuated to levels that have not been experienced for many years (RUTIBABARA, 2018). The agriculture sector uses 69% of the total population and contributes 26% of national GDP (MINAGRI, 2021).

MATERIALS AND METHODS

Research design

This research only used quantitative data in time series. Monthly rainfall and soil temperature (maximum and minimum) were considered for two agricultural seasons. (From September to January for agricultural

Season A and from February to May for agricultural season B). The season C was omitted because maize is only grown from September to June. To meet the objectives, researcher employed climate data (rainfall and temperature) versus production of maize over a period of 10 years in order to investigate the relationship between fluctuation of agricultural production and change in trends of climate variables (temperature and rainfall) in the sampled District.

Description of the study area

Bugesera District is one of the seven Districts that make up Rwanda's Eastern Province is the Bugesera District. It has a 1337 Km2 overall surface area. 72 Cells, 581 Villages, and 15 Administrative Sectors (Nyamata, Musenyi, Ntarama, Mwogo, Mayange, Juru, Rilima, Gashora, Ruhuha, Mareba, Ngeruka, Kamabuye, Nyarugenge, Rweru, and Shyara). It spans a surface area of 1337 km2 and is situated in the province's southwest. It is bounded by latitudes of 2o 09' south and 30o 05' east. The District is limitrophic with Rwamagana District of Eastern Province to its North-East, Nyarugenge and Kicukiro Districts of Kigali City to its North, Kamonyi District of Southern Province to its North- West, Ngoma District of Eastern Province to its East, Ruhango and Nyanza Districts southern province to its West, and finally the Republic of Burundi to its South where they are largely boundered with the Lake Rweru and Lake Cyohoha in the South.

The environment in Bugesera is dry compared to other regions of the nation, and the average annual temperature is between 20 and 30 °C. This area experiences temperatures that range from 26 to 29 °C on average. Long droughts plagued Bugesera in the prior years, turning it into a region that resembled the desert. However, the government increased its efforts and started an afforestation program, which greatly improved the District's climatic circumstances. (BUGESERA, 2013). Given that the months of January through May are expected to bring about sufficient rainfall and the months of June through September are usually dry, it is clear that the area is vulnerable to droughts. However, if an irrigation system is put in place, it would be possible to grow crops here all year long, successfully preventing both famine and poverty in the region. (RUTIBABARA, 2018). Below is the figure of Bugesera District.

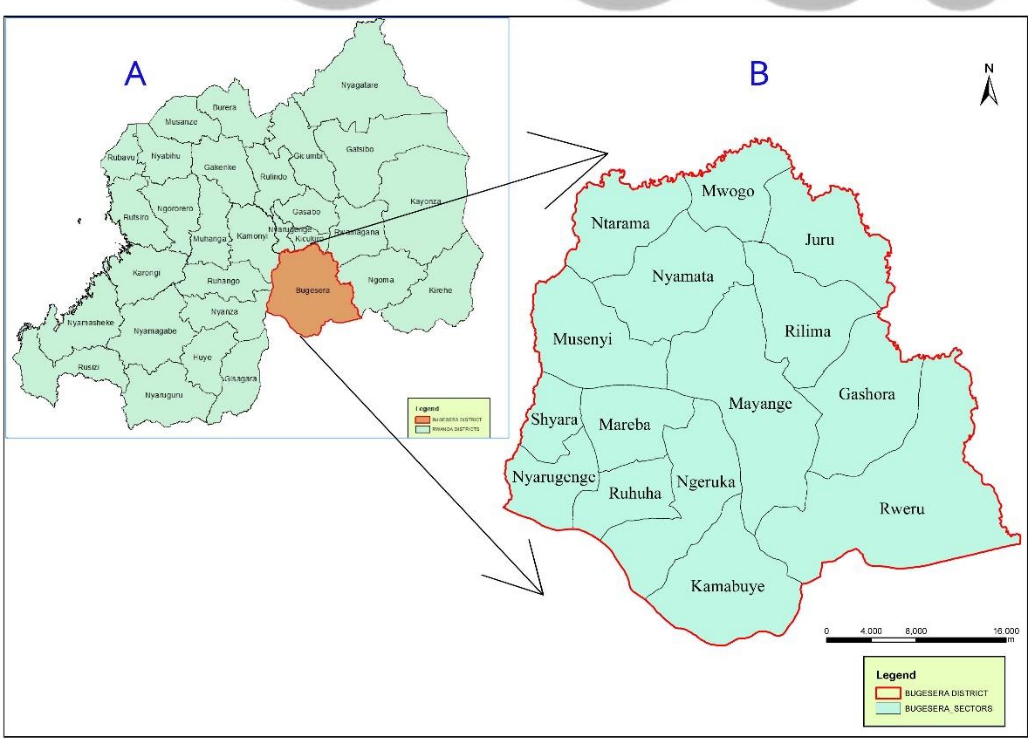

Figure 1: Location of study area

Data collection and analysis

This research relied on four categories of data. First, the review of the existing literature has contributed to the deep and specific understanding of the climate variability and related impacts in Bugesera district and all over the world. Second, climate data (mean, minimum and maximum daily temperature, as well as daily rainfall) was used to analyze the historical change of the climate in Bugesera district. Temperature and rainfall records was collected in the form of Excel sheet from the Rwanda Meteorological Centre.

Third, information on the agricultural production of maize in Bugesera District over a period of 10 years that means from 2012-2022; the researcher used Excel sheet form of seasonal agricultural survey (SAS) available on National Institute of Statistics of Rwanda (NISR) website. Finally, administrative shapefiles was used to delineate study area.

Statistical Package for the Social Sciences (SPSS) version 21 was used by the researcher in this study to process and analyze data, which influenced how the results, analysis, and interpretation were presented. The research topics was the main topic of the presentation. The type of statistical analysis is dependent on the nature of the issue, particularly the particulars and type of data collected. In this research, Spearman Test was used to analyze the relationship or correlation between climate variability and agricultural production.

A progression from basic linear regression is multiple regression. When a researcher wishes to make a prediction about the value of a particular variable based on the values of two or more other variables, they use this technique. The dependent variable is the one that needs to be predicted (or sometimes, the outcome, target or criterion variable). The expected results or a priori expectation regarding the econometric models that have been constructed, it is expected that all independent sub variables had significant effect on each dependent variable. This kind of effect is to positively check for each econometric model. Generally, there are significant and positive relationship between climate variability and agricultural production.

X = Factors of climate variability

Y = Agricultural production

Y = f(x)

Where,

X = (X1= Rainfall variability and $X_{2=}$ Temperature variability

Therefore the model used in the study took the form below :

$Y= \alpha+\beta_1X_1+ \beta_2X_2 +ȩ$

3. RESULTS AND DISCUSSIONS OF FINDINGS

The results were presented in accordance with specific goals, including an analysis of historical trends and patterns of temperature and rainfall variability in Rwanda's Bugesera District from 2012 to 2022, an analysis of variations in agricultural production from 2012 to 2022, and a relationship analysis between climate variability and agricultural production. Quantitative statisticians as well as charts and maps were used to ascertain the connection between the research's variables. Policymakers, farmers, and other stakeholders can understand the results because they are presented in a way that is pertinent to them.

Trends and patterns of temperature and rainfall

The section presents the result on the historical trends and patterns of temperature and rainfall variability in Bugesera District.

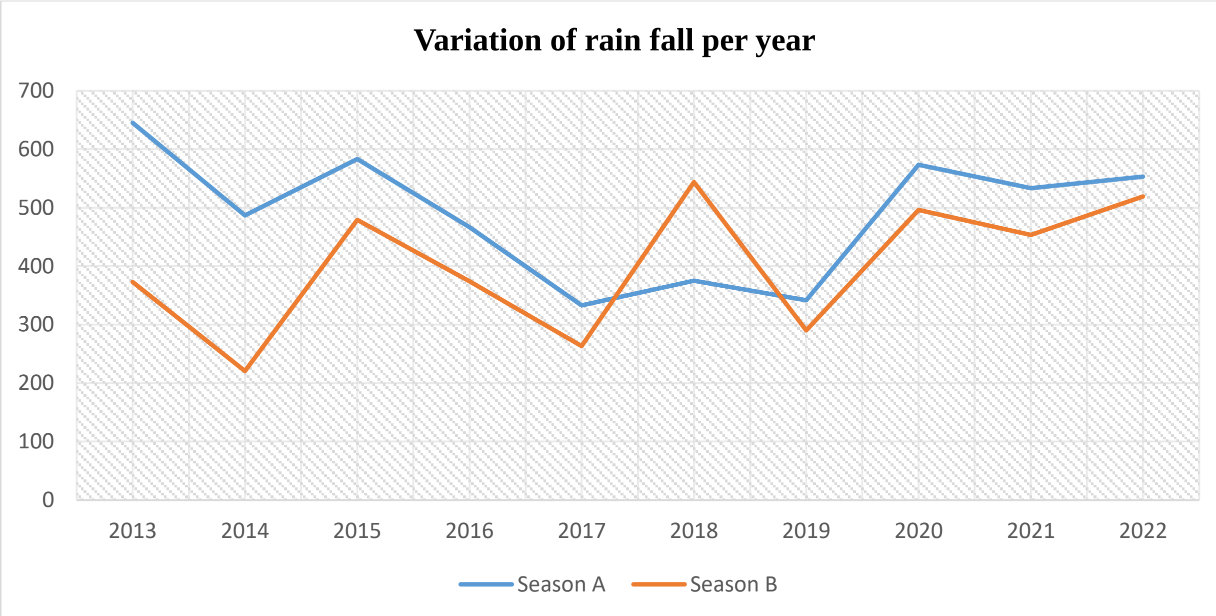

Figure 2: Variability of rain fall per year from 2012-2022
Source: Meteo Rwanda, 2012-2022

Results in figure 2 indicates that there has been variability of rain fall since to 2012 up to 20222. In this regard, the rainfall was presented in two seasons which are A and B seasons. A season which is shown by blue pattern, indicate that it is the time where Bugesera had too much rain measured in range between 332.78mm in 2017 which is the minimum and maximum was 645mm in 2013. However, when you look at the pattern it is clear that the rainfall reduced since 2013, and increased in 2019 and reduced again in 2020 up to 2022. For the season B, the rainfall indicated by orange pattern, from the graph, it is clear that the Bugesera has experienced a variation of rainfall ranging from 220.75mm in 2014 to 524mm in 2018.

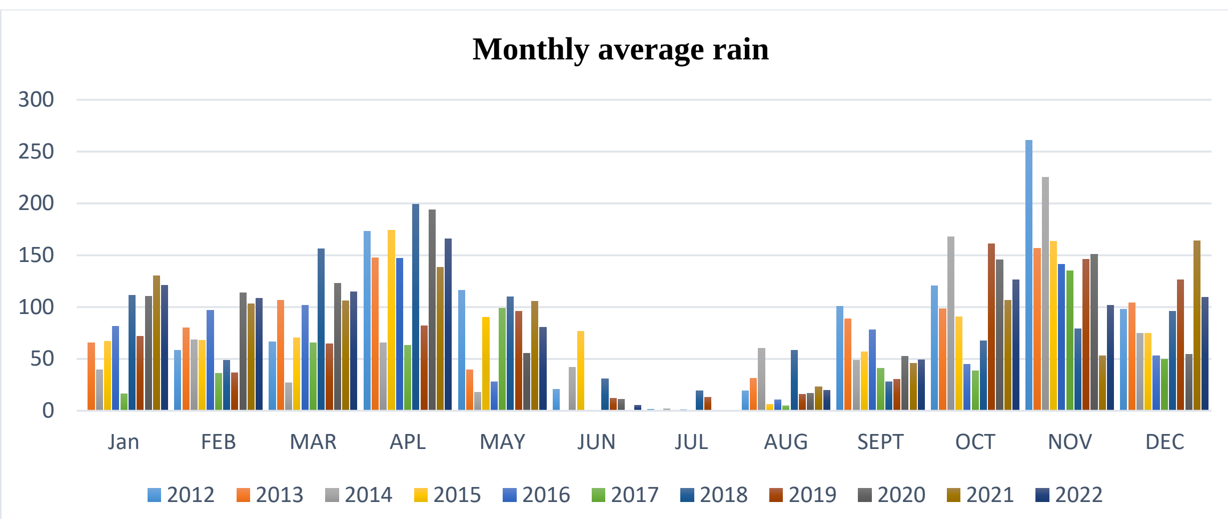

Figure 3: Monthly average rainfall from 2012-2022
Source: Meteo Rwanda, 2012-2022

The figure 3 indicated the pattern changes on monthly average of rainfall in Bugesera district, in 2012 the minimum average rainfall is in 1.25 in July 2012. The maximum rainfall monthly average is 216mm in 2012. Based on the patterns on rainfall it is clear that there a remarkable of monthly rain fall in Bugesera district and this affect the agriculture activities in this district. Selecting the ideal threshold level for the threshold technique of measuring rainfall is a challenge when dealing with data on rainfall. Less than 0.85 millimeters of precipitation were recorded, so it wasn't deemed to be a rainy day. To prevent any difficulties with the recording of extremely low values of rainfall data, we opt for a slightly higher threshold of 0.85 mm. It's also important to keep in mind that 0.85mm of precipitation is the actual cutoff point for a day being classified as rainy. The findings are consistent with Rugema (2019), who claimed that one of the major factors affecting farmers' agricultural output is the amount of rainfall. In rain-fed agriculture, the source of moisture and water intake for the crops is percolated rainfall in the roots. Rain fed agriculture is unreliable for farmers due to the unpredictable nature of rainfall, and as a result, its agricultural output is lower than that of irrigated areas.

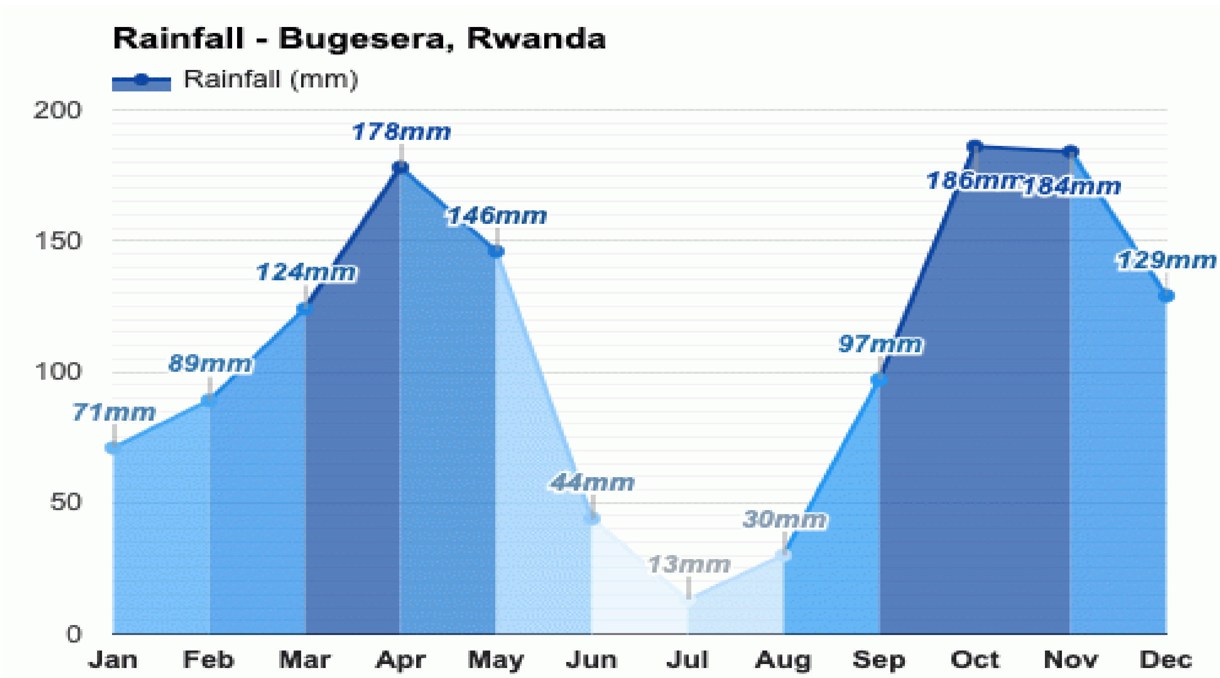

Figure 4: Average monthly rainfall in Bugesera
Source: Meteo Rwanda, 2012-2022

Figure 4 shows that the wettest month (with the greatest rainfall) is October and that the average monthly rainfall in March is 124 mm. (186mm). July is the coldest (lowest rainfall) month. (13mm).

Variability of temperature

Although temperature extremes and environmental variability are changing due to climate change, the dynamics and distributions of wild populations are still largely unaffected by changes in average circumstances. The frequency of extreme events, like marine heatwaves, as well as temperature variability are both shifting, however, along with the shift in normal temperatures. Since temperature affects a person's rate of metabolism, consumption, somatic growth, reproduction, and survival, temperature variations and extremes can have a significant impact on both people and populations.

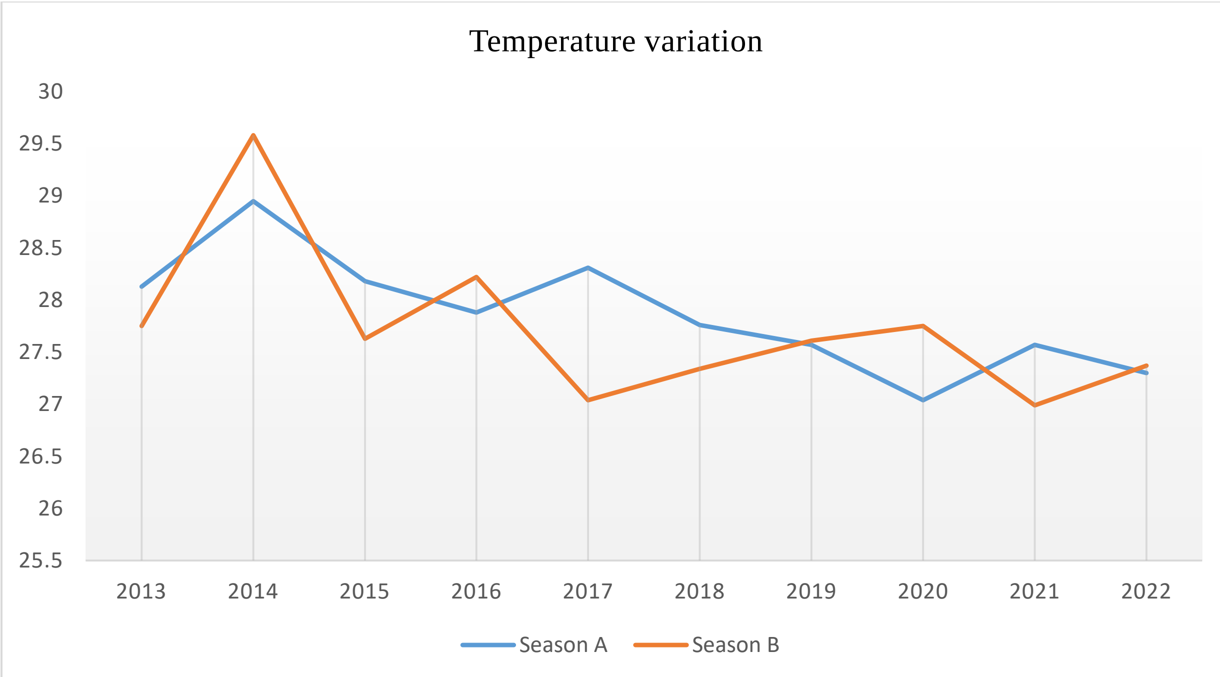

Figure 5: Temperature variation
Source: Meteo Rwanda, 2012-2022

Figure 5 indicates the variability of the temperature over period of 2012-2022 based on annual season basis.

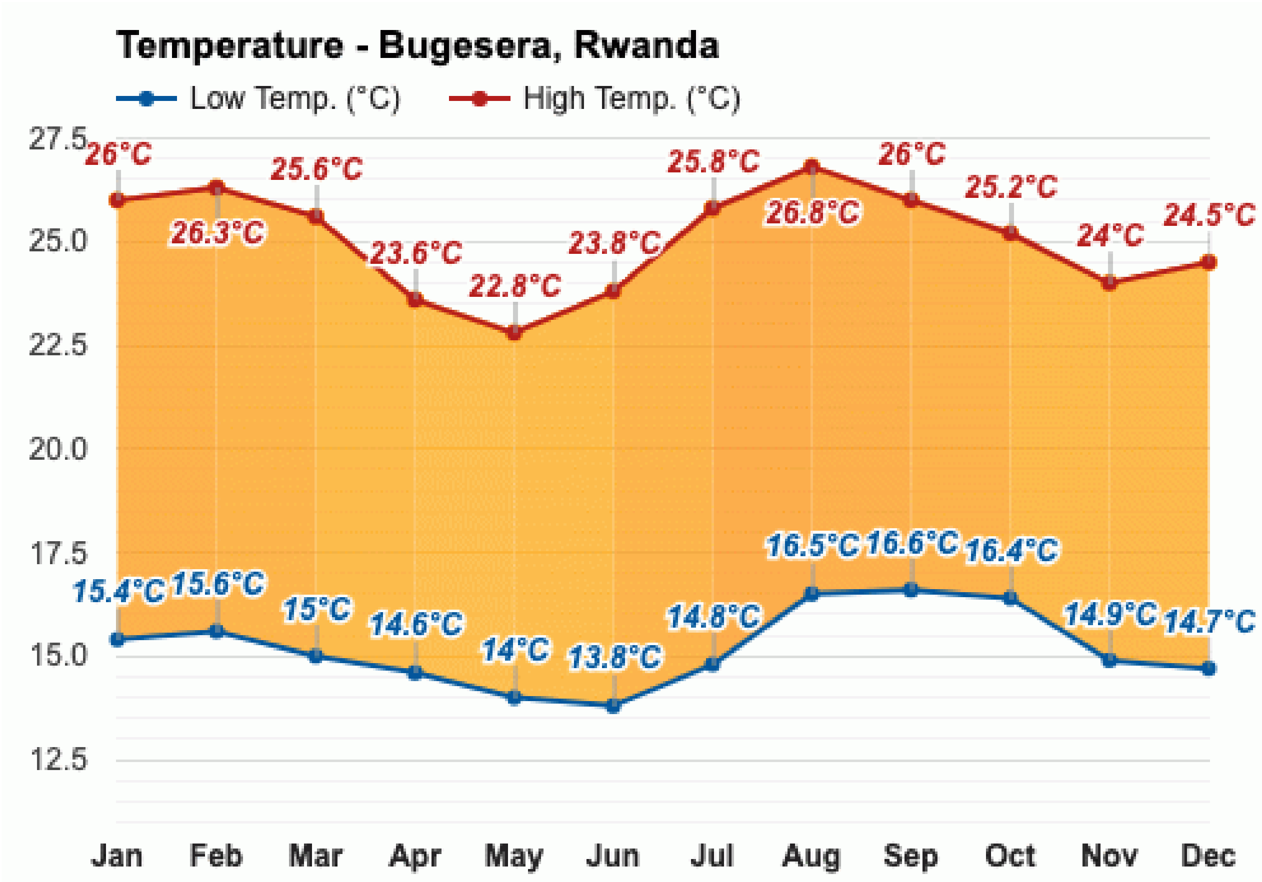

Figure 6: Average monthly temperature in Bugesera

According to figure 6, the maximum temperature on average for March is 25.6°C. August (26.8°C) is the warmest month (with the greatest average high temperature). May (22.8°C) has the lowest average maximum temperature of any month. The month with the greatest average low temperature is September (16.6°C), with the average low temperature in March being 15°C. June (13.8°C) is the coldest month (with the lowest average minimum temperature).

Maize production in Bugesera District

The section presents the findings on the maize production in Bugesera district based on the seasons of A and B. They were presented figure 7.

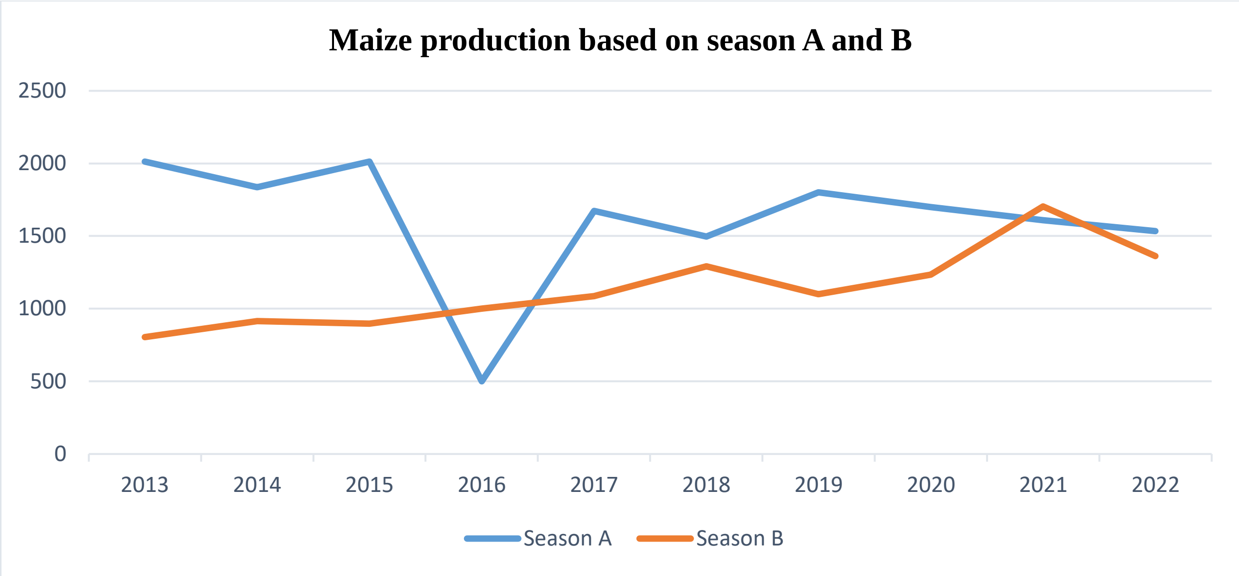

Figure 7: Trend of maize production in Bugesera district
Source of data: NISR (2012-2022)

The figure 7, indicated that in season A indicated by blue pattern, the maize production in Bugesera was 2012 Kg/Ha in 2013, in 2014 reduced to 1835.6 Kg/Ha, in 2015 the production increased to 2012.3 Kg/Ha, in 2016 the production declined to 500 Kg/Ha, in 2017 the production increased to 1,673 Kg/Ha, in 2018 the production of decreased again to 1,496 Kg/Ha, in 2019, the production increased a little bit to 1,801.4 Kg/Ha, in 2020 the production decreased again to 1,700 Kg/Ha, in 2021 the production decreased also 1,608.8 Kg/Ha and finally in 2022 the production reached to 1,533 Kg/Ha. In fact, the variation of Maize production had mixed slope but mostly there have been decrease of Maize production in Bugesera district over the period of 2013 up to 2022.

In relation to the season B indicated by orange pattern, the production of Maize in Bugesera was 805Kg/Ha in 2013, 915.3 Kg/Ha in 2014, 897 Kg/Ha in 2015, 1001Kg/Ha in 2016, 1,087Kg/Ha in 2017, 1,292 Kg/Ha in 2018, 1,100.14 Kg/Ha in 2019, 1,234 Kg/Ha in 2020, 1,704.3 Kg/Ha in 2021 and 1,363 Kg/Ha in 2022. By looking at the variation of Maize production in season B in Bugesera district, the figure indicates that there an increase slope over the period of 2013 up to 2022. However, the production in season B was less than the production in season A was bigger than production in season B.

Relationship between rainfall, temperature and maize production

According to Nabahungu & Visser (2021), an increase in dry spells during the rainy season causes crops to perform poorly and, as a result, agricultural output, as a result of the late start of rainfall and/or early cessation of rainfall. The part discusses the connection between the district of Bugesera's temperature, rainfall, and maize production.

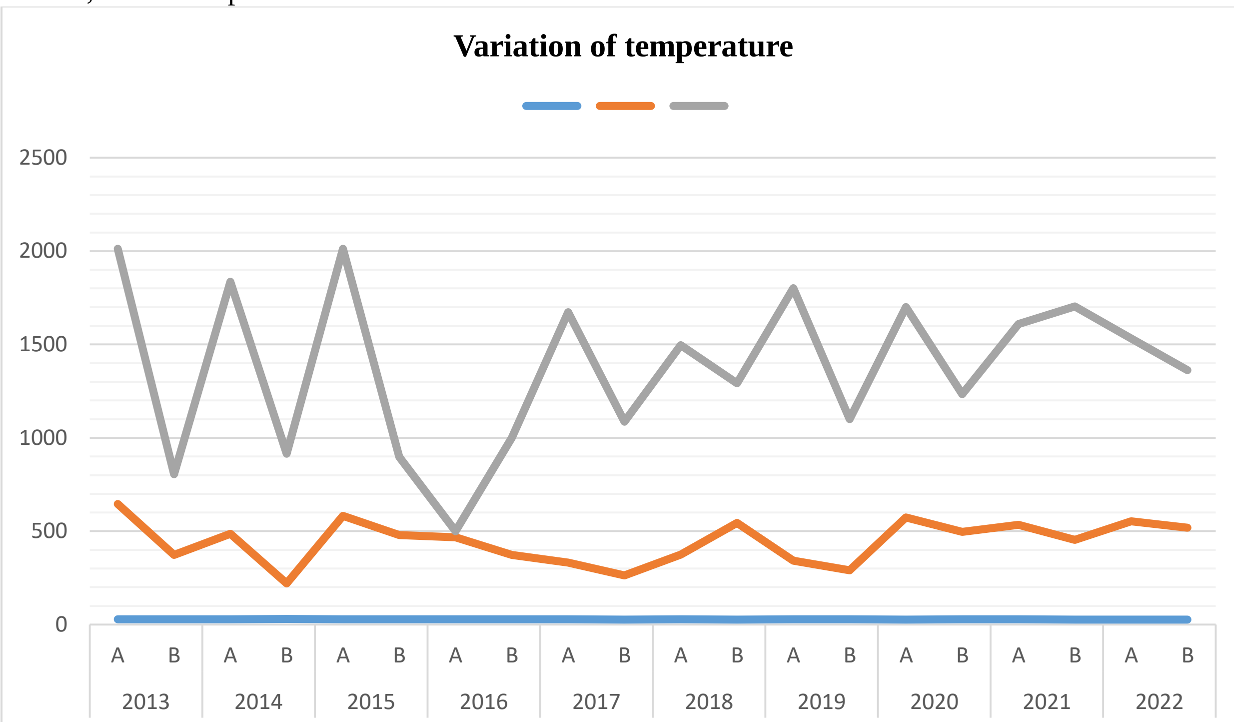

Figure 8: Variation of temperature, rainfall and production

Source: NISR and Meteo Rwanda (2012-2022)

By looking at the figure 8, it is clear that the variability of temperature, rainfall and production of maize in Bugesera is proportional to one another which show the relationship between the climate variability and agricultural production.

Regression analysis
In regression the researcher analyzed the coefficient of variables, model summary and ANOVA.

Table 1: Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	T	Sig.
1	(Constant)	.324	.863		.292	.774
	Rainfall variation	.415	.255	.212	1.844	.021
	Temperature variation	.316	.482	.237	0.655	.012

a. Dependent Variable: Agricultural production

Table 1, revealed that holding Rainfall variability, temperature variability to a constant zero, agricultural production would be 0.324. Indeed, this constant called y-intercept is not realistic but it is a needed parameter in the model. A unit increase in Rainfall variability, would lead to increase in Agricultural production by a factor of 0.212 which reject the first hypothesis of the research said that there is no significance relationship climate variability and agricultural production because the t test [t=1.844] was greater than p= 0.05. The $H_0$2 said that there is no significance effect of Temperature variability on agricultural production in Bugesera district was also rejected because the t test [t=0.655] was greater than p= 0.05 and in this research it has been revealed that a unit change in temperature variability, lead to change in Agricultural production by a factor of 0.237.

Table 2: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.716[a]	.512	.676	.16732

Source: Field data, 2023

a. Predictors: (Constant), Rainfall variability, temperature variability)

From the table 2; regression analysis revealed a positive relationship (R = 716). The R coefficient of 0.716 indicates that the predictors of the model which are rainfall variability and temperature variability, have a correlation of 71.6% with the dependent variable (Agricultural production in Bugesera district). The study also revealed that a combination of rainfall variability and temperature variability together contributed to 51.2 % (R^2= 0.512) of the Agricultural production in Bugesera district.

Table 3: ANOVA

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	.991	3	.248	10.747	.034[a]
	Residual	.369	5	.023		
	Total	1.360	9			

Source: Field data, 2023

a. Dependent Variable: Agricultural production

b. Predictors: (Constant), rainfall variability and temperature variability.

The Analysis of Variance means are displayed in table 3 in order to demonstrate whether there is a significant difference between the means of the variable and the one being studied as well as to assess the general significance of the model. In determining whether the model is fit to provide an accurate estimate of the variables, the overall significance of the model is crucial. ANOVA was used in this research to determine whether the independent and dependent variables had a significant relationship.

Table 3 demonstrates that the model can account for variations in agricultural production in the Bugesera district to the extent of 0.991 out of 1.360, or 72.8%, whereas other variables not included in this model can account for variations in agricultural production in the Bugesera district to the extent of 27.1% (0.369 out of 1.361). The model's F value yields a p-value of 0.015, which deviates considerably from zero. For data with a normally distributed distribution, a p-value of 0.015 is less than the predetermined threshold of significance of 0.05 (0.0150.05). In light of this, the model is important for illuminating the agricultural output in the Bugesera district.

Results discussions

Results in figure 3 indicates that there has been variability of rain fall since to 2012 up to 20222. In this regard, the rainfall was presented in two seasons which are A and B seasons. A season which is shown by blue pattern, indicate that it is the time where Bugesera had too much rain measured in range between 332.78mm in 2017 which is the minimum and maximum was 645mm in 2013. However, when you look at the pattern it is clear that the rainfall reduced since 2013, and increased in 2019 and reduced again in 2020 up to 2022. For the season B, the rainfall indicated by orange pattern, from the graph, it is clear that the Bugesera has experienced a variation of rainfall ranging from 220.75mm in 2014 to 524mm in 2018.

These extreme weather events lead to crop failure, soil erosion, and destruction of agricultural infrastructure. The effects of climate variability on crop production in Rwanda are further compounded by limited access to agricultural inputs such as improved seeds, fertilizers, and irrigation facilities. Smallholder farmers who form the majority of the population in Rwanda are particularly vulnerable to climate variability due to their reliance on rain-fed agriculture. As such, it is important to develop and implement adaptation and resilience strategies that take into account the effects of climate variability on crop production in Rwanda. These strategies should involve a multi-sectorial approach that involves farmers, government, civil society organizations, and the private sector (Ballantine et al. 2017).

The table 2; revealed a positive relationship (R =0. 716) between climate variability an agricultural production. The R coefficient of 0.716 indicates that the predictors of the model which are rainfall variability and temperature variability have a correlation of 71.6% with the dependent variable (Agricultural production in Bugesera district). The study also revealed that a combination of rainfall variability and temperature variability together contributed to 51.2% (R^2= 0.512) of the Agricultural production in Bugesera district.

The results of this study align with RAB's (2020) report that highlights a decline in crop productivity across different regions in Rwanda as a result of irregularities in weather patterns. Such irregularities are linked to extreme events that can directly and indirectly affect crop yield (Nahayo et al. 2017). This situation may worsen and lead to poor agricultural performance, resulting in food insecurity not only among local farmers but also in the entire country (Webber et al. 2022).

4. CONCLUSION AND RECOMMENDATIONS

4.1. Conclusion

The goal of this research was to investigate the impact of climate variability on agricultural production of maize in Bugesera District of Rwanda. The specific objectives were to analyze the historical trends and patterns of temperature and rainfall variability in Bugesera District of Rwanda from 2012 to 2022, to analyse agricultural production variation from 2012 to 2022 and to find out the relationship between climate variability and agriculture production.

The ANOVA tables proved better understandings of how the regression equation predicts the behaviors of the dependent against independent variables, and the model equation proved that the data are fit in the equation. The regression models predicted that the dependent variable was strongly significant as the data sample we have is fit. In the "sig." column, we find that the value of P is less than 0.005 that is P<0.005 (note that the value less than 0.005 is interpreted as 000 in the SPSS outputs).

According to the merged station satellite data, the mean temperature in Bugesera district has been steadily increasing from 2012 to 2022. Additionally, the same data revealed a decrease in the amount of annual rainfall in the area. The local maize farmers have also reported that the instabilities in rainfall and temperature patterns have resulted in a decline in maize yield. These variations in climate have affected the timing of planting, germination, and crop growth. High temperatures have also led to an increase in the proliferation of pests and diseases. Despite the use of advanced agriculture technologies in the study sites, there has been a decline in maize yield, primarily due to erratic rains and dry spells. This decline has resulted in food insecurity, characterized by poor quality and small quantity of food, leading to malnutrition.

4.2. Recommendations

While other factors like fertilizers, seeds, and pesticides play a significant role in achieving a good maize harvest, the stability of the seasonal climate is critical. To ensure sustainable maize production and improved food security, it is essential to provide support for adaptation and resilience strategies. These strategies may include managing watersheds, developing drought-resistant and early-maturing maize varieties, establishing community food reserves, forming savings and credit groups, improving irrigation infrastructure, diversifying sources of income, and enhancing the maize value chain.

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