# Assessing food crop vulnerability to fluctuating climatic trends in the Santa agro-basin of North West, Cameroon


## ABSTRACT

Santa Subdivision like many highland areas in Cameroon has enormous agricultural potentials. However, climate which plays a vital role in crop production process continues to threaten this agricultural strength through its variability. The study therefore aimed to assess climate variability and its impacts on food crop production in Santa Subdivision. This study used the mixed method. Rainfall and temperature data for a period of 40 years alongside food crop output data coupled with field observations and interviews were used to assess the link between climatic variations and food crop output in 4 communities. Results showed significant variations in climate with gradual decreasing rainfall trends of -3.7485x and increasing temperature trends of 0.0185x. Regression analysis test showed that there is a direct relationship between climate variability and food crop outputs. This study therefore recommended a series of policy measures and sustainable agricultural practices to help farmers cope with climate variability.



**Key words**: Climate variability, Food crop production, sustainable agricultural practices, Santa Subdivision.


**Comment [U1]:** The topic be rephrase to read :"Assessment of trends of food crop vulnerability to climatic fluctuations in the Santa agro-basin of North-west, Cameroon

**Comment [U2]:** Indicate the type of data used

**Comment [U3]:** Be specific on the kind of policy measures that will help farmers cope with climate vulnerability

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## 1. INTRODUCTION

Climate plays a very vital role in agriculture as it has direct impacts on the production process in different ways. According IPCC-AR5 (2014), the global climate is changing as a result of the combined anthropogenic forces which emit Greenhouse gases (GHGs) in to the earth's atmosphere. These changes in the world's climate are mostly seen in variations of the frequencies and intensities of climate events as well as the sea level alterations. Changes in the climate of a particular place can easily influence the agricultural output at any stage of agricultural production, from cultivation to harvest. Increase in temperatures for example, affects the soil moisture content as a result increase the rate of evapotranspiration. The intensity, amount, seasons and timing of rainfall is also greatly altered as a result of climate variability which could result to climatic extremes such as drought, frost, storms, soil moisture deficiency and erosion. As a result, recent variability in the climatic elements has posed a huge threat to food and agricultural sector worldwide. Given the location of Africa in the low-latitudes coupled with the fact that it is less developed, its vulnerability to climate change is greater, especially in sub-Saharan regions (IPCC, 2007), as a result of their over dependence on the environment especially agriculture, coupled with other factors like over reliance on rain-fed agriculture, poverty and low adaptive capacity. Ericksen *et al*. (2011), described Africa as climate change "hotspot" as a result of the projected impacts of changing climate, given that the coping capacity is hindered by poverty in this part of the world.

In Cameroon, about 70% of the active population is engaged in agricultural activities and contributes to about 80% of the country's GDP (NIS, 2010). Although Santa subdivision one of the areas in Cameroon that is more engaged in agriculture, this area is also seen to be one of the most vulnerable areas to climate variability because of high reliance on rain-fed agriculture. As a result, there has been a significant drop in crop yield in Santa subdivision due to climate variability (Fogwe and Bonglam, 2016). This is therefore a threat to the general food security of the country. This study therefore aims to investigate the degree to which the climatic conditions (rainfall and temperature) have varied and how climate variability have impacted food crop production in Santa Subdivision.

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Santa Sub Division is located in the South of Mezam division in the North West region of Cameroon. It lies between latitude $5^0$ 42' and $5^0$ 56' North of the equator and between longitude

$9^0$ 58’ and $10^0$ 18’ East of the Greenwich Meridian (Figure 1), with a total surface area of about 534 square kilometres.

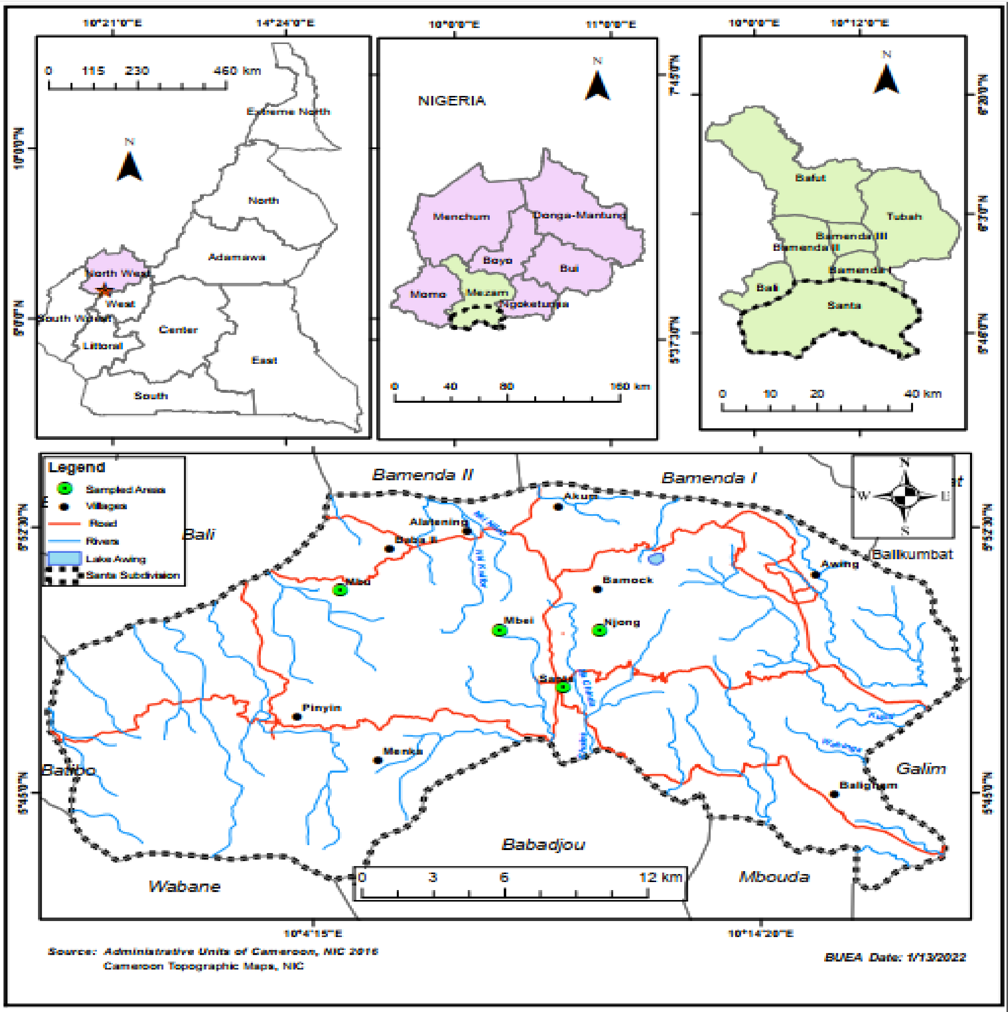


**Figure 1: Map of the study area**
**Source: Administrative Units of Cameroon, NIC (2016)**

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The climate of this region is the Equatorial Mountain type, with two distinct seasons; The rainy season starts from the month of March to mid-October, while the dry season takes place between the end of October to mid-March. The mean annual temperature of the area ranges from $21.8^0$C to $30.8^0$C with an average of about $18.5^0$C (Santa Agricultural post-SAP, 2013). The vegetation of this region is the montane forest vegetation, classified in to three sub types; the montane forest, sub montane forest, which has been degraded and domesticated sub montane landscape (Fogwe and Bonglam, 2016). This area has three types of soil. Santa, Njong and Baligham have the penevolated ferralitic soil type; the highlands of Akum, Awing, Mbu and Baba have the modified orthic soil type and the intermediate relief areas of Mbei and Pinyin have aliatic and penevolated ferralitic red soil type (Magha, 2003). This area is characterised by dendritic hydrological patterns. It has a hilly and mountainous topography (>2000m) with steep slopes and U-shaped valleys (Morin, 1998) and it lies along the Cameroon Volcanic Line. The total population of Santa Sub Division was 77,406 inhabitants in 2005 (Population census, 2005) and was estimated to be 99,851 inhabitants in 2008 (Fogwe, 2014), with about 80% currently engaged in agriculture (Santa Council-2011).

## 2. Literature Review

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### Climate variability and casual factors

Many studies have shown that the rate at which the global temperatures have been rising over the last century has increased. According to United Nations Framework Convention on Climate Change (UNFCCC, 2007), even though several GHGs such as methane and nitrous oxide are recognized as major greenhouse gases in the atmosphere, it is convincingly argued that Carbon dioxide is one of the most anthropogenic produced GHG, that causes the warming of the atmosphere. The IPCC-AR5 (2014) report on mitigation of climate change identified that climate trends indicate that the global average surface temperatures have been increasing since the mid-19th century with greater rates observed since the mid-1970s. IPCC (2007) projected that, countries are expected to experience an increase in average temperature overall by 1°C by 2030 and by 1.4°C by 2050. Similarly, Jidauna *et al*. (2011) carried out a research on the effect of climate change on agricultural activities in selected settlements in the Sudano-Sahelian region of Nigeria. The results showed that the duration and quantity of rainfall pattern that was experienced in Nigeria decreased by 78.6% while the rainfall intensity experienced in the rainy season decreased as well by 77.3% over the years with an increase in temperature conditions.

Another similar research carried out by Lawrence (2015), on the effects of climate variability on tomato crop production showed an increase in the maximum and minimum temperature coupled with unreliable rainfall distribution in the Offinso North District of Ashanti region. A study carried out by Cinco *et al.* (2014) on long-term trend and extremes in observed daily precipitation and near surface air temperature in Philippines showed that there has been an

Comment [U9]: NOT CITED IN THE REFERENCE increase in extreme events and an overall increasing temperature trend with positive values since 1977 and 1998 being the peak year with a +1.0 °C anomaly. This study used linear trend analysis to analyse the annual mean temperature, daily minimum mean temperature and daily maximum mean temperature. The study showed an increase in both the frequency and intensity of extreme rainfall events in the majority of the weather stations in Philippine.

**Impacts of climate variability on crop production**

According to IPCC report of 2014, changing climate and extreme climatic events have posed great threats to agricultural production, food security, community health, natural resources, biodiversity and water availability. This report showed that, agriculture in African countries is projected to be significantly impacted by climate change and it is expected to cause about 50% yield loss by the year 2020. As a result of increasing climate variability, farmers will experience regular crop failure and there will be a shift from farming to herding/livestock rearing as well as decrease investments in the overall agriculture and livestock herders will also experience losses (IPCC, 2014; FAO, 2011). IPCC (2014) Projections showed that a general increase in the average temperatures for Africa are predicted to result in increased rainfall variability and incidence of extreme weather condition, which will negatively affect crop production.

Amawa *et al*. (2015) carried out research on the implications of climate variability on market gardening crop production in Santa Sub-division of Cameroon. Using Pearson's Product-Moment Correlation Coefficient, they established a relationship between climate variability and market gardening which showed that, both direct and inverse relationships between these two variables resulted in differential implications for market gardeners. Their results showed that rainfall has critical effect on market gardening yields while temperature has no significant effect on these yields.

Eisenack and Stecker (2011) adopted the Action Theory of Adaptation (ATA) in order to give an explanation on how to undertake effective adaptive measures to sustain agricultural production in response to climate variability and change impacts. Thus, actions are taken in the form of strategies of adaptation in order to response and cope with the impacts of climate variability. The ATA consist of four major concepts which are, Stimuli (actual or potential), Exposure unit, Operator and Receptor. Eisenack and Stecker (2011) pointed out that, stimulus refers to a change of biophysical (such as meteorological) variables which drives climate change; Exposure unit refers to all social and/or non-human systems that depend on climatic conditions and are therefore exposed to the stimuli; Operators are a collection of actors, individuals or institutions that have the power, knowledge and means to exercise or initiate the response or adaptation strategies while receptors are the actors or systems that are seen as targets or purpose of an adaptation. Thus, operators and receptors initiate actions needed to adapt to climate variability (stimulus) and change impacts (exposure unit).

## 3. Methodology



This study made use of the mixed methods approach that is both quantitative and qualitative methods. The research techniques used by this study were: Observations and inquiries, survey studies wherein, interviews were used to collect data. Data collection instruments composed of interview guides that helped to collect qualitative data from the farmers and authorities through individual interviews; A pen, a pencil and a book were also used to jot down the responses from those who were interviewed and a sound recorder was also used to record the responses of the respondents, with their permission; and Global Positioning System (GPS) was used to snap 3 dimensional pictures of the crops that are affected by climate variability. Farmers were the main unit of analysis. Also, the views and ideas of the Sub Divisional Delegation of Agriculture personnel, members of the community council, and the local authorities, were considered. Both male and female farmers involved in food crop cultivation and market gardening were selected for interviews. A purpose sampling technique was also used in order to select the heads of institutions and farmers to be interviewed. 10 farmers, both male and female were interviewed on the effects they have been experiencing on their crops as a result of climate variability for an average of 18 minutes each. Interviews were also conducted with the 2 personnel at the Subdivisional Delegation of Agriculture, 2 council authorities and 1 personnel from the Northwest Development Authority-Trial and Demonstration Center (MIDENO-TDC). The interviews at the council lasted for 20 minutes each while the interviews at the delegation lasted for 45 minutes each.

The primary data was collected through field observations and interviews of personnel from the Santa Subdivisional Delegation of Agriculture and Rural Development, Santa Community Council and a few farmers who have lived in the community for at least 35 years. Meanwhile the secondary data was collected by reviewing existing literature from documented sources. These secondary data sources included climatic data from National Aeronautics and Space Administration (NASA), existing literature from textbooks, journals, articles, the internet, TV/Radio news, other researchers and Sub-divisional delegation. Temperature and rainfall data of Santa was accessed from NASA. The climatic data provided by NASA were very adequate and were good to analyse the degree of rainfall and temperature variability.

This study collected information on the effects of climate variability on crop production and output through field observations of the study area, interviews and agricultural archives from the Sub Divisional Delegation of Agriculture. Data collected were analysed using IBM Statistical Package for Social Science (SPSS) 26 and Excel 2010. The data collected from the field were analyzed both quantitatively and qualitatively. Both descriptive and inferential statistics data analysis methods were used to analyse the data collected from the field. Descriptive statistics encircled the frequencies table, graphs, and maps. Inferential statistics analysis such as Pearson's correlation test, correlation analysis, coefficient of variation, mean deviation, climate anomalies and regression analysis.

Temperature and rainfall variability data were analysed using mostly inferential statistical analysis. A time series analysis was done where linear regression analysis was used to analyze climate variability trends. Temperature and precipitation ranges were analysed using coefficient of variation this is because it gave the annual averages of temperature and precipitation and their variability. Climate anomaly was used to analyse both temperature and rainfall anomalies. Also, the Pearson's Correlation Test was used to analyse the relationship between rainfall, temperature and time. Correlation analysis was used to analyse the impacts of climatic variables on crop production and factor analysis was used to evaluate the most influencing climatic variable, between temperature and rainfall so as to know which one to focus on more when putting in place coping mechanisms. In addition, regression analysis was used to show the relationship between climate variability (temperature and rainfall variability) and food crop outputs. With a probability value of 0.05, the value of 0.05 or <0.05 was considered significant while a value of >0.05 was considered insignificant.

**Comment [U12]:** Sub heading: Method of data analysis

- **Analysis of Coefficient of Variation (CV) for climatic variables**

CV is the ratio of the standard deviation to the mean. This was used to calculate the variability of rainfall in Santa Subdivision using the mean rainfall and standard Deviation.

$$Coefficient\ of\ variation = \frac{\sigma \times 100}{\bar{y}}$$

Where;

$\bar{Y}$= mean and σ= Standard deviation

- **Regression Analysis**

Simple linear regression is a model that assesses the relationship between a dependent variable and one independent variable. The simple linear model is expressed using the following equation:

Y= a + bx

Where **Y** is the dependent variable (that is the variable that goes on the **Y** axis), **X** is the independent variable (that is plotted on the X axis), **b** is the slope of the line and **a** is the intercept.

The linear regression was used in this trend analysis which describes X *trend (i)* by means of two parameters, namely the intercept, βo, and the slope, β1. The model is given by

$$Y_i = f(Xi, \beta) + e_i$$

Where $Y_i$= dependent variable, $f$= function, Xi= independent variable,

β=unknown parameters and $e_i$= error terms.

- **Pearson's Correlation**

The Pearson's or product moment correlation is a measure of the linear correlation between two variables X and Y.

- **Climate Anomaly**

This refers to the deviation of the climate parameter from the average score/mean. In this study, it is gotten by the formula:

O-X

O = observed climate variable

X = average climate variable

The qualitative data analysis technique that was used to analyze the qualitative data collected from the field was the Dey's three-step approach (1993). This approach consists of three descriptive processes which are; transcription, classification and interconnecting. The transcription is converting data acquired from interviews in to a text. Classification is a process whereby the converted data was related to their respective major themes. Lastly, interconnecting involves linking the themes to the objectives of the study.

## 4. Results/Findings

**Comment [U13]:** RESULT AND DISCUSSION

### Climate variability in Santa Subdivision: Rainfall Variability and Trends

**Monthly rainfall variability**

The climate of Santa subdivision is characterized by two distinct seasons; the rainy season and the dry season. The rainy season is marked by a period of down pours while the dry season is marked by a period of little or no rainfall across the study area. Generally, the rainy season in the Santa begins in March and ends in October while the dry season takes place during the other remaining months (from November to February). The trends of climatic parameters under consideration is shown by monthly rainfall variability, the CV, anomalies and trend analysis (Figure 2 and 3).

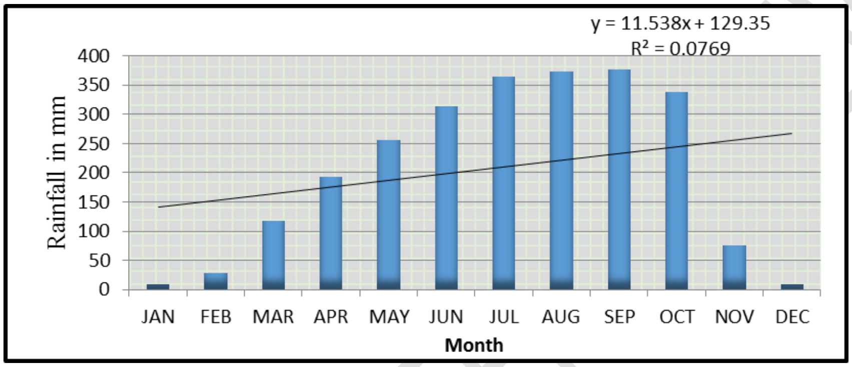



**Figure 2. Mean monthly Rainfall Variability**
**Source: Plotted with data from NASA Database (2022)**

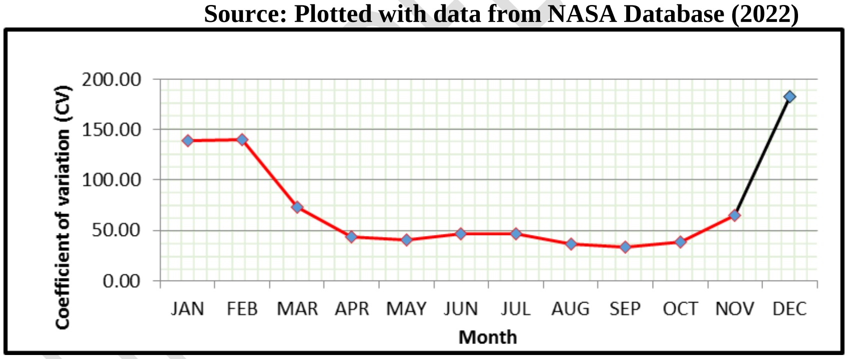



**Figure 3. Changes in monthly CVs in Santa**
**Source: Plotted with data from NASA Database (2022)**

Figure 2 and 3 show the mean monthly rainfall variability and monthly CVs in Santa respectively over a period of 40years. The average monthly rainfall was seen to be 204.33mm and fluctuations occurs below and above the mean monthly rainfall (Figure 2). The figure shows that, the rainfall amounts began to rise although with lighter rains from the month of March (117mm) and April (192mm), wuth August (373mm) and September (376mm) the months with the highest mean and the lowest CVs of 36% and 33% respectively. This could have the potentials to affect farmers who planted crops that needed rains after planting. The rainfall started dropping around October (339mm) right to February with a greatest drop in December and January indicating the peak of the dry season with low rainfall amounts of 9mm and the highest CV (182%) recorded in December (Figure 3). These changes in monthly CVs imply that most of the months that rainfall was reliable are mostly months that make up the rainy season. While the high dry season monthly CVs imply that rainfall was not reliable during this season over the past 40 years across the Subdivision. These disparities in rainfall inputs leads to crop output fluctuations in both the dry season and the rainy season across the various years from 1981 to 2020.

**Seasonal Rainfall variability**

Seasonal variability of rainfall across the study area is shown by variability in rainfall amounts and anomalies during the dry season as well as during the rainy season. Given that this seasonal variation is characterized by variations in the dry and the rainy season, the dry with little or no rainfall recoded low amounts of rainfall while the rainy season recorded very high amounts of rainfall which as well vary from 1981 to 2020 (Table 1 and Table 2).

**Table 1. Summary of dry season rainfall**

| Rainfall Parameter | Values (mm) |
|---|---|
| Average | 121.88 |
| Max | 340 |
| Min | 21.99 |
| St. Dev. | 72.78 |
| CV | 59.72% |

**Source: Calculated from NASA-base Data (2022)**

**Table 2. Summary of rainy season rainfall**

| Rainfall Parameter | Values (mm) |
|---|---|
| Average | 2330.32 |
| Max | 4034.32 |
| Min | 1409.78 |
| St. Dev. | 696 |
| CV | 29.87% |

**Source: Calculated from NASA-base Data (2022)**

The average seasonal rainfall during the dry season from 1981 to 2020 across the study area was 121.88mm (Table 1). The maximum dry seasonal rainfall during the study period was 340mm while the minimum amount of dry seasonal rainfall was 21.99mm. With standard deviation of 72.78mm and a CV of 59.72 %, there was high variability in the rainfall conditions across the study are during the dry season. Meanwhile the highest rainy season rainfall was 4034.32mm and the lowest was 1409.78mm (Table 2). The average rainy season rainfall over the past 40 years was calculated at 2330.32mm and the Standard deviation stood at 696mm. A CV of 29.87%

shows a variability in the rainy season rainfall patterns in the study area with fluctuations. Although the rainy season CV shows variability in rainfall patterns in the study area, this variability is less compared to the dry season with a higher CV of 59.72%. this shows that rainfall is more reliable during the rainy season than the dry season. Thus, indicating high soil moisture which favours food crop production during the rainy seasons as compared to the dry season. Rainfall deviations from the mean rainfall in the dry and rainy seasons show significant variations in rainfall from 1981 to 2020 across the study area (Figure 4 and Figure 5).

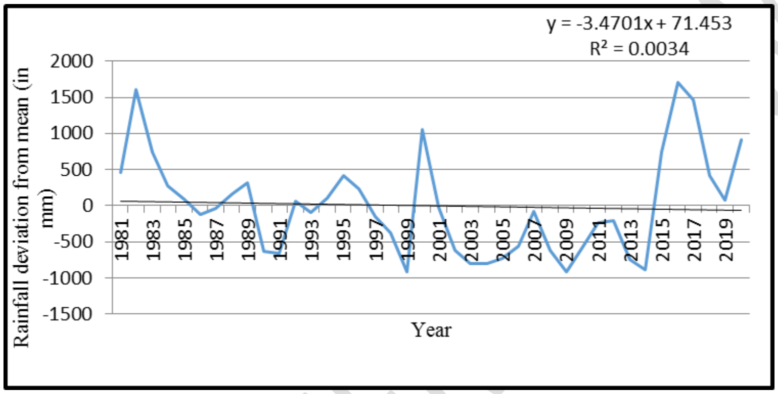



**Figure 4: Dry season rainfall anomaly**
**Source: Plotted with data from NASA Database (2022)**

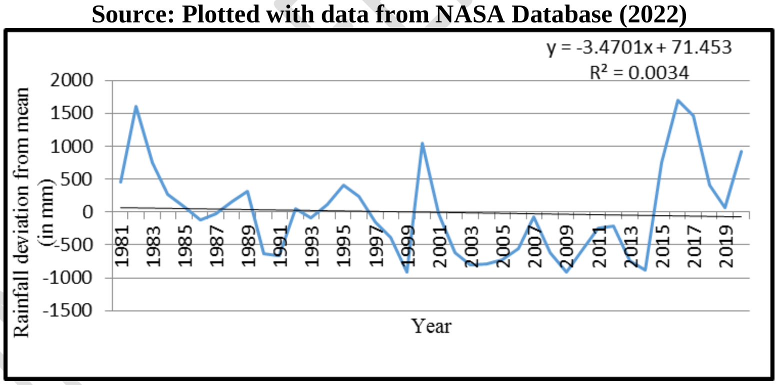



**Figure 5: Rainy Season Rainfall Anomaly**
**Source: Plotted with data from NASA Database (2022)**

The figures show that some years recorded positive anomalies while others recorded negative rainfall anomalies during both the dry and the rainy seasons. Rainfall positive anomalies of +3 and +2 were recorded in years like 2016 during the dry and the rainy season respectively. On the other hand, the negative anomalies of dry season rainfall were recorded in years such as 1999 with anomalies of -950mm and the negative rainy season rainfall anomalies (-1) were recorded in years like 2014 and 2013. While 1986, 1993, 2007, 1992 and 1985 were years with normal rainfall amounts during the rainy season. Negative rainfall anomalies during the dry season recorded a frequency of 70% against 30% for the positive dry season rainfall anomalies. This explains the declining trends of dry season rainfall in the Subdivision. Thus, farmers who cultivate during this season cultivate around watersheds and practise irrigation. The degree of variation of the rainy season rainfall ($R^2$=0.0034) is less than 1%. A general decreasing trend anomaly (-3.4701x) indicates a decrease in rainfall in the Subdivision. The implication of these anomalies is that the decrease in rainy season rainfall in the study area had the potentials to affect food crop production during this season especially for farmers who highly depended on rainfall for agriculture as they would have poor crop yields.

**Annual rainfall variability**

The manifestation of rainfall variability over the past years in Santa is seen as some years recorded higher annual rainfall amounts while others recorded lesser amounts of annual rainfall. Annual rainfall variability in the study area is seen as some years recorded extremely high amounts of rainfall above the average (2452.19mm), while others recorded very low rainfall amounts as shown in Figure 6.

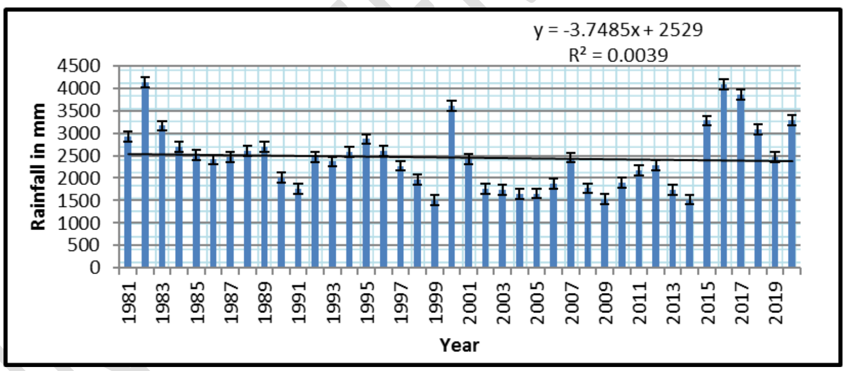



**Figure 6: Inter Annual Rainfall Variability for Santa**
**Source: Plotted with data from NASA Database (2022)**

Annual rainfall variability in the study area is seen as some years recorded extremely high amounts of rainfall above the average rainfall (2452.19mm), while others recorded very low amounts of rainfall below the average for four decades. From 1981 to 2020, the highest annual rainfall mean was 4127.27mm (1982). The years with extreme amounts of rainfall were 1982, 2016, 2017, 2000 and 2020 with annual rainfall records of 4127.27mm, 4076.78mm, 3855.98mm, 3607.52mm and 3285.29mm respectively. These years were characterised by heavy rainfall which led to an increase in the soil moisture. This favoured the growth of some food crops and hindered the growth of other which do not need so much water. On the other hand, the lowest annual rainfall amount was 1504.89mm (1999) being the driest year. Generally, there have been a decrease in rainfall amount over the past 40 years (1981-2020). This is evident by the depressing trend (-3.7485) over the past 40 years. Depending on planting season, this inter-annual rainfall variability affects crop production in different ways throughout the production period as some crop require more moisture than others. This also causes pest and diseases as well as crop withering during as a result of water stress, most especially for non-drought resistant crops like most market gardening crops, thus leading to low crop yield. Some years recorded negative anomalies of -1 while others recorded positive anomalies of +2 and +1 (Figure 7).

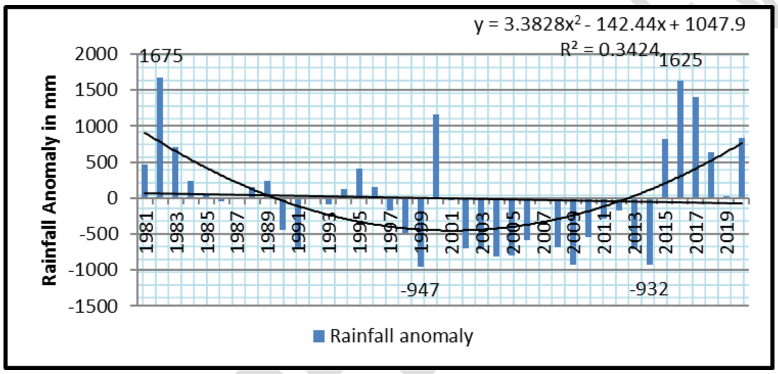



**Figure 7: Inter-annual rainfall anomalies for Santa**
**Source: Plotted with data from NASA Database (2022)**

There has been a significant variation in rainfall over the period of study (past 40 years) as some years registered higher annual rainfall amounts while others registered low annual rainfall amounts from the mean. Positive anomalies are recorded in years like 2016, 1982 and 2017 as well as 2000, 2015 and 2020 with +2 and +1 annual rainfall anomalies respectively. These positive values indicated years with extremely wet climatic conditions. Meanwhile, years like 1999, 2014, 2009 and 2004 registered negative anomalies with -1 annual rainfall anomalies. These negative values indicated years with water stresses as a result of rainfall decrease. These variations in rainfall accounts for several effects on agriculture in general and food crop productivity in particular.

**Decadal Rainfall variability**

Rainfall conditions in Santa shows significant variations in rainfall amounts over the last four decades across the study area (Table 3).

**Table 3: Decadal rainfall variability**

| Decade & Parameters | Value (mm/%) |
|---|---|
| 1981-1990 average | 2759.24 |
| 1991-2000 average | 2399.60 |
| 2001-2010 average | 1874.07 |
| 2011-2020 average | 2775.87 |
| **Max** | 2775.87 |
| **Min** | 1874.07 |
| **St. Dev.** | 366.08 |
| **CV** | 14.93% |

**Source: Calculated from NASA-base Data (2022)**

Table 3 shows that the average amount of rainfall for the last four decades is 2452.19mm and the Standard deviation of 366.08mm with the maximum rainfall of 2775.87mm and minimum rainfall of 1874.07mm. The first and fourth decades recorded higher rainfall amounts of 2759.24mm and 2775.87mm as compared to the second decade and the third decades (2399.60mm and 1874.07mm respectively). The CV is 14.93% implies that there is a substantial fluctuation in the pattern of rainfall over the four decades under study. This therefore means that the rainfall has not been liable all over the four decades. With this, different decades witnessed different manifestation of rainfall that either favour or hinders food crop production in the study area.

**Annual Temperature Variability**

Temperature variability is one of the determinants of the rate of crop growth from germination to maturity. Food crop production in Santa is alarming because this area has a mild temperature that favours the cultivation of these crops. Over the past years, there has been fluctuations in this temperature. Temperature oscillations are seen in years with high temperature values and low temperature values (Figure 8).

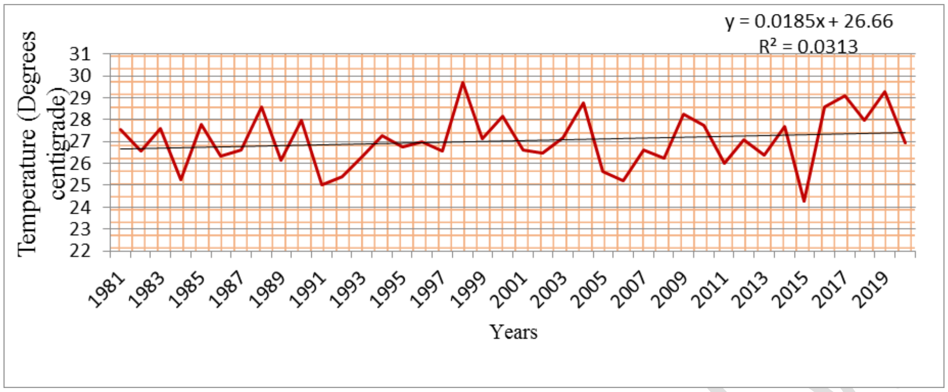



**Figure 8: Average Annual Temperature Variations within the Study Area**
**Source: Plotted with data from NASA Database (2022)**

As shown in Figure 8, the annual temperature variations from 1981-2020 were very significant as the average temperature recorded by hottest years was $29^0$C (1998, 2019, 2017). However, other years such as 2015 recorded relatively low average annual temperatures of $24^0$C. Despite these high and low average annual temperatures recorded by some years, most years were average years with average annual temperatures of $26^0$C. The general annual temperature trend here is rising as indicated by the trend line (0.0185x). This means that there is a general increase in the annual average temperature which has posed effects on crop production in the study area which indicated low crop yields due heat stress and increases in evapotranspiration. Annual temperature anomalies also shows there were some years such as 1998 and 2019 that recorded positive anomalies of +2 while others such as 2015 recorded negative anomalies of -2 (Figure 9).

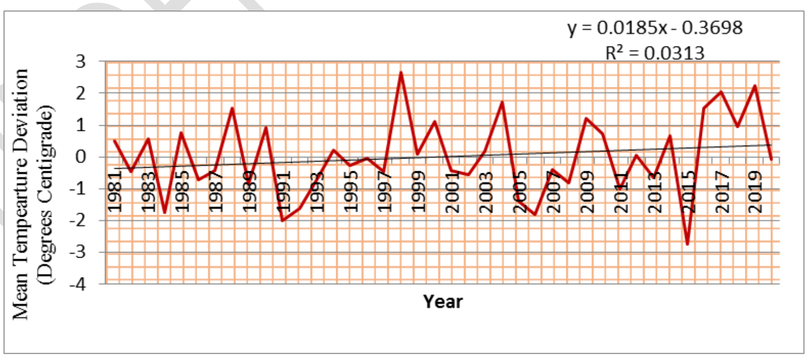



**Figure 9: Annual Temperature Anomalies within the study Area**
**Source: Plotted with data from NASA Database (2022)**

**Seasonal Temperature Variability**

Given that the study area is characterised by two seasons (the dry and the rainy seasons), temperature values vary in Santa over the past four decades from one season to another. This seasonal temperature variability is indicated by the rainy and the dry season temperature anomalies as some years registered positive anomalies while others recorded negative anomalies. It is evident that the last three decades (1990 -2020) recorded mostly positive temperature anomalies during the wet season as compared to the earlier decade (1981-1990) which showed negative anomalies. Amongst the years that registered positive anomalies during the past three decades, 1998 and 2005 registered temperature anomalies of +1 during the rainy season (Figure 10).

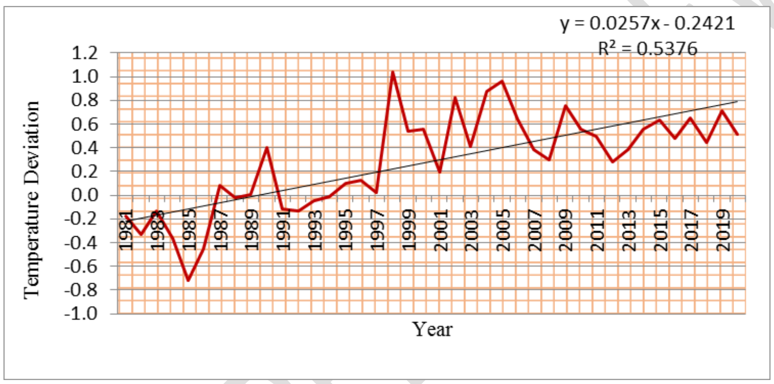



**Figure 10: Temperature Anomalies for the Wet Season**
**Source: Plotted with data from NASA Database (2022)**

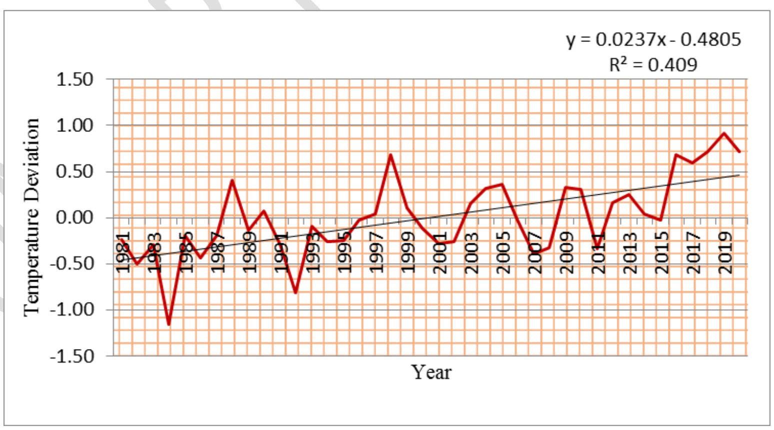



**Figure 11: Temperature Anomalies for Dry season**
**Source: Plotted with NASA Data (2022)**

Unlike the wet season temperature anomalies, the dry season temperature anomalies indicate that the last two decades (2001 to 2020) recorded mostly positive anomalies while the earlier decades

(1981 to 2000) registered mostly negative temperature anomalies. (Figure 10). Amongst the years that recorded negative dry season temperature anomalies, 1984 peaked with an anomaly of -1. Despite the fact that some years registered low temperature values that deviate from the mean, the general dry season and wet season temperature trends are increasing as shown by the trend line (0.0237x and 0.0257x respectively). These temperature increases indicated low crop yields as a result of heat stress and increases in evapotranspiration during the planting periods.

**Monthly Temperature Variability**

Temperature variability is seen to be a function of seasons as each season influences temperature in one way or the other in the study area. The rainy season which is characterised by cloudy skies and downpours influences temperature differently from the dry season which is marked by clear skies and little no rainfall. Figure 12 shows that March and April recorded the highest temperatures ($23^0$C). While the coldest month were August and December ($20^0$C). Paradoxically, high temperatures were recorded in months that the rainy season is usually expected to start, while some dry months also recorded low temperature values over the past years (1981-2020). This indicates drought conditions, heat stresses and increase in evapotranspiration which may lead to a decrease in stream water recharge, low water table and soil moisture deficiency.  Thus, the high temperatures during these months of April and March therefore affect crops as they lose a lot of water through evapotranspiration during their planting periods as they require more moisture.

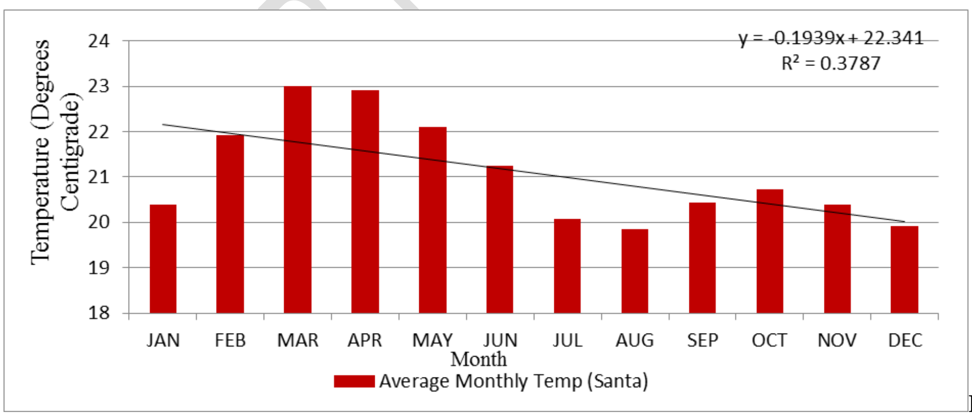



**Figure 12: Average Monthly Temperature for Santa**
**Source: Plotted with data from NASA Database (2022)**

**The Climograph for Santa**

The climatic pattern of Santa Subdivision shows different climatic conditions during different periods of the year across different years. The climate has two distinct seasons which run through different months of the year with different characteristics. The rainfall regime of Santa Subdivision over the past 40years has a pyramidal configuration (Figure 13).

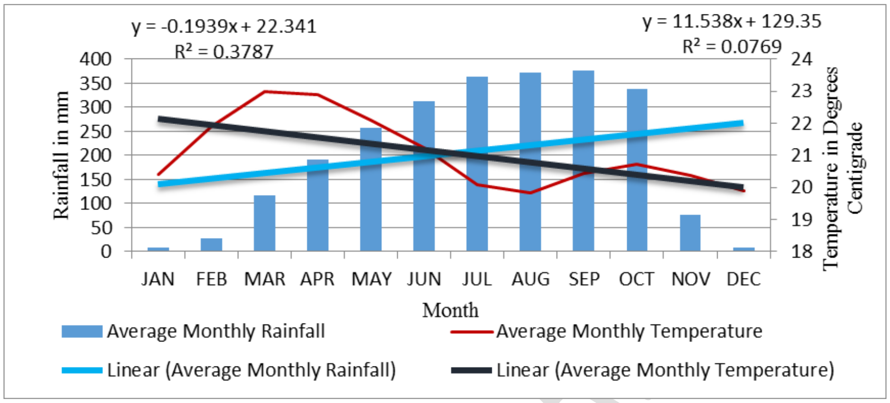
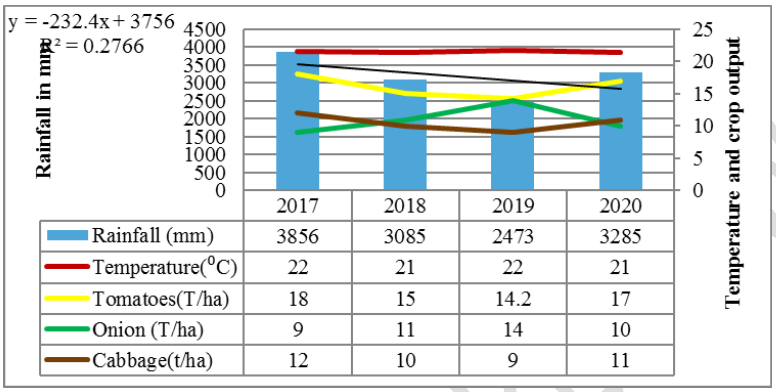



**Figure 13: Climograph for Santa**
**Source: Plotted with data from NASA Database (2022)**

This is seen as rainfall starts rising from January, reaching its peak in September and falling back right to December (Figure 13). Meanwhile, the temperature polygon shows fluctuation in the average monthly temperature. This is illustrated as temperatures start rising from January. Reaching the peak in March, temperatures begin to fall back right to August where the lowest temperature is recorded and thereafter, they start rising from September to December. Given that these months of the year reflect either of the two seasons with different characteristics, the rainy season (March to October) records high average monthly rainfall and low average monthly temperatures. While the dry season months (November to February) recorded low average monthly rainfall and high average monthly temperatures from 1981 to 2020. The figure shows that there is a general increase in the average monthly rainfall trend (11.538x) while the average monthly temperature trend has been declining (-0.1939x) over the past four decades. This rising temperatures implies an increase in evapotranspiration which may lead to a decrease in stream water recharge, low water table, water stress and soil moisture deficiency and thus causing pest and diseases and crop withering.

**Impacts of climate variability on food crop outputs**

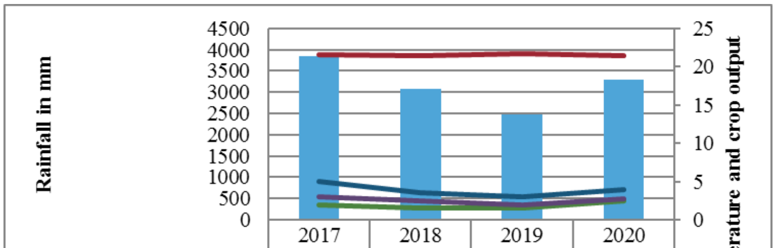
The study analysed the outputs of market gardening crops, tubers/root crops, grains and tree crops from 2017 to 2020 in Santa Subdivision. The results showed that variation in the various food crop outputs is a function of variations in climatic parameters over the past years. That is, years with high rainfall recorded higher output for crops that need more water to grow than crops that require less water. This therefore means that there is a relationship between the crop outputs and the climatic variables most especially rainfall (Figure 14 and Figure 15).




| | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|
| Rainfall (mm) | 3856 | 3085 | 2473 | 3285 |
| Temperature($^0$C) | 22 | 21 | 22 | 21 |
| Tomatoes(T/ha) | 18 | 15 | 14.2 | 17 |
| Onion (T/ha) | 9 | 11 | 14 | 10 |
| Cabbage(t/ha) | 12 | 10 | 9 | 11 |

**Figure 14: Relationship between climate (Rainfall and temperature) and Market gardening crop output**
**Source: Plotted with data from Santa Subdivisional delegation of Agriculture and NASA-base data (2022)**

Figure 14 shows that rainfall fluctuation is more significant than temperature. This indicates that due to a drop in rainfall, there is less water to sustain crops and with a slit variation in temperatures, pest and disease tend to attack crops. It therefore shows that variation in rainfall and temperature led to variation in output of market gardening crops (Figure 14 and Figure 15**).** This relationship is seen as output of crops such as tomatoes and cabbage increase with increasing rainfall (2017 and 2020) and decreases with decreasing rainfall (2018 and 2019) as shown in Figure 14. Thus, this shows a positive relationship between these variables. This is not the case with other crops such as onions with outputs that drop with increasing rainfall (2017 and 2020) and rise with decreasing rainfall (2018 and 2019), showing an inverse relationship between these variables. This is because these crops require less water to grow. Similarly, there is also a relationship between climate variability and grains, tubers and tree crops (Figure 15)




| | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|
| Rainfall (mm) | 3855.98 | 3085.26 | 2473.36 | 3285.29 |
| Temperature($^0$C) | 22 | 21 | 22 | 21 |
| Irish Potatoes(T/ha) | 5 | 3.5 | 3 | 4 |
| Corn(T/ha) | 2 | 1.5 | 1.5 | 2.5 |
| Plantain(T/ha) | 3 | 2.5 | 2 | 2.8 |

**Figure 15: relationship between climate (Rainfall and temperature) and grains, tubers and roots and tree crops**
**Source: Plotted with data from Santa Subdivisional delegation of Agriculture and NASA-base (2022)**

The relationship between rainfall and temperature and grains, tubers/roots and tree crops is seen as increases in rainfall leads to increases in the outputs of crops such as Irish potatoes, corn and plantain (2017 and 2020). Meanwhile when the rainfall amount reduces, the outputs of these crops also reduces (2018 and 2019), showing a positive relationship between these variables. This therefore implies that these crops require enough water to grow and yield more. Although there is a general drop in the crop outputs, the fluctuations in food crop outputs lead fluctuations in prices of these crops which in turn leads to a drop in the income of the farmers.

**Pearson's Correlation**

**Table 4.**

**Relationship between rainfall and temperature variations and time**

Variables: Rainfall and temperature and time over the period of 40 years

- Assumed Alpha = 0.05
- Pearson *r* = 1

A Pearson r of 1 shows a perfect relationship between time and variations in rainfall and temperature. This therefore shows that climate has been varying over the past 40 years in Santa as seen by temperature and rainfall variabilities.

**Regression analysis**

**Table 5.**

**Summary of results of the relationship between climate variability and food crop outputs**

**Variables:** Rainfall and temperature of Santa **and food** Crop output in Santa (average Output/hectare)

- Assumed Alpha = 0.05
- Pearson *r* = 0.96
- *p*-value (Significance)= 0.034

Conclusively, since the p-value (0.034) is less than the assumed Alpha (0.05), there is a significant relationship between climate variability and food crop output in Santa. This is because food crop yields highly depend on climate, although having a good knowledge of specific climatic condition impacts on specific crop types is still a problem to majority of the farmers.

## 5. Discussion

**Comment [U14]:** DELETE

**Rainfall and temperature variability**

The first objective of this study was to climate variability over the past years. The study found that there has been variation in the climatic conditions of both rainfall and temperature as the monthly, seasonal annual and decadal rainfall and temperature values have varied over the past 40 years. The mean monthly rainfall variability and CVs from 1981 to 2020 (see Figures 2 and 3) showed that most months that constitute the rainy season (March to October) recorded high rainfall amounts with low CVs compared to months that makeup the dry season (November to February). This was a similar case with seasonal variabilities and anomalies (see Figures 4 and 5) which showed that over the past 40years, generally, the dry season rainfall means were lower than those during the rainy seasons as confirmed by Ebode (2022) in a study carried out in Cameroon. The extremely low rainfall amounts indicate a drop in the water table and soil moisture which cannot support food crop production, the reason why so many farmers have adopted measures to supply water to plants from the nearby streams (irrigation) especially during these driest periods. This was confirmed by a study carried out by Amawa *et al*. (2015) and SAP (2013) in Santa Subdivision as well. Despite the disparity in rainfall inputs, crops are cultivated throughout the year.

**Comment [U15]:** REPHRASE

The inter annual rainfall variability (see Figures 6 and 7) also showed several anomalies over the past 40 years as some years (such as 1999 and 2014) recorded very low annual rainfall while others (such as 1982 and 2016) recorded very high annual rainfall from the mean. This indicated unpredictable and unreliable nature of rainfall patterns in the Subdivision as confirmed by Lawrence (2015), who found similar results in Ashanti District in Ghana. Again, the inter annual rainfall variability also indicated a general gradual decreasing trend of rainfall from 1981 to 2020. The rainfall variations in Santa are similar to those observed in South Cameroon and Cameroon in general by Ebode et al. (2022) and Bomdzele and Molua (2023) respectively. They identified rainfalls trends in Cameroon have been greatly declining. Meanwhile this study contrast to the increasing trends of rainfall in West Scotland and Philippines (Afzal, 2011 and Cinco et al., 2014 respectively). This could be because Scotland is located in the high latitudes while Philippines is an Island with high humidity as compared to Africa which is located in the low latitudes and it is not an Island.

Comment [U16]: NOT CITED IN THE REFERENCE

The study also revealed variability in temperature from 1981 to 2020 as annual temperature variability (see Figures 8 and 9) showed several anomalies and a general increasing trend of annual temperature in the Santa. These temperature increases over the past years indicated low crop yields as a result of heat stress and increases in evapotranspiration which reduces soil moisture during the planting periods. This is similar to the results of IPCC reports (2014) on the global surface temperature showing increasing temperature trends since mid-19th Century especially in Sub-Sahara Africa, as well as the results Molua and Lambi (2006) in Cameroon, Amawa et al. (2015) in Santa Subdivision as well as Bakri and Abou-Shleel (2013) in Egypt. This means that study area just like the study areas of these empirical studies is located in Sub-Saharan Africa. Also, Seasonal temperature anomalies (see Figures 10 and 11) showed that several anomalies were recorder both in the wet and dry seasons, depicting variability of temperature. There has been a general increase in the Mean Minimum and Maximum Monthly temperatures over the past 40 years with temperature fluctuations across the months (see Figure 12) as confirmed by the study of Lawrence (2015) in the Ashanti district in Ghana. This implies an increase in evapotranspiration which may lead to a decrease in stream water recharge, low water table and soil moisture deficiency and can have adverse effects on food crop growth and yields. Similarly, the results of Walthall *et al*. (2012) in United States pointed out that, many water reserves are projected to decline most especially during the dry season as crops demand

Comment [U17]: NOT CITED IN THE REFERENCE much water during these periods as altering temperature and precipitation which pose an impact on surface water resource which always contribute to irrigation practices.

**Effects of climate variability on food crop production**

The results of this study showed that climate variability has affected the outputs of food crops in Santa Subdivision. This is seen as there was a great fluctuation in the output of crop over the past years in relation to variations in climatic parameters especially rainfall (Figures 14 and 15). This means that some years recorded high outputs for some crops and low outputs for others. It indicated that years with high rainfall recorded high outputs for crops that required enough water as compared to low outputs for crops that needed less water to do well. This is supported by the study of Wanie et al. (2020) in Buea which revealed that, the variability in temperature and rainfall are precursors to the prevalence of insect pest and diseases decreasing market gardening crop production. Notwithstanding, the results implies that there is a general drop in crop outputs as a result of the unreliability in rainfall and variations in temperature in the study area as confirmed by the work of (Fogwe and Bonglam, 2016) in the same area. These results are also supported by the study of Walthall *et al.* (2012) which pointed out that precipitation has a direct and close link with crop production, with an increase or decrease in precipitation having impacts on the yield. The fluctuations in food crop outputs contributes to nutritional deficiency, increase in diseases, food insecurity and a decrease in livelihood, as confirmed by (Komba and Muchapondwa, 2015) who identified similar Impacts on the farmers in Africa in general and Cameroon in particular as a result of climate variability. Thus, if measures are not put in place to ameliorate the present variations in climate, the future impacts will be devastating.

Although there was fluctuation in the crop yields, the results showed a general drop in the crop outputs in Santa Subdivision. This implies that the general drop in crop outputs is as a result of unreliability of rainfall and variations in temperature in the study area. This can lead to a drop in the farmers' incomes and a decrease food security especially is measures are not put in place to ameliorate the present variations in climate. This is substantiated by IPCC report (2014) which indicated a 50% drop in crop yields of African countries by 2020 as a result of changes in climate. It was also confirmed by Amawa *et al*. (2015) who identified a negative relationship between climate variability and market gardening crops in Santa. These results are similar because the studies were carried out in the same study area as of this study.

## 6. Implication to Research and Practice

Comment [U18]: DELETE 6, REPHRASE: POLICY IMPLCATION, TAKE THIS TO WHERE RECOMMENDATION IS.THE SUBTITLE WILL BE RECOMMEDATION AND POLICY IMPLICATION

Studies related to climate are very important because as humans, nearly all the aspects of lives are climate related, either directly or indirectly. All humans directly or indirectly depend on agricultural outputs and given that agriculture is influenced by climate, it is important to understand the relationship between climate and agriculture, the adverse effects of climate variability on agriculture as well as adaptation strategies toward these impacts. This study will therefore have numerous implications on the whole economy, ranging from the agricultural sector, agricultural consumers, agricultural Non-Governmental Organisations (NGOs), researchers, to policy makers/government

This study will create awareness among farmers and agricultural managers in general on the dangers involve in climate variability and change in relation with agricultural production at all levels. The study will help to improve on information about projections of changes in the average temperature and precipitation as well as related elements in the research field. This will enable the understanding of how farmers and their products are exposed to climate risks. Thus, the study will set planning and decision making by farmers against climate risk to be effective. The study will as well improve on climatic information on the temporal as well as spatial scale, which will enhance farmers, researchers and agricultural decision makers to evaluate the direct and indirect climate variability impacts on farmers in specific regions such as Santa Sub division in order to reduce their vulnerability. The study will encourage famers in general to make accurate observations and have better understanding of the spatial and temporal socio-economic impacts of climate variability. It will help scientists and researchers to provide projection models through the use of socio-economic conditions of the farmers, which will be essential in reducing the future impacts of climate variability on agriculture.

The study will go a long way to bridge the gap in the existing literature on climate variability and its impact on the agricultural sector. This study will also add up to the existing literature on climate related issues in Northwest region of Cameroon (Santa Sub Division) in particular and generally in Cameroon, Africa and the world.

## 7. Conclusion

Comment [U19]: REMOVE 7

Variations in Climatic parameters (rainfall and temperature) over the past 40 years on monthly, seasonal and annual bases have been established for Santa Subdivision. With the Level of significance of 0.05, variations in rainfall and temperatures greatly affected food crop production. Given that rainfall variability in this area is more significant it therefore poses devastating effects on food crops more than temperature. There is a positive relationship between rainfall and temperature and some market gardening crops, tubers, grains and tree crops. Given the enormous problems brought by climate variability, there is need to adopt climate-related policies and programmes to help enforce food crop farmers to take action towards sustainable agriculture. This study therefore brought up the following recommendations.

Climatic data/information and steady early warning systems should be provided and interpreted to farmers through documents, new papers and the media such as TV/radio stations in the Subdivision. This will enhance farmers' knowledge on climate variability through updates on the state of the weather and possible variations in climate. This will thus help them to sustainably manage and plan their seasonal farming activities. It is also imperative that research centres in Cameroon such as MIDENO-TDC and Santa Agricultural Post should make use of the available resources and develop more seed multiplication techniques so as to always multiply and supply more varieties that resist changes in climatic conditions that can withstand temperature variability and unreliable rainfall. These institutes should as well provide adequate and effective training on sustainable agricultural practices to reduce climate variability effects on food crop.

The Cameroon government, the ministry of Agriculture and Rural development and agricultural NGOs in the country should provide farmers with farm inputs most especially through their subsidization and price reduction. The government and other financial institutions also need to grant facilities with low rate of interest to help. Also, non-climate related aspects that can exacerbate the impacts of climate variability should also be improved upon to curb down the climate variability effects on food crops. These aspects include Construction of farm-to-market roads implementation price stabilisation policies and creation of a ready market which will all help to boost food crop production in the Santa Subdivision.

## 8. Future Research

- Since this study was carried out in only Santa Subdivision with few communities selected, it is necessary to expand the geographical scope of the study area so as to carry out a comparative study of two Subdivisions of different topography and climatic characteristics to assess the level of climate variability impacts on these areas.
- It is also necessary to evaluate farmers' perception of climate variability and their adaptation practices in Santa Subdivision.

**Comment [U20]:** DELETE 8, THIS SHOULD BE POLICY IMPLICATION AND RECOMMENDATION

- It is necessary to carry out a comparative research on the effects of climate variability on small-scale farmers and large-scale farmers in Cameroon.

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