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# Climate Dynamics and Sweet Potato Yield Across the Agroclimatic Belts of Nigeria

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**Abstract:** *Rainfall and Temperature are very important elements and factors of weather and climate needed in the successful production of crops, including sweet potato. The performance of this crop yield in relation with climate elements across the climate belts in Nigeria has not been given the due attention in Nigeria. Therefore, this study examined the changing pattern of sweet potato cross the Climate Belts of Nigeria. Rainfall and Temperaturedata were obtained for the study from Nigerian Meteorological Agency (NiMet), Abuja while sweet potato yield data were collected from the experimental farms of National Root Crops Research Institute (NRCRI), Umudike, Agricultural Development Programme (ADP) and Nigerian Bureau of Statistics, Abuja. These data covered a period of 40 years (1980 -2019) and were analyzed using simple linear regression, correlation and Analysis of Variance (ANOVA). Results obtained showed that rainfall and temperature significantly predicted sweet potato yield across the four climate belts at $p<0.05$:Tropical Monsoon(TM) (F,187.2301)and jointly explained 45% of variation in sweet poyato yield(r=.671and the $R^2$=.45);Tropical Savanna (TS)(F,17.132.1410) and jointly explained 56.4% of variation in sweet potato yield (r = .751 and $R^2$= 56.4);Warm Semi-Arid (WSA) (F,111.0451)and jointly explained 61% of variation in sweet potato yield(r= .781 and $R^2$= .610); and Warm Desert (WD)(F,45.0051) and jointly explained 30.1% of variation in sweet potato yield(r =.549 and $R^2$= .301).Based on these results, it is concluded here that there is a significant relationship between rainfall and temperature and sweet potato yields over the years and across the climate belts. The study recommends among others that planting and harvesting of sweet potato by farmers should align with the seasons as found in each of the four climate belts.*

**Key words:** sweet potato yield**,** climate belts, variables, rainfall, temperature, climate belts

## INTRODUCTION

Climate, especially rainfall and temperature, is generally perceived to affect the growth, development and yield of crops in Nigeria (Agele & Bolarinwa, 2018). Temperature and rainfall are critical elements of weather and climate in crop performance in Nigeria hence, increase in temperature could result in evaporation, which in turn can reduce soil moisture and affect plant growth. Since each crop requires different climate and environmental conditions to grow. Food and nutritional security are the major concerns in major countries of the world and many have potentials to contribute to sustainable food systems. To address the nutritional and food insecurity, it has become utmost important to diversify the present day agricultural system as well as to search for alternative food and feed ingredients. Sweet potato crop occupy a remarkable position towards food security of the developing world due to their high calorific value and superior carbohydrate content.

Sweet potato crop occupy a remarkable position towards food security of the developing world due to their high calorific value and superior carbohydrate content. It is a global important sweet tasting dicotyledonous tuberous root crop that belongs to the family Convolvulaceae (Purseglove, 1991). It has smooth skin with different shapes and sizes. The colour is in various shades of creamy white, white, yellow-orange, Medium Orange, Burnt Orange, Purple Red, Pink-Red, Copper, brilliant Copper, tan, Cream-Tan, Rose-pink, brown and reddish-purple, purple and red. Its flesh colour is in shades of orange, Light Orange, Dark Orange, Deep Orange, yellow-orange, Yellow-Greenish (cooked), Orange Mottled, white, purple and red (Edmond and Ammerman, 1971; Woolfe, 1992; Bourke and Vlassak, 2004; USDA, 2001).

Sweet potato (*Ipomoea batatas* Lam.) ranks seventh as the most produced crop worldwide after wheat, rice, maize, potato, barley, and cassava, and the fifth in developing countries (Jung J.-K., Lee S.-U., Kozukue N., Levin C.E., Friedman M.., 2011, FAOSTAT, 2014). The origin of sweet potato is Central America, but at present it is widely grown in many tropical, subtropical and warm temperate countries in different ecological regions of the world. Agricultural data made available by the Food and Agriculture Organization (FAO) indicate that in 2019, sweet potatoes were produced in 109 countries, with China (mainland) standing out as the largest producer with a harvest of more than 51 million tons of tuberous roots, providing about 80% of the world's supply. Among the main sweet potato producers in 2019 are the countries that make up the African and Asian continents such as Nigeria the second largest producer of the crop with an annual yield of 3.45 tonnes per hectare [Food and Agricultural Organization (FAO), 2016) Others include Uganda with 2.7%, Tanzania with 1.31%, Vietnam with 1.32, Indonesia with 1.88%, India with 1.1% and Japan with 1.0%. As well as the United States of America, the states of North Carolina, California, Louisiana and Mississippi produced over 95% of the U.S totals. These states produced 38.5%, 23%, 15.9%, and 19% respectively. (Food and Agriculture Organization of the United Nations, 2021).

Sweet potato is primarily a human food, although the leaves and root can also serve as animal feed. In technologically advanced countries it is processed into chips, flour, and baby food, among others, but in Nigeria it is usually eaten boiled or fried. Some tribes boil and pound as they do yam, but few people have knowledge of this process. It is also used by the indigenous people to treat diseases such as mouth tumour, asthma, whitlow, catarrh Pink, yellow and green varieties are high in carotene, the precursor of vitamin A. (Matthew Olaniyi Adewumi & Fatimoh Adebayo, 2008; Olotu *et al.,* 2017; Tewe *et al*., 2003).

Sweet potato is a hardy drought tolerant crop that can grow on marginal lands. It requires minimal input during cultivation and because it covers the ground it prevents soil erosion where water runoff may be a problem. In Nigeria, it is grown mostly as a secondary crop, except in Offa local government area of Kwara state where it is held in high esteem as a cash crop. Adeyonu *et al.* (2019) reported shortage of labour, insect infestation and poor access to improved varieties as the major constraints to sweet potato production. It is a good food security crop with low input and production costs compared to the output, so that smallholder farmers get good returns for their labour. There is the added nutritional benefit of beta-carotene, which helps the human body produce Vitamin A, so that the nutrient requirements for children, pregnant women and nursing mothers are met by consuming sweet potato regularly (Odebode *et al.,* 2008). Daily consumption of sweet potatoes have various beneficial possible health benefits of, such as improving digestion and reducing inflammation. They are a good source of fiber, potassium, vitamins, and other essential nutrients (Wang et al., 2016; Alam, 2021; Amagloh et al., 2021). The cultural practices in its production include planting on mounds or ridges, intercropping it with other crops, because the sweet potato vines serve as a cover crop to suppress weeds. Weeding of the plot is not necessary once the plant is well established as it suppresses the weeds itself. Being highly perishable, sweet potatoes are not stored for long and are sold off fresh.

Sweet potato can play a key role in the recovery of food supplies after a disaster, as the crop can be produced in cool and dry (monthly rainfall around 100 mm) conditions and also when it is hot and wet (monthly rainfall around 200 mm), though faster growth and higher yields are obtained when it is cool and dry locations with high sunshine, an average temperature of 24°C or more, and well distributed annual rainfall of 1000 to 2000mm are required to obtain the highest yield potential for sweet potato (Lebot, 2009). Lebot (2009) reports that average yields in temperate countries tend to be higher than in tropical developing countries due to more to differences in management than to climate factors. Spence and Humphries (1972) found that sweet potato produces the greatest increase in storage root weight when grown at a constant soil temperature of 30°C, combined with an air temperature of 25°C at night. Tuber formation is impaired when air temperature exceeds 34°C (Bourke, 2013). Tuber growth and yield can be severely reduced by temperature fluctuations outside 5-30$^{o}$C. The effects include slow tuber growth and initiation, less partitioning of starch to the tubers, physiological damage to tuber (e.g. brown spot), shortened/non-existent tuber dormancy, making tubers sprout too early. These effects can reduce crop yield and the number and weight of tubers. At low temperatures sweet potatoes are at risk of first damage, which can reduce growth and badly damage tubers (Hijmans, 2003; Olatunji, Omotesho, Ayinde

& Adewumi, 2012; Kwawu, Sarpong & Agyire-Tettey, 2021). Sweet Potatoes are sensitive to soil water deficits compared to other crops and need frequent irrigation, especially while tubers are growing (FAO, 2012). Reduced rainfall in many areas is predicted to increase the need for irrigation of sweet potato. Despite the low tolerance to high moisture conditions, farmers manage to grow sweet potato in locations with high to very high rainfall, (up to 5000 mm/year), using mounds or drains to reduce soil water levels (Bourke and Harwood 2009). However, excess rainfall is also detrimental to potato yield due to water-logging condition (leaching) (Daccaache *et al*, 2012). Sweet potato requires heat and plenty of sun, grows better under high light intensity and frequently cultivated between 30 and 40° latitudes in both hemispheres. Ideal temperature during growing period is 30–35°C during day and 20°C at night to encourage storage root development. High night temperature decreases vegetative and storage root growth. Like high temperature, low night temperature also reduces storage root development. Growth may cease <10°C and chilling injury may occur when the plants are exposed to low temperatures. In addition, sandy-loam textured well-drained soils provides optimum environment for storage root development **(**Wariboko C, Ogidi IA.2014 and Islam *et al.*, 2002).

Cultivation of crops in Nigeria is generally rain fed and with significant diurnal and seasonal variations in temperature thus making rainfall and temperature strong factors in crop production in the country. Rainfall does not start at the same time across the country and amounts also vary from the coast hinterland with the coastal areas receiving the highest while the extreme north receives the lowest. The success of Sweet potato cultivation across Nigeria could be said to be largely dependent on rainfall and temperature, which are not only elements of weather and climate but also factors of climate. Despite this and the estimated magnitude of nutritional and potential economic importance of Sweet potato farming in Nigeria, the impact of rainfall and temperature on the yields of Sweet potato across the climate belts of Nigeria has not received the deserved attention. Therefore, this study is meant to bridge this gap.

## METHODOLOGY

### Study Area

The study area is Nigeria and lies between longitudes 2°49'E – 14°37'E and latitudes 4°16'N – 13°52'N (Fig. 1). It is bounded on the North by the Republic of Niger, East by Cameroon and West by Benin Republic while the Southern boundary is Gulf of Guinea which is an arm of the Atlantic Ocean (Ofomata, 1975). Following Koppen's Climate Classification Nigeria has four climate types. As one moves from the Tropical Monsoon Climate (Am) type in Southern part of Nigeria to the Tropical Savannah belt (Aw) in north-central Nigeria through to Warm Semi-arid Climate belt (Bsh) in Northern part and finally Warm Desert Climate in the far eastern part of Nigeria with boundary with Chad , these climate belt (SWh) are distinguishable. (but for easy identification of these climate belts in this study, they were recoded as TM, TS, WSA and WD respectively).

The Tropical monsoon climate has a very small temperature range. The temperature ranges are almost constant throughout the year but experiences heavy and abundant rainfall. Due to the regions proximity to the equatorial belt these storms are usually convectional in nature. The annual rainfall received in this region is very high, usually above the 2,000mm (78.7 in) rainfall totals giving for tropical rainforest climates worldwide. Over 4,000 m (157.5 in) of rainfall is received in the coastal region of Nigeria around the Niger delta area (Mmom, 2003).The Tropical Savannah Climate or Tropical Wet and Dry climate, is extensive in area and covers most of Western and north-central parts of Nigeria beginning from the Tropical Monsoon Climate boundary in Southern Nigeria to the Central part of Nigeria, where it exerts enormous influence on the region. This climate exhibits a well-marked rainy season and a dry season with a single peak known as the summer maximum due to its distance from the equator. Temperatures are above 18°C (64 °F) throughout the year (Obasi and Ikubuwaje, 2012). Rainfall total in Tropical Savanna Nigeria varies from 1,100 mm (43.3 in) in the lowlands of the river Niger Benue trough to over 2,000 mm (78.7 in) along the south western escarpment of the Jos Plateau (Okoh *et al*., 2017). The Warm Semi-arid Climate or Tropical Dry climate is the predominant climate type in the northern part of Nigeria. Annual rainfall totals are lower compared to the Tropical Monsoon and Tropical Savanna belts of Nigeria. The rainy season in this belt last for only three to four months (June–September) while the rest of the year is hot and dry with temperatures climbing as high as 40°C (Okoh *et al*., 2011).Warm Desert Climate is found on highlands regions in Nigeria. Highlands with the alpine climate in Nigeria, are well over 1,520 metres (4,987 ft) above sea level. Due to their location in the tropics, this elevation is high enough to reach the temperate climate line in the tropics thereby giving the highlands, mountains and the plateau regions standing above this height, a cool mountain climate (Oluwole and Ike, 2013).

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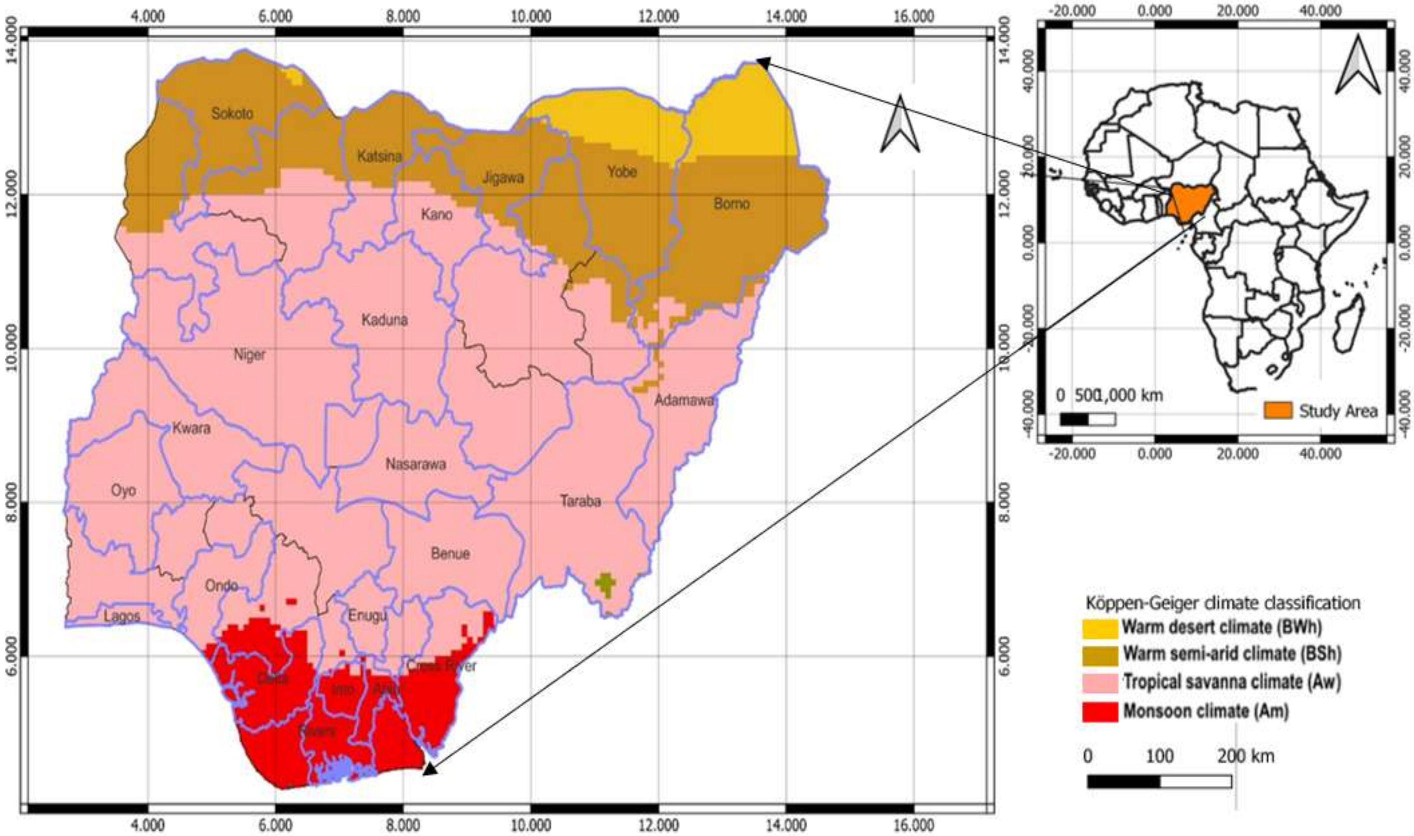


**Fig. 1 Map of Nigeria showing the Study Areas**

Nigeria is covered by three types of vegetation: forests (where there is significant tree cover), savannahs (insignificant tree cover, with grasses and flowers located between trees), and montane land. (The latter is the least common, and is mainly found in the mountains near the Cameroon border.) Both the forest zone and the savannah zone are divided into three parts. Some of the forest zone's most southerly portion, especially around the Niger River and Cross River deltas, is mangrove swamp. North of this is fresh water swamp, containing different vegetation from the salt water mangrove swamps, and north of that is rain forest (Olajuyigbe & Adaja, 2014).The Savannah zone's three categories are divided into Guinean forest-savanna mosaic, made up of plains of tall grass which are interrupted by trees, the most common across the country; Sudan savannah, similar but with shorter grasses and shorter trees; and Sahel savannah patches of grass and sand found in the Northeast (Mohammed, 2013).

## Data Collection and Analysis

The data used in this study include the primary and secondary data types. The secondary data are the climate data covering a period of 40 years from 1980 -2019 include mean monthly maximum and minimum temperatures; and mean monthly rainfall were obtained from the office of Nigerian

Meteorological Agency (NiMet), Abuja for this study, and data on ginger in tons per hectare were collected from the experimental farms of National Root Crops Research Institute (NRCRI), Umudike, Agricultural Development Programme (ADP) and Nigerian Bureau of Statistics, Abuja.. The study employed the use of Statistical Package for Social Sciences (SPSS) version 22. Simple linear regression and correlation were employed to explain the time series variations in meteorological parameters and ginger yield. The ANOVA was used because it has the capacity to determine the divergence in the mean of data, particularly, when the data sets are up to or more than three independent sets (Wahab & Jiao, 2020; Kumawat & Yadav, 2021).

## RESULTS

Table 1 shows the mean monthly distribution of rainfall amounts in the climate belts of Nigeria. During the study period, the month of January was wetter in the Tropical Monsoon (TM) Climate Belt with mean monthly rainfall of 33.5mm. The highest mean total rainfall amount of 348.4mm was recorded in the month of September whereas the lowest mean total rainfall amount of 33.1mm was recorded in the month of December. The month of July also recorded high amount of rainfall of 327.2mm followed by June that recorded 291.9mm mean amount of rainfall. There is rainfall in all the months of TM climate belt. The Warm Desert (WD) Climate Belt recorded the lowest amount of mean monthly rainfall. Its highest mean monthly rainfall of 202.1mm was in the month of August followed by the month of July which recorded 173.9mm amount of rainfall. The lowest amount of rainfall of 6.4mm was recorded in the month of April. The WD climate had total number of six months of rainfall which starts from the month of April and ends in the month of October. The WD climate recorded the highest number of months without rainfall (January, February, March, November and December). The mean monthly rainfall amount is higher than that of the Tropical Savanna (TS) Climate Belt which had a mean monthly rainfall for January as 9.3mm. In TS climate, the highest mean total amount of 265.5mm rainfall was recorded in the month of September as well whereas the lowest of 9.3mm of mean rainfall amount was recorded in the month of January. The month of July also recorded high amount of rainfall of 222.9mm, followed by June which recorded 210.4mm. TS climate had rainfall in all the months. The other two climate belts of Warm Semi-arid (WSA) Climate Belt and the Warm Desert Climate are exceptionally dry in the month of January with 0.2mm and 0mm of mean monthly rainfall respectively. The same pattern can be seen for February and March. Though, in April, the sign of wetness is witnessed in the Warm Desert Climate and a 6.4mm mean monthly rainfall is documented. For WSA climate, the highest mean monthly rainfall of 205.7mm was observed in the month of August and 179.4mm in the month of July while the lowest was 0.2mm in the month of January. However, the months of November and December recorded 0.0mm and 0.0mm respectively making it have total number of seven months of rainfall.

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**Table 1: Monthly Rainfall (mm) distribution across the climate belts of Nigeria (1980-2019)**

| Months | Tropical Monsoon Climate | Tropical Savanna | Warm Semi-arid Climate | Warm Desert Climate |
|---|---|---|---|---|
| January | 33.5 | 9.3 | 0.2 | 0 |
| February | 54.8 | 20.8 | 0.3 | 0 |
| March | 126.4 | 55.2 | 1.8 | 0.3 |
| April | 186 | 113.7 | 7.9 | 6.4 |
| May | 248.6 | 175.2 | 52.2 | 30.9 |
| June | 291.9 | 210.4 | 82.5 | 75.3 |
| July | 327.2 | 222.9 | 179.4 | 173.9 |
| August | 282.8 | 203.8 | 205.7 | 202.1 |
| September | 348.4 | 265.5 | 108.5 | 102.7 |
| October | 277.3 | 167.4 | 20.4 | 13.2 |
| November | 103.5 | 27.3 | 0 | 0 |
| December | 33.1 | 11.2 | 0 | 0.1 |
| Mean | 2313.7 | 1482.6 | 659 | 604.8 |

**Source: Author's data analysis**

Table 2 reveals the ANOVA computations for differences in the seasonal amounts of rainfall in the study area. The Year was classed into four and thereafter denoted acronymically using the first letters of the months of the year. The seasons were the December January and February (DJF), March April and May (MAM), June July and August (JJA), then September October and November (SON). The essence here was to see if there have been differences in the patterns of rainfall within the seasons of the year. It is also critical to understand that whereas the second season (MAM) is critical for the planting, the third season (JJA) is majorly for growth and maturity of root and tuber crops in Nigeria, while the fourth (SON) and the first (DJF) seasons are critical for the harvest and storage of root and tuber crops in Nigeria in the Tropical Monsoon Climate. Similarly, the second season (MAM),

For the Tropical Monsoon, all the seasons appeared to have been significantly different at $p<0.05$. The same can be said about the other climate belts of the country. This explains in clear terms that there have been significant changes in the seasonal rainfall amounts across the climate belts of the country over the past 40years (1980 – 2019).

The temperature data presented in Figure 2 shows that in the Tropical Monsoon Climate Belt, temperature ranged from 25.6$^{o}$C in July to 27.5 in May. The months of June July August, appear cooler due to the effect of the rainy season in this belt at this period of the year. The Tropical Savanna Climate belt observed the highest temperature a little differently from the Tropical Monsoon Climates'. In this belt the highest temperature was encountered in the months of March

**Table 2: Seasonal differences in rainfall in the climate belts**

| Tropical Monsoon | | | | | | |
|---|---|---|---|---|---|---|
| Months | Groups | Sum of Squares | Df | Mean Square | F | Sig. |
| DJF | Between | 902365.12 | 3 | 157 | 7.1363 | .006 |
| | Within | 813565.23 | 116 | 22 | | |
| MAM | Between | 848565.13 | 3 | 144 | | .001 |
| | Within | 712265.11 | 116 | 11 | 13.0909 | |
| JJA | Between | 765165.13 | 3 | 163 | 11.6428 | .003 |
| | Within | 622365.15 | 116 | 14 | | |
| SON | Between | 635565.21 | 3 | 164 | 13.6666 | .000 |
| | Within | 479765.11 | 116 | 12 | | |
| Tropical Savanna | | | | | | |
| DJF | Between | 772639.33 | 3 | 451 | | .040 |
| | Within | 684730.31 | 116 | 68 | 6.6323 | |
| MAM | Between | 580822.56 | 3 | 131 | | .031 |
| | Within | 474914.16 | 116 | 17 | 7.7058 | |
| JJA | Between | 259005.85 | 3 | 168 | | .000 |
| | Within | 164097.54 | 116 | 10 | 16.800 | |
| SON | Between | 147189.23 | 3 | 289 | 15.2105 | .000 |
| | Within | 44280.22 | 116 | 19 | | |
| Warm Semi-arid Climate | | | | | | |
| DJF | Between | 880364.11 | 3 | 201 | 10.5789 | .001 |
| | Within | 704455.45 | 116 | 19 | | |
| MAM | Between | 557547.15 | 3 | 189 | | .000 |
| | Within | 245638.24 | 116 | 15 | 12.6000 | |
| JJA | Between | 644729.99 | 3 | 204 | | .001 |
| | Within | 192178.99 | 116 | 22 | 9.2727 | |
| SON | Between | 843564.12 | 3 | 228 | | .000 |
| | Within | 563455.11 | 116 | 13 | 17.5384 | |
| Warm Desert Climate | | | | | | |
| DJF | Between | 868557.39 | 3 | 296 | | .000 |
| | Within | 622659.45 | 116 | 24 | 12.3333 | |
| MAM | Between | 730354.01 | 3 | 189 | 14.5384 | .000 |
| | Within | 631255.7 | 116 | 13 | | |
| JJA | Between | 606760.77 | 3 | 263 | 16.4375 | .000 |
| | Within | 550862.47 | 116 | 16 | | |
| SON | Between | 499464.16 | 3 | 223 | 10.6190 | .001 |
| | Within | 239065.85 | 116 | 21 | | |

***DJF=December, January, February; MAM=May, June, July; JJA=June, July, August; SON=September, October, November.***

**Source: Author's data analysis**

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and April, with 28.5ºC and 28.7ºC respectively. The coolest temperature was recorded in September with a mean monthly temperature of 26.1ºC. In the Warm Semi-arid Climate, April also recorded the highest temperature of 29.5ºC. The coldest month was the month of January with a temperature of 23ºC.

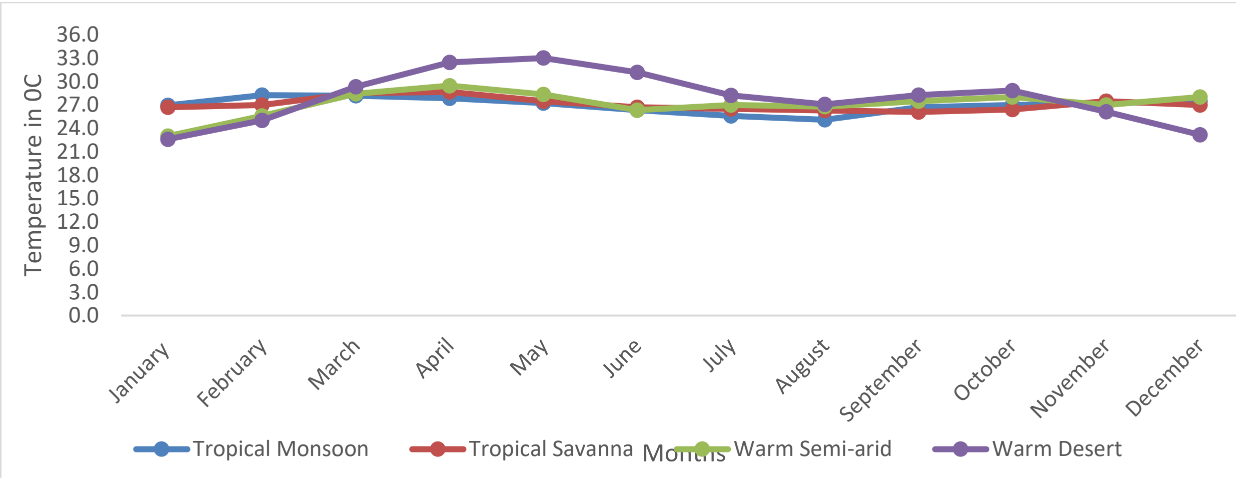


**Figure 2: Mean monthly temperature distribution across the climate belts of Nigeria**
**Source: Author's data analysis**

The adducible reason for this low temperature in January is the closeness of the region to the Sahara Desert and the cold tropical continental air mass which is more boisterous at that time of the year thereby affecting temperature of the area. This same condition applies to the Warm Desert Climate, which also had its coldest mean monthly temperature in the month of January (22.6º*C*). Table 3 reveals the ANOVA computations for differences in the seasonal mean temperature in the study area. The Year was classed into four seasons and thereafter denoted acronymically using the first letters of the months of the year. The seasons were the December January and February (DJF), March April and May (MAM), June July and August (JJA), then September October and November (SON). The essence here was to see if there have been differences in the patterns of temperature values within the seasons of the year. It is also imperative to understand that whereas the first two seasons are critical for the planting and growth of root and tuber crops in Nigeria, the last two are critical for the maturity, harvest and storage of root and tuber crops in Nigeria. For the Tropical Monsoon, all the seasons appeared to have been significantly different at $p<0.05$. In the Tropical Savanna belt all the other seasons of the year were significantly different at $p<0.05$, but DJF was not significant at $p>0.05$. This could be possibly caused by the closeness of the region to the region where the tropical continental air mass prevails at the time of the year. In the Warm Semi-Arid Climate, it was MAM that was not significant at $p>0.05$. The other seasons of the year were significant at $p<0.05$. Finally, the Warm Desert Climate had all seasons of the year statistically significantly different at $p<0.05$ except DJF season that was not significant at $P>0.05$.

**Table 3: Seasonal differences in temperature across the climate belts in Nigeria**

| Tropical Monsoon | | | | | | |
|---|---|---|---|---|---|---|
| Months | Groups | Sum of Squares | Df | Mean Square | F | Sig. |
| DJF | Between | 900365.22 | 3 | 123 | 10.2500 | .000 |
| | Within | 854565.2 | 116 | 12 | | |
| MAM | Between | 808765.17 | 3 | 181 | | .000 |
| | Within | 762965.15 | 116 | 15 | 12.0667 | |
| JJA | Between | 717165.13 | 3 | 103 | 5.7222 | .012 |
| | Within | 671365.10 | 116 | 18 | | |
| SON | Between | 625565.08 | 3 | 134 | 6.3810 | .010 |
| | Within | 579765.05 | 116 | 21 | | |
| Tropical Savanna | | | | | | |
| DJF | Between | 672639.08 | 3 | 89 | 1.4127 | 1.04 |
| | Within | 586730.77 | 116 | 63 | | |
| MAM | Between | 500822.47 | 3 | 112 | | .034 |
| | Within | 414914.16 | 116 | 19 | 5.8947 | |
| JJA | Between | 329005.85 | 3 | 193 | | .041 |
| | Within | 243097.54 | 116 | 45 | 4.2889 | |
| SON | Between | 157189.23 | 3 | 123 | 7.2352 | .020 |
| | Within | 71280.926 | 116 | 17 | | |
| Warm Semi-arid Climate | | | | | | |
| DJF | Between | 980364.23 | 3 | 108 | 9.8182 | .000 |
| | Within | 744455.67 | 116 | 11 | | |
| MAM | Between | 508547.11 | 3 | 192 | | .231 |
| | Within | 272638.55 | 116 | 79 | 2.4304 | |
| JJA | Between | 636729.99 | 3 | 134 | | .003 |
| | Within | 199178.56 | 116 | 14 | 9.5714 | |
| SON | Between | 830564.006 | 3 | 117 | | .005 |
| | Within | 624455.698 | 116 | 15 | 7.8000 | |
| Warm Desert Climate | | | | | | |
| DJF | Between | 718557.39 | 3 | 161 | | .067 |
| | Within | 662659.08 | 116 | 97 | 1.6598 | |
| MAM | Between | 830354.01 | 3 | 110 | 5.0000 | .001 |
| | Within | 774455.7 | 116 | 22 | | |
| JJA | Between | 606760.77 | 3 | 143 | 3.7632 | .051 |
| | Within | 550862.47 | 116 | 38 | | |
| SON | Between | 494964.16 | 3 | 119 | 4.9583 | 0.041 |
| | Within | 439065.85 | 116 | 24 | | |

***DJF=December, January, February; MAM=May, June, July; JJA=June, July, August; SON=September, October, November.***

**Source: Author's data analysis**

Figure 3a reveals the time series plot for rainfall in the Tropical Monsoon Climate belt. The plot yielded a model with an $R^2$ 0.6 and Y=1.85x + 2269.5. The model revealed a quasi-decadal pattern with no much noticed anomaly or deviation. Also, Figure 3b showed that there are some inherent anomalies in the rainfall distribution. Particularly, 1986 was exceptionaly dry and represented the year with the driest rainfall with anormaly value of -350mm. In Figure 3c the temperature timeseries plot is presented. In the figure the temperature ranges between 26°C to 30.5°C. The temperature appeared to be on the increase contineously, although with some anomalies. There are two deviations within the continum, as seen in the year 1995 and 2004. In Figure 3d showed the anormalies in the temperature data, where 1995 and 2002 were very cool with the temperature anomalies of -1.5°C for each of them.

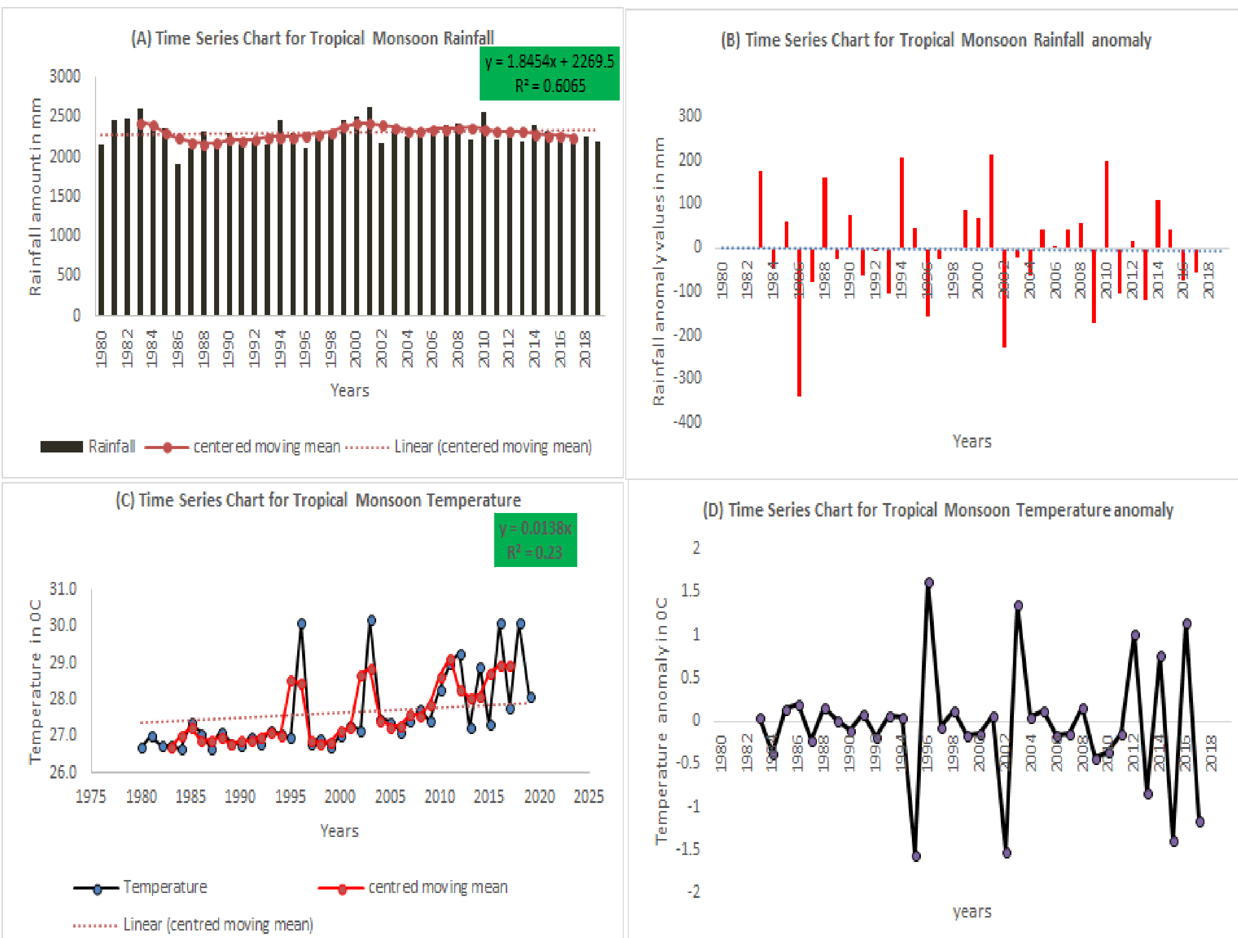


**Figure 3: Rainfall and temperature time series and anomaly plots for the Tropical Monsoon Climate Belt.**
**Source: Author's data analysis**

Figure 4a reveals the time series plot for rainfall in the Tropical Savanna Climate belt. The plot yielded a model with an $R^2$ 0.046 and Y=58.15x. The model revealed a quasi-decadal pattern with no much anomaly or outliers. On the other hand, Figure 4b showed that there are some inherent anomalies in the rainfall distribution. Particularly, 1996 was abnormaly dry and represented the year with the driest rainfall with anormaly value of -45mm. In Figure 4c the temperature timeseries plot is presented. In the figure the temperature ranges between 26°C to 29.5°C. The temperature appeared to be on the increase contineously, although with some anomalies. There are two deviations within the continum, as seen in the year 2016 and 2018. In Figure 4d showed the anormalies in the temperature data, where 2013 and 2015 were very cool with the temperature anomalies of -0.13°Cand 0.15$^0$C respectively.

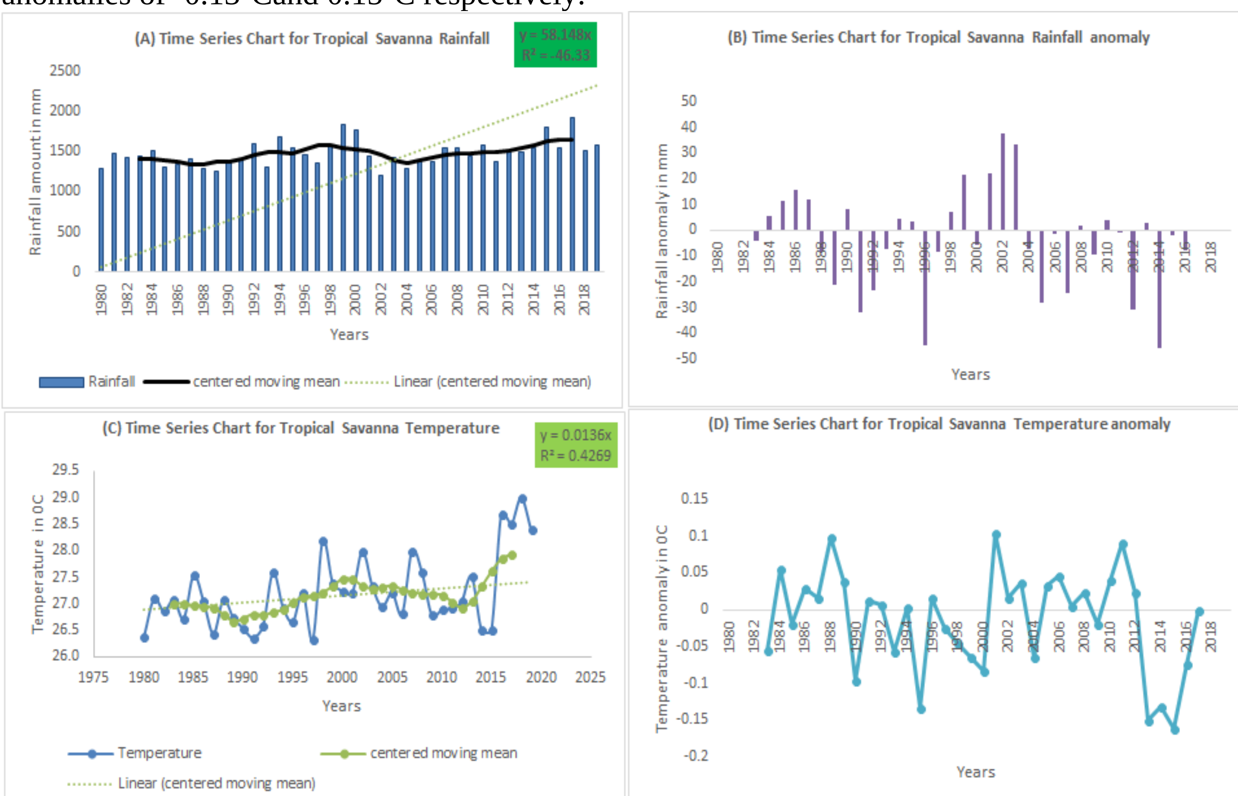


**Figure 4: Rainfall and Temperature time series and anomaly plots for the Tropical Savanna Climate Belt.**
**Source: Author's data analysis**

Figure 5a reveals the time series plot for rainfall in the Warm Semi-arid Climate belt. The plot yielded a model with an $R^2$ 0.7 and Y=35.05x. The model revealed a quasi-decadal pattern with two peaks while Figure 5b showed that there are some inherent anomalies in the rainfall distribution. Particularly, 1995 was abnormaly dry and represented the year with the driest rainfall with anormaly value of -48mm. In Figure 5c the temperature timeseries plot is presented. In the figure the temperature ranges between 26°C to 28°C. The temperature appeared to be on the increase contineously, although with some anomalies. There is one peak within the continum, as seen in the year 2010. In figure 5d showed the anormalies in the temperature data, where 2010 was very cool with the temperature anomaly of - 0.15°C.

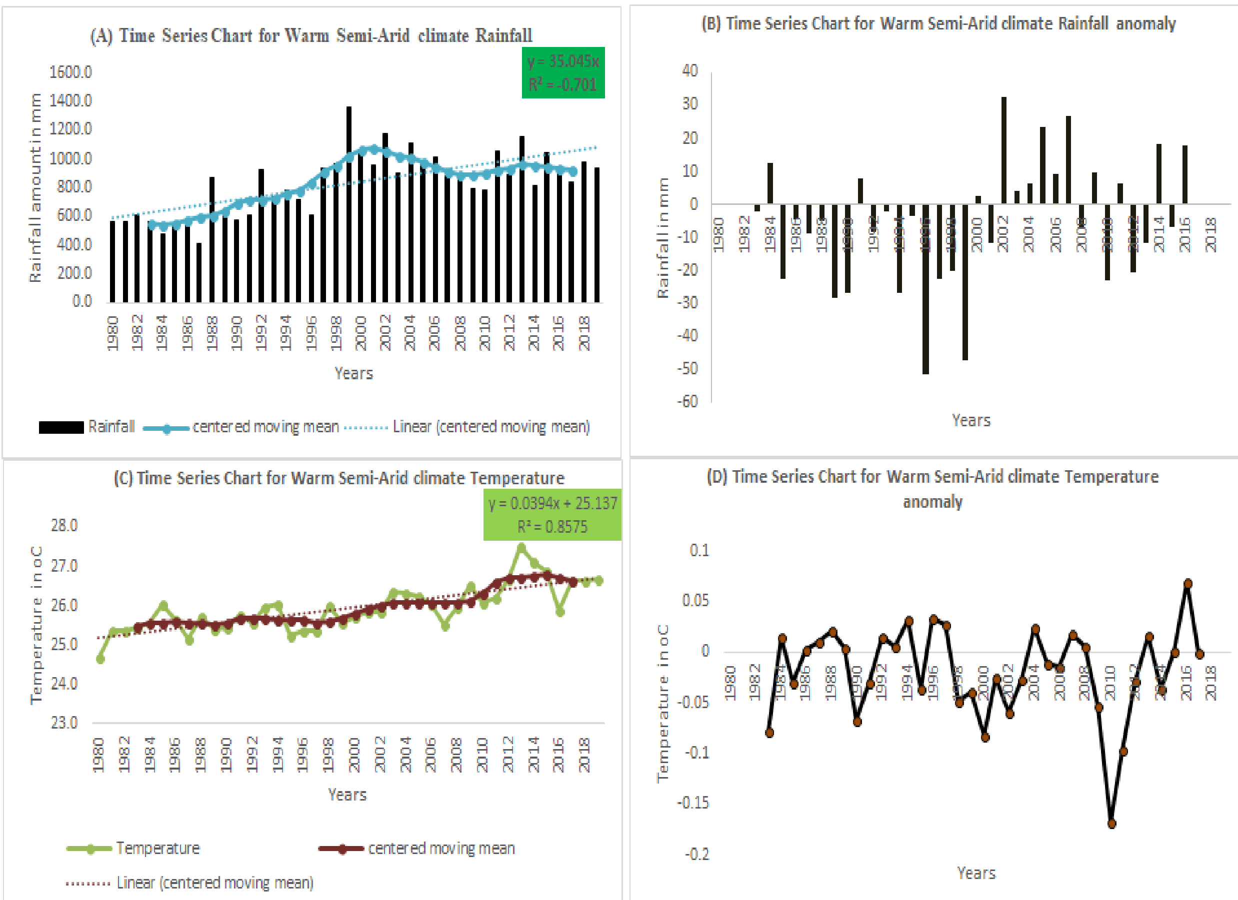


**Figure 5: Rainfall and Temperature time series and anomaly plots for the Warm Semi-Arid Climate Belt.**
**Source: Author's data analysis**

Figure 6a reveals the time series plot for rainfall in the Warm Desert Climate belt. The plot yielded a model with an $R^2$ 0.55 and Y=1.17x +692.73. The model revealed a quasi-decadal pattern with two peaks. However, Figure 6b showed that there are some inherent anomalies in the rainfall distribution. Particularly, 2000 was abnormaly dry and represented the year with the driest rainfall with anormaly value of -212mm. In Figure 6c the temperature timeseries plot is presented. In the figure the temperature ranges between 26.5°C to 31.5°C. The temperature appeared to be on the increase continuously, although with some anomalies and a decade long consistent temperature distribution. There is three peaks within the continum, as seen in the years 1988 (30.5°C) 1997

(30.7ºC) and 2017 (31ºC). Figure 6d showed the anormalies in the temperature data, where 1997 was very hot with the temperature anomaly of 2.5ºC.

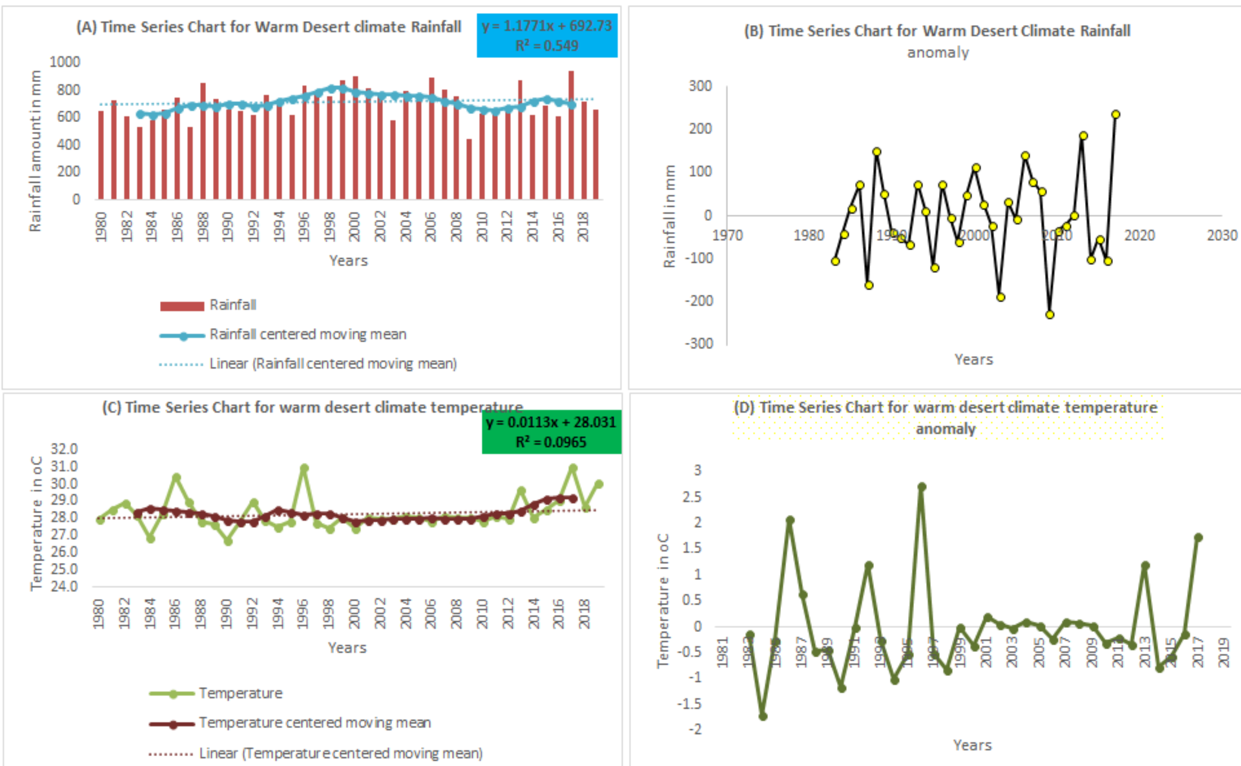


**Figure 6: Rainfall and temperature time series and anomaly plots for the Warm Desert Climate Belt.**
**Source: Author's data analysis**

Also, in finding out the relationships between the climate and Sweet potato crops across the contrasting climate belts. It is therefore possible to trace the yields of crops to the climate of the place hence, the amount and buoyancy of rainfall and temperature are used to measure these relationships. This is because these elements of weather are pervasive and have controlling effects on the climate of tropical environments. Herein, the dependent variable (sweet potatoes) is regressed against rainfall and temperature (predictors). In the Tropical Monsoon Climate environment, rainfall and temperature significantly predicted sweet potatoes yield (F,182.2301) = $p<0.05$ which indicate that temperature and rainfall (climate) play significant role in the yield of sweet potatoes in the Tropical Monsoon Climate environment ($b_1$= R; .155 $P<0.05$, $b_2$= T.438 $P<0.05$). The model revealed a positive relationship (r=.671) and the $R^2$ was .450. This means that rainfall and temperature jointly explained 45% of variation in sweet potatoes yield in the Tropical Monsoon environment of Nigeria. In the Tropical Savanna Climate environment, rainfall and temperature significantly predicted sweet potatoes yield (F,132.1410) = $p<0.05$ which indicate

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that temperature and rainfall (climate) play significant role in the yield of sweet potatoes in the Tropical Savanna Climate environment ($b_1$= R; .231 $P<0.05$, $b_2$= T.420 $P<0.05$). The model revealed a positive relationship (r=.751) and the $R^2$ was .564. This means that rainfall and temperature jointly explained 56.4% of variation in sweet potatoes yield in the Tropical Savanna environment of Nigeria. In the Warm Semi-arid Climate environment, rainfall and temperature significantly predicted sweet potatoes yield (F,111.0451) = $p<0.05$ which indicate that temperature and rainfall (climate) play significant role in the yield of sweet potatoes in the Warm Semi-arid Climate environment ($b_1$= R; .332 $P<0.05$, $b_2$= T.458 $P<0.05$). The model revealed a positive relationship (r=.781) and the $R^2$ was .610. This means that rainfall and temperature jointly explained 61% of variation in sweet potatoes yield in the Warm Semi-arid Climate environment of Nigeria.

**Table 4: The relationship between Sweet Potato yields and climate (*rainfall and temperature*) in the climate belts of Nigeria.**

| Climate zone | Regression weights | N | *Beta* | R | $R^2$ | *F* | *P*-value |
|---|---|---|---|---|---|---|---|
| TM | Rainfall, Temp→S/potatoes | 40 | .155<br>.438 | .671 | .450 | 182.2301 | 0.009 |
| TS | Rainfall, Temp→S/potatoes | 40 | .231<br>.420 | .751 | .564 | 132.1410 | 0.003 |
| WSC | Rainfall, Temp→S/potatoes | 40 | .332<br>.458 | .781 | .610 | 111.0451 | 0.001 |
| WDC | Rainfall, Temp→S/potatoes | 40 | .218<br>.369 | .549 | .301 | 45.0051 | 0.004 |

***N:B: TM=Tropical Monsoon; TS=Tropical Savanna; WDC= Warm Semi-Arid Climate; WDC=Warm Desert Climate.***
**Source: Author's data analysis**

In the Warm Desert Climate environment, rainfall and temperature significantly predicted ginger yield (F,29.8517) = $p<0.05$ which implies that temperature and rainfall play significant role in the yield of ginger in the Warm Desert Climate environment ($b_1$= R; .317 $P<0.05$, $b_2$= T.281 $P<0.05$). The model revealed a positive relationship (r=.549) and the $R^2$ was .301. This means that rainfall and temperature jointly explained 30.1% of variation in ginger yield in the Warm Desert Climate Belt of Nigeria. In the Warm Desert Climate environment, rainfall and temperature significantly predicted sweet potatoes yield (F,45.0051) = $p<0.05$ which indicate that temperature and rainfall (climate) play significant role in the yield of sweet potatoes in the warm desert climate environment ($b_1$= R; .218 $P<0.05$, $b_2$= T.369 $P<0.05$). The model revealed a positive relationship (r=.549) and the $R^2$ was .301. This means that rainfall and temperature jointly explained 30.1% of variation in sweet potatoes yield in the Warm Desert Climate environment of Nigeria.

## DISCUSSION OF RESULTS

Annual, seasonal and monthly Rainfall and temperature values have been seen from the results of the study that they vary with climate belt thus affecting the yields of Sweet Potato across the climate belts of Nigeria. The relatively low amounts of rainfall of WSA and WD Climate Belts as against TM and TS threatens the yield of Sweet potato in the belts which call for irrigation if maximum yield is to be attained (Agele & Bolarinwa, 2018). This is corroborated by Kwawu, Sarpong & Agyire-Tettey, 2021who stated that successful production of sweet potato can be attained where a moderate rainfall at the sowing time till the rhizomes sprout, fairly heavy and well-distributed showers during the growing period, and dry weather with a temperature of $28^0$ to $35^0$C for about a month before harvesting are available. On the other hand, flooding and water-logging resulting from heavy rainfall and water stress such as drought resulting inadequate rainfall reduce the yields of agricultural crops including sweet potato (Daccaache *et al*, 2012).Generally, the identified climate events that affect sweet potato farming are extreme rainfall (TM & TS), Flooding (TM, TS & WSA) and drought conditions (TS, WSA & WD). This is in line with the work of (Agele & Bolarinwa, 2018) who affirms that rainfall and temperature significantly affect agricultural production.

## CONCLUSION AND RECOMMENDATION

Over the period studied across the climate belts rainfall is more variable than temperature. Also, the relationship between rainfall, temperature and yield during the period studied is significant (1980 – 2019). Sweet potato is purely a product of the rainfall and temperature as observed, although, other climate variables and factors notwithstanding.

This study recommends innovation specific to agriculture and that focuses on the impact on food and nutrition security, risk management, sustainable natural resources management and economic development outcomes (FAO, 2012, 2014). Drawing on this definition, climate-smart innovations include technologies and farming practices (e.g., new types of crops), farm production processes (e.g., conservation agriculture) and postharvest management (e.g., improved crop storage) that are diffused to improve farm productivity, conservation agriculture, crop diversification and improved crop storage technologies. climate change adaptation and mitigation. These innovations are diverse and range from farm-level techniques to international policy and finance mechanisms (Arslan et al., 2015) that climate smart agriculture should be encouraged. Planting and harvesting of sweet potato by farmers should align with the seasons as found in each of the four climate belts. Also, improvement in the agricultural practice and technology for farming is greatly needed. If Nigeria continues to rely on rainfall for sweet potato production without involving irrigation when the rains are gone will make the country not maximize the yield of the crop, and by extension reducing the economic benefits from the crop. Therefore, dams should be built by governments at all levels (Federal, State and Local Government Area) so as to encourage irrigation. Future growth in sweet potato is essential to provide sustainable supplies for human nutrition, creating jobs, and meeting the food security of the rapidly growing population.

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