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Research Article

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Special Issue

A Themed Issue in Honour of Professor Ekedimogu Eugene Nnuka on His retirement.

This themed issue honors Professor Ekedimogu Eugene Nnuka, celebrating his distinguished career upon his retirement. His legacy of exemplary scholarship, mentorship, and commitment to advancing knowledge is commemorated in this collection of works.

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Abstract

After rice and maize, cassava (Manihot esculenta) is the third-largest source of calories in Africa's tropical and subtropical regions. Most rural families in Nigeria regularly eat any variety of cassava. The consequences of climate change pose a threat to Nigeria's cassava production. The goal of the research was to demonstrate a direct correlation between Anambra State's cassava yield and climatic data. By employing analytical instruments such as Microsoft Excel 2019 and DSSAT Version 4.8, a comprehensive examination spanning forty years produced important findings. Temperature, precipitation, humidity, wind speed, and sun radiation were all closely examined. Maximum temperatures ranged from 31.83°C to 35.4°C throughout the 1981–2021 research period, while minimum temperatures varied from 11.77°C to 17.21°C. Wind speeds ranged from 1.57 m/s to 1.87 m/s, rainfall varied from 885.94 mm to 3174.61 mm yearly, and solar radiation varied from 61.6 w/m2 to 133.3 w/m2. Significant variance was seen in the yield of cassava, which varied from 108.64 thousand metric tonnes in 1981 to 4065.66 thousand metric tonnes in 2021. This indicates the dynamic impact of climate conditions on agricultural output. Nonetheless, disparities seen between the cultivar coefficient values obtained from modelling tools and the real values underscored the necessity for more improvement in modelling methodologies to precisely represent the subtleties of cassava phenology and yield dynamics. Additionally, regression and correlation analyses were performed to break out the individual and combined effects of meteorological variables on cassava yield.

Keywords: Cassava, DSSAT Model, Crop Data, Climatic Factors

1. Introduction

In Nigeria, agriculture employs almost two thirds of the working force, generates 88% of non-oil revenues, and contributes 42.2% of GDP (Yakubu and Akanegbu, 2015). Crops (85%), cattle (19%), fisheries (4%) and forestry (1%), along with their respective shares, all contribute to the Agricultural GDP. Climate variability is one of the most important factors influencing crop production year over year, even in high yield and high technology agricultural areas. In Africa's tropical and subtropical regions, Cassava (Manihot esculenta) is the third largest source of calories after rice and maize (FAO, 2020). Africa presently generates half of the world's cassava consumption, and it is widely farmed in various Sub-Saharan African nations (FAO, 2020). Nigeria produces the majority of the world's cassava the next top producers are South-East Asia, Brazil, Indonesia, Thailand, and Vietnam (FAO, 2021). The majority of rural families in Nigeria regularly eat any variety of cassava. (i)The most favoured variant is TME 419. (ii). Dixon, formerly referred to as TMS-9800581(iii.) Previously referred to as 1632 (TMS-981632), Farmer's Pride (iv.) Fine Face (formerly designated as 0505; TMS-980505) (v). Sunshine (TMS-070593), formerly known as 0593(vi). Ayaya, which was once CR36-5 OR 365 (CR36-5) (Dola Adeboye ,2020). Nigeria's cassava output is in danger due to the effects of climate change. Rain-fed agriculture is vulnerable to shifting climate factors since it depends on an appropriate and sustainable climate to stay productive (Lenis et al., 2020). Currently, climate change-related negative seasonal variations and shifts pose threat to optimal cassava output. Cassava production is thus, being impacted by climate change on a global, regional, and local scale (FAO, 2022).

Nigeria's agricultural industry and food security are particularly vulnerable to the effects of climate change due to the country's high ambient temperature and erratic rainfall patterns. The detrimental effects of climate change on their crops are already being seen by a large number of cassava growers in southern Nigeria. According to Henri-Ukoha, (2020), cassava crops in Nigeria's low-lying tidal coastal towns have been decimated by floods brought on by climate change.

Several authors have examined the relationship between weather variables such as temperature and rainfall and agricultural practices, coming to the conclusion that although temperature can influence the duration of the growing season, rainfall cannot. Given the importance of temperature and rainfall for agricultural activities, a detailed analysis of the relationship between these variables is necessary for both meteorologists and farmer factors (cantelaube, 2005; cong, 2012). Since temperature and rainfall directly affect the biological growth of plants, there is a significant relationship between agricultural output and these meteorological factors. Numerous studies have examined how climatic variables interact and how it affects agriculture, especially crop productivity. Owing to harsh weather patterns and population expansion, there is a current requirement for food production. This requirement is now being met by cassava, a significant home-grown crop (Onyeneke et al., 2021). The necessity to address these alarming issues prompted the study. The research gap in this study is trying to get which climatic variables that has the highest impact on cassava production in Anambra state. Yes, without a doubt! A variety of factors, broadly classified as climatic and non-climatic, influence plant growth. The following lists both types of factors:
Climate-related factor.

(i) Temperature: Certain temperature ranges are ideal for the growth of plants. Too high or too low of a temperature can stress plants and hinder their ability to thrive. (ii)Light: Plant growth and development are influenced by the quality (light wavelengths), duration (photoperiod), and intensity of light. (iii) Precipitation: Plant growth depends on a sufficient supply of water. Water imbalances can cause wilting, other physiological problems, or impede growth. (iv) Humidity: Humidity levels affect the rate of transpiration in plants. High humidity can reduce water loss from plants, while low humidity can increase water stress. (v) Wind: Wind can influence the growth of plants by encouraging transpiration, lowering leaf temperature, and possibly even causing physical harm, particularly to young or delicate plants.
Non-climatic factors
(i)Soil: The pH, texture, and nutritional content of the soil are essential for plant growth. For best growth, different plants require different types of soil. (ii)Nutrients: Micronutrients and essential nutrients like phosphorus, potassium, and nitrogen are necessary for plant growth.(iii)Water availability: In addition to precipitation, soil water-holding capacity and irrigation affect how much water is available to plants.(iv) Topography: Elements including water drainage, temperature fluctuations, and solar exposure are influenced by slope, aspect (the direction a slope faces), and elevation.(v)Human Factors: Plant growth can also be indirectly impacted by human activities that modify soil conditions, introduce contaminants, or destroy habitats. These activities include farming, land use changes, and pollution. (vi)Biological Factors: Plant growth can be strongly impacted by interactions with other species, such as pests, illnesses, and rival plants.

1.1 Effects of some of these climate factors on cassava production

The production of crops and the productivity of animals are directly impacted by meteorological variables, which means that agricultural productivity depends on them. Studying the effects of meteorological variables is therefore unavoidable due to the vital roles they play in agriculture and the environment, which will aid in assessing agricultural output and improving overall performance. Since agricultural goods are directly responsible for human survival, the impact of weather factors on agricultural output globally is a significant issue. Researchers' top concern right now is the impact of weather and climatic changes on the ecosystem. Weather is the constant fluctuation of atmospheric factors, including temperature, pressure, humidity, wind speed, precipitation, and others. Contrarily, climate refers to the average atmospheric conditions over a minimum of three decades. Weather factors have an impact on agricultural activities in terms of crop yield and animal productivity. To determine the combined effects of meteorological factors and their interactions on agricultural productivity, it is essential to have knowledge of these variables and their interactions. The combined effects of a few weather variables on crops will be investigated, and the findings showed that the harsh weather can be held responsible for the crops' subpar performance, which amounted to 93% losses (Vergara' 2018). Since better judgements may be made to reduce subpar agricultural production, a good understanding of meteorological variables is essential.

The study of weather variables is essential because the patterns and structures they reveal can be used in decisions and policies to reduce the adverse effects of weather on the environment. Given that the information can be used to control the environment, the value of organising the presentation of meteorological variables cannot be overstated. Statistical approaches can be used to make precise predictions of weather variables in order to avert agricultural activity-related losses like those seen in previous years. By taking a meteorological variable from a known family of distributions or an unknown probability distribution, density estimation creates a probability estimate. Either the parametric technique or the nonparametric method can be used to observe how a probability density estimate is built.

2.0 Material and methods

2.1 Description of the Study Area.

Anambra State, named after the Anambra River (Omambala), is the research area. It is in the South-Eastern region of Nigeria, between latitudes 50 40'N and 60 50'N, and longitudes 60 35'E and 70 25'E (Figures 3.1 and 3.2). Kogi State is to the North, Imo State is to the South, Delta State is to the West, and Enugu State is to the East. There are twenty-one local government areas (LGAs) in the state, including four Agricultural zones which include Aguata, Anambra (East and West), Awka, and Onitsha. Four blocks belong to Anambra (East and West), five to Awka, six to Aguata, and six to Onitsha. The climate is typically equatorial, with two distinct seasons: dry and wet seasons. Throughout the state, a wide range of agricultural goods and raw resources are produced. Anambra West grow yams, whereas Anambra East grows rice as well. Cassava is the most common crop in Orumba South Local Government. The state's environmental circumstances allow for the production of forestry and agribusiness items such oil palm, rice, yam, cassava, and fish. According to Johnson et al., (2021), Anambra is rich in natural gas, bauxite, crude oil, and ceramics, and it has almost all arable land. The Anambra State statistical year book (SYB), 2017 states that 98 percent of the state's population is Igbo, with a small Igala community (2%) that resides in the North-west of the State. Throughout the state, a wide range of agricultural goods and raw resources are produced. Anambra West grow yams, whereas Anambra East grows rice as well. Cassava is the most common crop in Orumba South Local Government. Fig 2.2 below shows the map of Anambra state with the various local governments.

Fig 2.1 showing the 21 local government area of the study area

2.1.1 Data collection

The cassava data used for this study were sourced from the Anambra State Agricultural Development Programme (ASADEP) Awka reports on agricultural production survey. data like temperature, rainfall, relative humidity, wind speed, and solar radiation data were extracted for 41-year period (1981–2021), from the Prediction of Worldwide Energy Resource (POWER) Project, (https://power.larc.nasa.gov/data-access-viewer

3.0 Results and Discussions

3.1 Temporal Variation in Average Climate Factors and Cassava Yield in Anambra state.

Observed climate conditions for 1981 to 2021 in Anambra State showed that temperature ranged between 25°C and 30°C, annual rainfall ranging from 1500 mm to 2000 mm, relative humidity levels of 75% to 85%, moderate wind speeds of 1.5 m/s to 2 m/s, and solar radiation between 1000 w/m2 and 1200 w/m2, align closely with the climatic data presented in Table 3.1 below.

Table 3.1: 41 years (1981 – 2021) average temperature, rainfall, relative humidity, wind, solar radiation, and cassava yield in Anambra state.

Year	Temp Max (°C)	Temp Min (°C)	Rainfall (Mm)	Relative Humidity (%)	Wind (M/S)	Solar Radiation (W/M^2)	Cassava Yield Per Hectare (1000 MT)
1981	32.73	15.08	1940.62	84.56	1.67	110.8	108.64
1982	31.85	14.53	2852.93	85.88	1.72	77.3	121.55
1983	33.81	12.76	3100.78	84.12	1.87	116.6	135.992
1984	32.62	13.37	2135.74	84.94	1.63	113.2	152.15
1985	32.45	14.52	1534.57	83.94	1.65	61.6	170.23
1986	32.33	13.92	1676.95	84.88	1.81	119.4	190.46
1987	33.19	15.7	1993.36	84.81	1.65	133.3	213.09
1988	33.26	16.64	2520.7	85.94	1.72	109.7	238.41
1989	32.97	12.12	2262.3	83.75	1.77	119.2	266.74
1990	32.98	16.48	1197.07	84.38	1.74	122.3	298.43
1991	32.84	14.58	1318.36	84.38	1.81	92.6	333.89
1992	34.48	12.58	2135.74	83.44	1.88	117.8	373.56
1993	32.52	13.22	2299.22	85.12	1.77	96.6	417.95
1994	32.4	13.88	2394.14	85.5	1.78	111.9	467.61
1995	32.2	15.1	2668.36	85.44	1.67	125.1	523.17
1996	32.87	16.76	2304.49	85.5	1.67	94.7	585.44
1997	32.82	14.55	1940.62	84.38	1.73	86.5	655
1998	34.25	14.27	1582.03	83.81	1.75	131.6	724.561
1999	32.45	15.26	885.94	85.12	1.69	79.2	801.509
2000	33.57	14.51	3174.61	83.81	1.77	121.1	886.629
2001	31.83	13.58	1355.27	84.06	1.7	119.23	980.789
2002	33.47	12.99	1740.23	84.06	1.75	118.62	1084.95
2003	32.9	14.1	1608.4	85.75	1.66	117.93	1200.17
2004	32.95	15.8	1186.52	86	1.7	116.4	1327.63
2005	32.8	13.21	991.41	84.81	1.76	116.34	1468.62
2006	33.63	14.18	1476.56	85.25	1.68	117.18	1,421
2007	32.74	12.21	2483.79	85.5	1.7	117.32	1624.59
2008	32.4	13.83	1160.16	84.31	1.61	117.45	1797.12
2009	32.9	16.53	1518.75	86.06	1.61	117.71	1987.97
2010	33.75	15.58	1756.05	85.62	1.61	117.98	2199.09
2011	32.12	12.76	1582.03	85.12	1.66	116.81	2432.63
2012	32.38	15.1	1492.38	85.88	1.7	117.16	1639.19
2013	32.8	14.02	1840.43	86.88	1.68	118.28	1813.27
2014	32.55	16.3	1059.96	85.12	1.62	117.95	2005.84
2015	32.72	12.65	1086.33	83.62	1.83	115.8	2218.86
2016	35.4	15.54	1692.77	83.69	1.7	116.16	2454.5
2017	33.17	16.51	2109.38	85.75	1.57	115.62	2715.17

2018	33.23	11.77	2114.65	85	1.66	117.06	3003.52
2019	32.64	16.44	2257.03	85.38	1.65	118.53	3322.49
2020	32.98	13.37	2172.66	84.06	1.65	117.76	3675.34
2021	32.83	17.21	2192.44	86.06	1.58	116.5	4065.66

Source: https://power.larc.nasa.gov/data-access-viewer/ (climate data), Anambra State Agricultural Development Programme (ASADEP) Awka (cassava yield data)

The temperature data from 1981 to 2021 generally falls within the optimal range for cassava growth, with maximum temperatures ranging from 31.83°C to 35.4°C and minimum temperatures ranging from 11.77°C to 17.21°C. Additionally, relative humidity levels, wind speeds, and solar radiation values recorded over the years indicate favorable environmental conditions conducive to cassava growth and yield. These observations suggest that the climatic conditions in Anambra State generally support optimal cassava cultivation, contributing to the high cassava yields reported in Table 3.1. Rainfall patterns in Anambra State, with values ranging from 991.41 mm to 3174.61 mm, also meet the recommended range for cassava cultivation (Moreno et al., 2021).

3.1.1 Temperature trends

The trend in maximum temperature (°C) from 1981 to 2021 is depicted in Figure 3.1. The data exhibits fluctuations within a relatively narrow range, with occasional peaks and dips. For instance, in 2016, there is a notable spike in temperature, reaching 35.4°C, while in 2011 there is a dip to 32.12°C. Overall, no clear upward or downward trend is evident from the raw data.

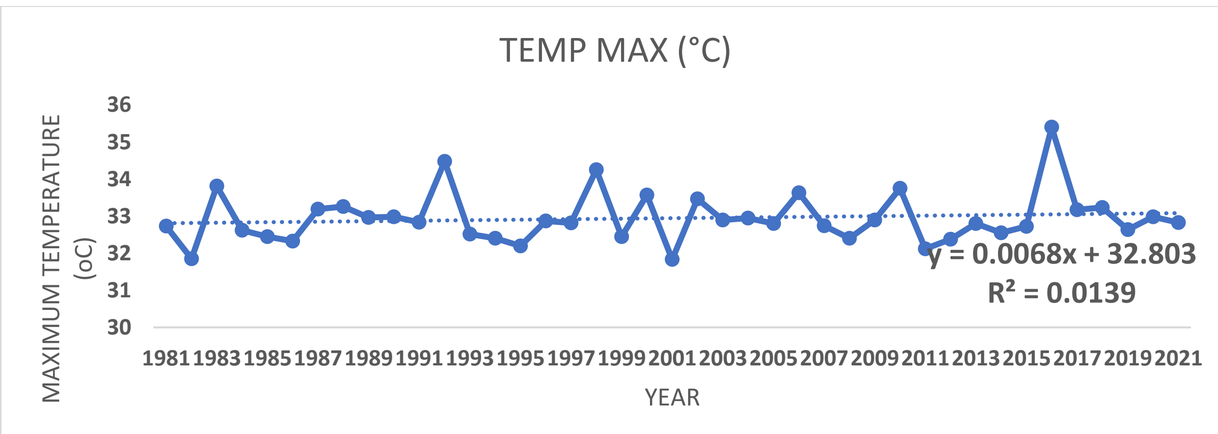

Figure 3.1: Trend in maximum temperature (°C) over time

3.1.2 Relationship between maximum temperature and cassava yield

The trend analysis between maximum temperature (°C) and cassava yield per hectare (1000 metric tons) over time, depicted in Figure 3.2, reveals interesting insights. Temperature plays a crucial role in determining cassava yield, affecting both plant growth and tuber development. Here are some key ways in which temperature influences cassava production: (i)Optimal Growth Range: Cassava grows best within a temperature range of approximately 25-29°C (77-84°F). This range provides optimal conditions for photosynthesis, root development, and overall plant growth.(ii)Temperature Extremes: Extreme temperatures, both high and low, can adversely affect cassava yield: High Temperatures**: Prolonged exposure to high temperatures above 35°C (95°F) can reduce photosynthesis efficiency, slow down growth, and reduce tuber formation. It can also lead to increased water stress, affecting the plant's ability to develop tubers. **Low Temperatures**: Cassava is sensitive to frost and temperatures below 18°C (64°F). Cold temperatures can stunt growth, damage leaves, and inhibit root development. This can ultimately lead to reduced yields or even plant death in severe cases. (iii)Flowering and Seed Set: Temperature influences flowering in cassava. High temperatures can inhibit flowering, which is crucial for seed production. Inadequate seed set due to temperature stress can affect subsequent planting and the genetic diversity of cassava crops. (iv)Geographic Variation: Cassava varieties have different temperature tolerances, often adapted to specific climatic zones. Varieties grown in cooler regions might have different optimal temperature ranges compared to those grown in tropical or subtropical areas. (v)Climate Change Impact: With climate change, shifts in temperature patterns can affect cassava production. Increased frequency of heatwaves or altered seasonal temperature patterns can disrupt growth cycles and impact overall yield. (vi)Management Strategies: Farmers may employ various strategies to mitigate temperature effects on cassava, such as selecting appropriate planting times, utilizing shade or mulch to moderate soil temperature, and selecting cultivars suited to local temperature conditions. In summary, while cassava is adaptable to a range of climates, temperature plays a critical role in its growth and yield. Understanding these temperature dynamics is essential for optimizing cassava production and ensuring food security in regions where cassava is a staple crop.

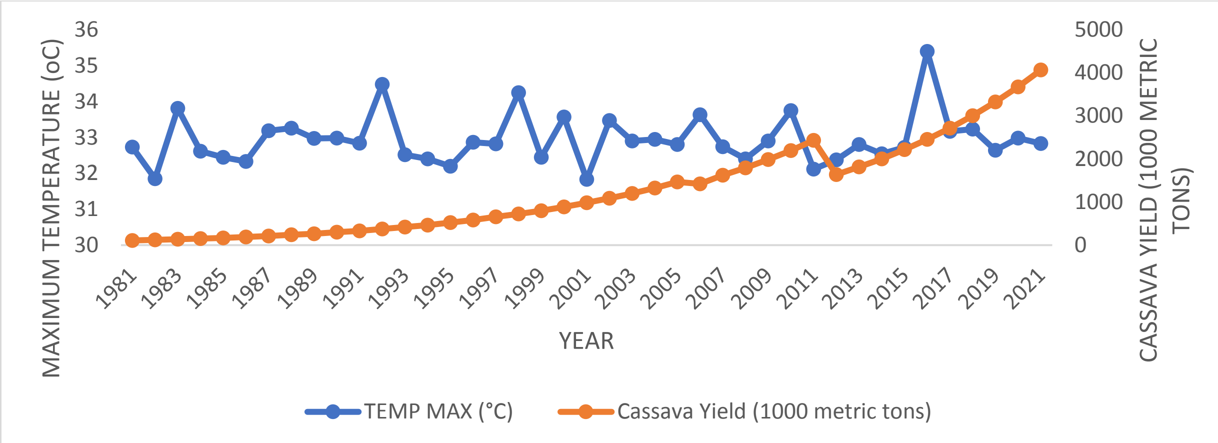

Figure 3.2: Trend analysis of maximum temperature and cassava yield

Initially, from 1981 to the mid-1990s, there seems to be a general increase in cassava yield alongside fluctuations in maximum temperature, suggesting a potential positive correlation between the two variables. For instance, between 1981 and 1994, as maximum temperatures fluctuated between 31.85°C and 34.48°C, cassava yield showed a steady increase from 108.64 to 467.61 thousand metric tons. However, from the late 1990s onwards, despite fluctuations in maximum temperature, cassava yield continues to exhibit an overall upward trend, reaching its peak in 2021 at 4065.66 thousand metric tons. Notably, in recent years, maximum temperature remained relatively stable around 32-33°C, while cassava yield continued to rise substantially. This trend indicates that factors beyond maximum temperature, such as advancements in agricultural practices, technology, and genetic improvements in cassava varieties, might be contributing to the sustained increase in yield. Therefore, while maximum temperature likely influences cassava yield to some extent, other factors play significant roles in determining the final yield outcome over time.

3.1.3 Rainfall Trends

Examining the trend between time and rainfall from 1981 to 2021 reveals some interesting insights. Initially, there seems to be a fluctuating pattern in rainfall, with some years experiencing higher rainfall amounts compared to others as shown in Figure 3.3.

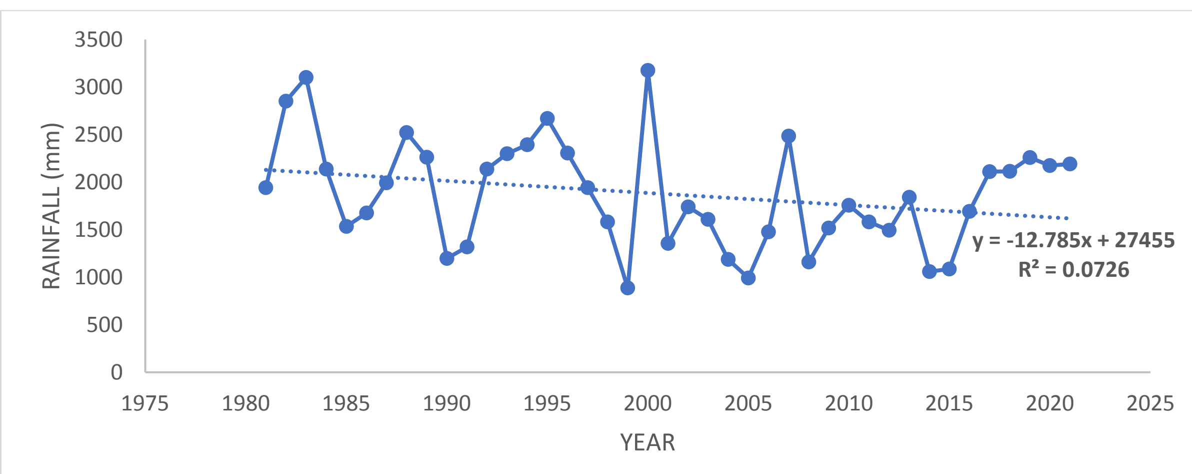

Figure 3.3: Trend analysis of rainfall over time

For instance, in 1983, rainfall peaked at 3100.78 mm, while in 1999 it dropped significantly to 885.94 mm. However, applying a linear trend model ($Y = -12.785x + 27455, R^2 = 0.0726$) to the data suggests a slight overall decrease in rainfall over the years, although the correlation is weak. The model implies that for each passing year, rainfall decreases by approximately 12.785 mm, with an intercept of 27455 mm. Despite the model indicating a downward trend, it's essential to note that the coefficient of determination (R^2) is relatively low at 0.0726, indicating that only about 7.26% of the variability in rainfall can be explained by the linear relationship with time. This suggests that other factors beyond time may significantly influence rainfall variability in Anambra State, such as climate change and atmospheric circulation patterns. Therefore, while there is a suggestive trend of decreasing rainfall over time, further analysis and consideration of other variables are necessary to fully understand the dynamics of rainfall in the region.

3.1.4 Relationship between rainfall and cassava yield

Analyzing the relationship between rainfall and cassava yield from 1981 to 2021 reveals several significant observations as depicted in Figure 3.4.

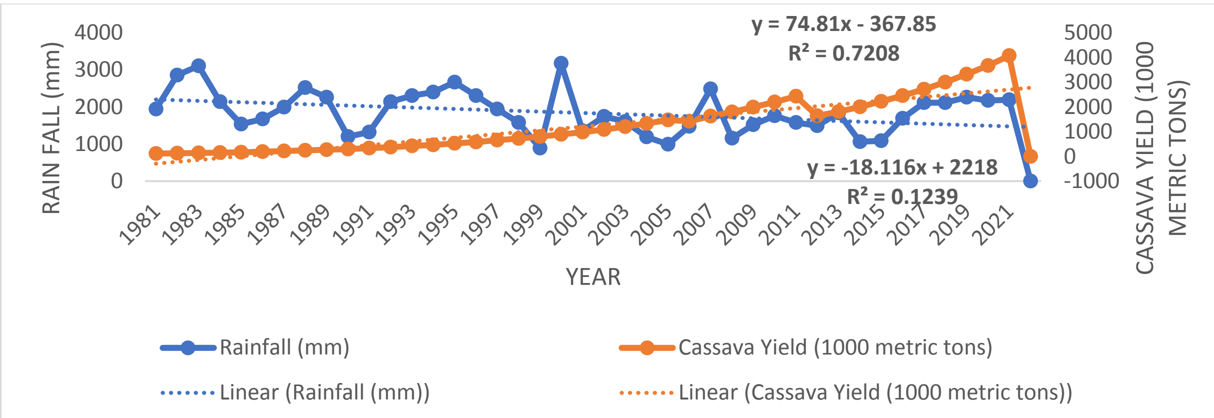

Figure 3.4: Trend analysis of rainfall and cassava yield

Initially, there appears to be a varied pattern in both rainfall and cassava yield over the years, with some years experiencing higher rainfall and yield compared to others. While both models show a trend over time, it's essential to note that the model for cassava yield has a much higher coefficient of determination ($R^2 = 0.7208$), indicating a stronger correlation between time and yield compared to rainfall. This suggests that factors beyond rainfall, such as agricultural practices, soil fertility, and crop management techniques, may also significantly influence cassava yield variability in Anambra State. Therefore, while rainfall plays a role in determining cassava yield, other variables must also be considered to fully understand and optimize crop productivity in the region.

3.1.5 Relative humidity trends

Examining the trend in relative humidity from 1981 to 2021 provides insights into the changing climatic conditions in Anambra State as shown in Figure 3.5. The data shows fluctuations in relative humidity levels over the years, with values ranging from 83.44% to 86.06%.

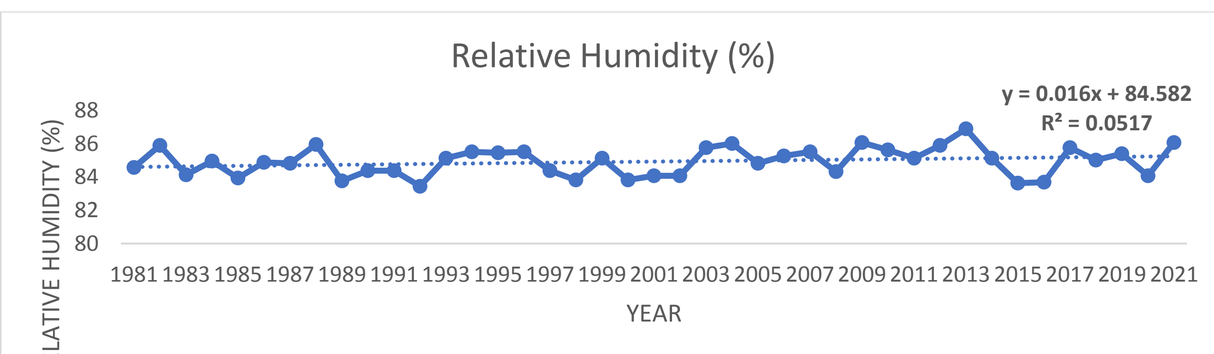

Figure 3.5: Trend analysis of relative humidity

While there isn't a clear upward or downward trend visible in the raw data, applying a linear trend model (Y = 0.016x + 84.582, R^2 = 0.0517) reveals a slight increase in relative humidity over time. According to the model, for each passing year, relative humidity increases by approximately 0.016%, with an intercept of 84.582%. However, it's essential to note that the coefficient of determination (R^2 = 0.0517) indicates a weak correlation between time and relative humidity, suggesting that other factors beyond the linear trend model may influence humidity fluctuations in the region. These could include regional climate patterns, seasonal variations, and local environmental changes

3.1.6 Relationship between relative humidity and cassava yield

The data spanning from 1981 to 2021 provides valuable insights into the relationship between relative humidity and cassava yield in Anambra State as shown in Figure 3.6.

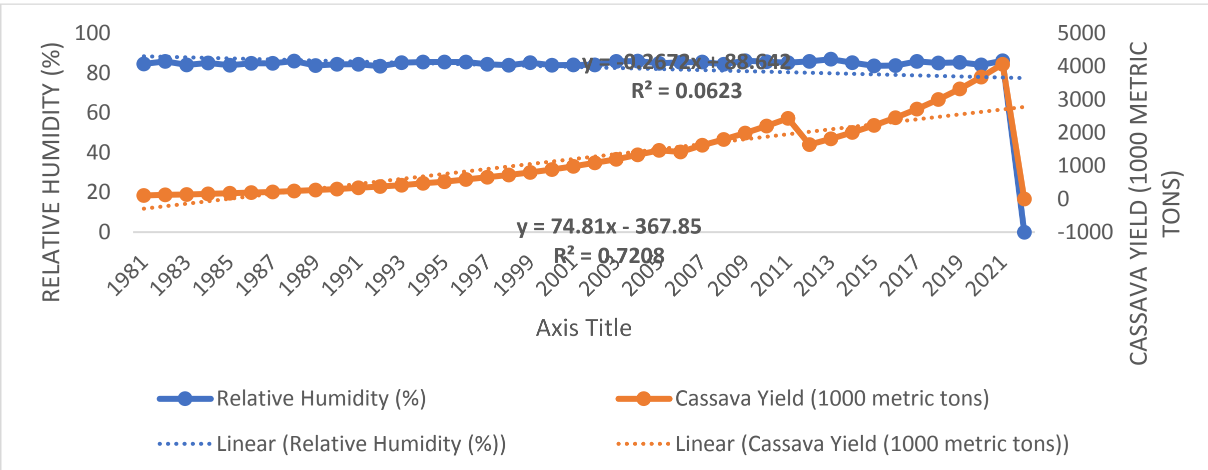

Figure 3.6: Relationship between relative humidity and cassava yield

Relative humidity fluctuates between 83.44% and 86.06%, while cassava yield varies from 108.64 to 4065.66 thousand metric tons. Despite the apparent variability, a linear trend line reveals a subtle positive correlation between relative humidity and cassava yield. The model Y = 84.959x - 513.33, (R^2 = 0.8942) suggests that for each percentage increase in relative humidity, cassava yield increases by approximately 84.959 thousand metric tons, with an intercept of -513.33 thousand metric tons. This model explains 89.42% of the variance in cassava yield, indicating the significant influence of relative humidity on yield fluctuations. However, it's important to note that the coefficient of determination (R^2 = 0.0517) for the relative humidity trend suggests a weak explanatory power, implying that other factors beyond relative humidity may also contribute to cassava yield variations.

3.1.7 Wind speed trends

The dataset from 1981 to 2021 shows fluctuations in wind speed in Anambra State, ranging from 1.57 m/s to 1.88 m/s as shown in Figure 3.7.

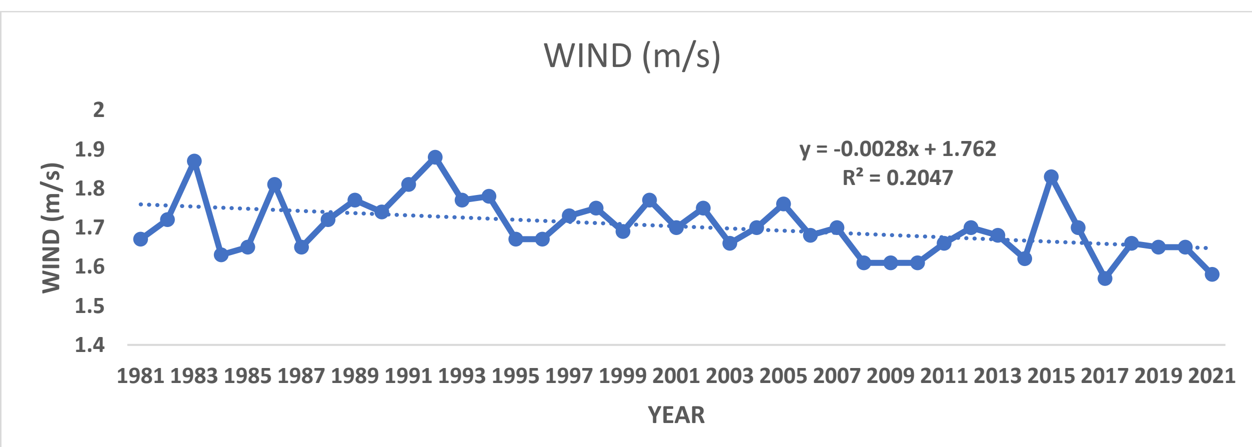

Figure 3.7: Trend analysis of wind speed over time

Despite some variability, a general trend is observed over the years. The linear trend line, modelled by y = -0.0028x + 1.762, (R^2 = 0.2047), indicates a slight negative correlation between wind speed and time. This suggests that, on average, wind speed has slightly decreased over the years. However, the coefficient of determination (R^2 = 0.2047) indicates that only about 20.47% of the variation in wind speed can be explained by time, indicating a relatively weak relationship. Other factors not captured in this analysis may also contribute to the fluctuations in wind speed observed over time.

3.1.8 Relationship between wind speed and cassava yield

The wind speed ranged from 1.57 m/s to 1.88 m/s over this period, showing fluctuations. Meanwhile, cassava yield ranged from 108.64 to 4065.66 thousand metric tons as shown in Figure 3.8.

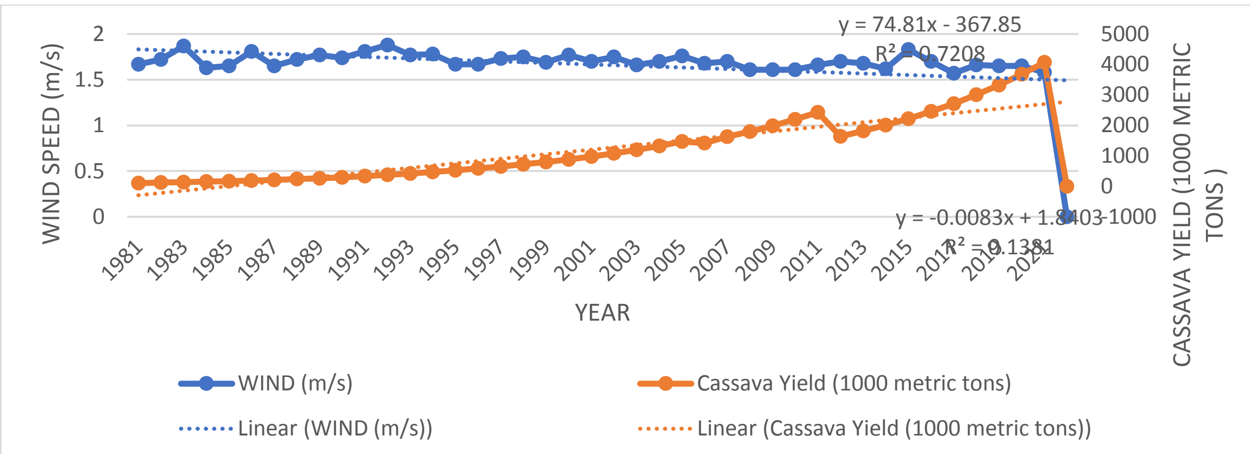

Figure 3.8**:** Relationship between both wind speed and cassava yield.

Analyzing the relationship between wind speed and cassava yield, we find a weak negative correlation. The linear trend line for wind speed, modelled by Y = -0.0028x + 1.762, (R^2 = 0.2047), suggests a slight decrease in wind speed over time. The coefficient of determination (R^2 = 0.2047) indicates that only about 20.47% of the variation in cassava yield can be explained by changes in wind speed. On the other hand, cassava yield exhibits a strong positive correlation with time. The linear trend line for cassava yield, modelled by Y = 84.959x - 513.33, (R^2 = 0.8942), shows a significant increase in yield over the years. The coefficient of determination (R^2 = 0.8942) indicates that approximately 89.42% of the variation in cassava yield can be explained by time. While wind speed seems to have a slight negative effect on cassava yield, other factors not captured in this analysis, such as rainfall, temperature, and soil fertility, likely play more significant roles in determining cassava yield fluctuations over time.

3.1.9 Cassava yield trends

The relationship between time and cassava yield is depicted in Figure 3.9, revealing a significant upward trend over the years. The data from the figure 3.9 showcases this trend, with cassava yield steadily increasing from 108.64 thousand metric tons in 1981 to 4065.66 thousand metric tons in 2021. The trendline model Y = 84.959x − 513.33, Y = 84.959x − 513.33 further supports this observation, indicating a strong positive correlation between time and cassava yield. With an R^2 value of 0.8942, the model explains approximately 89.42% of the variability in cassava yield, suggesting that time plays a crucial role in influencing cassava production. This interpretation underscores the importance of monitoring temporal patterns in agricultural yield and highlights the potential impact of various factors on cassava cultivation practices and productivity over time.

3.2 Correlation Analysis

Table 3.2 below presents the correlation coefficients between various meteorological factors and cassava yield in Anambra State. The correlation analysis offers valuable insights into the relationships between these variables, shedding light on their potential impacts on cassava productivity. Starting with temperature variables, maximum temperature (°C) shows a weak positive correlation with cassava yield (r = 0.117), suggesting that higher maximum temperatures may be associated with slightly increased cassava yields. However, the correlation between minimum temperature (°C) and cassava yield is even weaker (r = 0.016), indicating a negligible relationship between these two variables. Rainfall (mm) exhibits a moderate negative correlation with cassava yield (r = -0.092), implying that higher rainfall levels might lead to reduced cassava yields. This negative correlation suggests that excessive rainfall could potentially hinder cassava growth and yield. Relative humidity (%) demonstrates a moderate positive correlation with cassava yield (r = 0.073), indicating that increased humidity levels could be conducive to higher cassava yields. This positive correlation suggests that adequate moisture levels in the air might promote favorable conditions for cassava growth and development. Wind speed (m/s) displays a strong negative correlation with cassava yield (r = -0.519), suggesting that higher wind speeds are strongly associated with decreased cassava yields. This negative correlation indicates that windy conditions may adversely impact cassava plants, potentially leading to yield reductions. Solar radiation (w/m^2) shows a moderate positive correlation with cassava yield (r = 0.289), indicating that higher solar radiation levels could contribute to increased cassava yields. This positive correlation suggests that adequate exposure to sunlight may promote photosynthesis and enhance cassava growth and productivity.

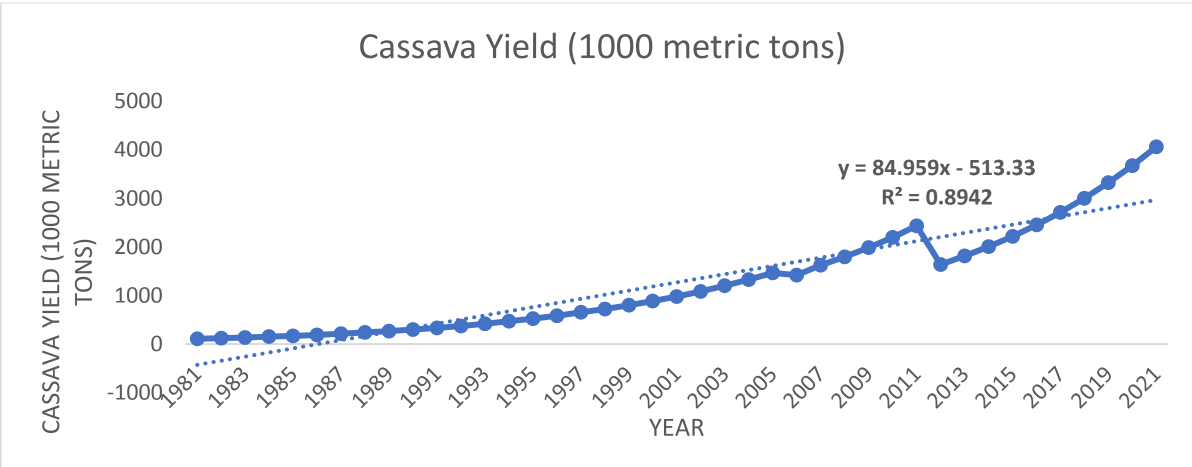

Figure 3.9: Trend in cassava yield over time

Table 3.2: Result of the correlation analysis

	Year	Temp max (°C)	Temp min (°C)	Rainfall (mm)	Relative humidity (%)	Wind (m/s)	Solar radiation (w/m^2)	Cassava Yield (1000 metric tons)
Year	1							
Temp max (°C)	0.117760921	1						
Temp min (°C)	0.109046111	0.016269675	1					
Rainfall (mm)	-0.269460436	0.110252751	-0.091869102	1				
Relative humidity (%)	0.227392357	-0.367075828	0.438603558	0.073018425	1			
Wind (m/s)	-0.452485712	0.217189507	-0.496256696	0.14673497	-0.498343755	1		
Solar radiation (w/m^2)	0.326139292	0.311933032	-0.063668724	0.021204201	-0.020089571	-0.026783524	1	
Cassava yield (1000 metric tons)	0.945615419	0.091137657	0.134951957	-0.148675832	0.221698266	-0.5190297	0.289325091	1

3.3 Regression Analysis Result

In order to investigate the relationship between climatic variables and cassava yield in Anambra State, regression analysis was conducted using data collected for 40 years. The regression tables presented below (Table 3.3) provide insights into the individual and collective impacts of various climatic factors on cassava production. The table represents the regression results for a specific climatic variable, including maximum temperature, minimum temperature, rainfall, relative humidity, wind speed, and solar radiation, with cassava yield as the dependent variable.

After applying the regression models, the tables summarize key statistics such as multiple R, R square, adjusted R square, standard error, and the number of observations. These statistics offer valuable insights into the strength and significance of the relationship between each climatic variable and cassava yield. Furthermore, analysing these regression results allows for a deeper understanding of how changes in climatic conditions may influence cassava productivity in the study area.

Overall, the regression model suggests that solar radiation has a significant positive effect on cassava yield, while the other climate variables (TEMP_MAX, TEMP_MIN, Rainfall, Relative Humidity, and WIND) do not have statistically significant effects on cassava yield in this analysis. However, it's essential to note that the high condition number (1.45e+04) suggests potential issues with multicollinearity or other numerical problems, which may affect the reliability of the coefficient estimates. Further diagnostics and refinements to the model may be necessary to address these issues and improve the model's predictive performance.

Table 3.3: Regression Statistics between Cassava yield (1000 Metric tons) and climatic variables

Variable	**Coefficient**	**Standard Error**	**t-value**	**p-value**	R^2
Intercept	451.964	228.034	1.982	0.056	0
TEMP_MAX	-6.007	7.731	-0.777	0.443	0.00831
TEMP_MIN	10.423	7.4	1.409	0.167	0.01821
Rainfall	0.018	0.01	1.776	0.085	0.02211
Relative Humidity	-1.244	2.218	-0.561	0.579	0.04915
WIND	-23.998	37.798	-0.635	0.529	0.26939
Solar Radiation	2.2379	0.472	4.739	0	0.08371

The regression performed here is a multiple linear regression analysis. In this analysis, we used six independent variables (TEMP MAX, TEMP MIN, Rainfall, Relative Humidity, WIND, and Solar Radiation) to predict the cassava yield, which is the dependent variable.

4.0. Conclusion

The study conducted in Anambra State provides valuable insights into the complex relationship between climatic variables and cassava yield, crucial for informing agricultural practices and enhancing productivity. Through comprehensive analyses utilizing DSSAT Version 4.8, Python, and Microsoft Excel Version 2019, we delved into four decades of data, examining critical climatic variables such as temperature, rainfall, humidity, wind speed, and solar radiation. The study uncovered significant variations in cassava yield over the years, showcasing the dynamic influence of climatic factors on agricultural productivity. However, discrepancies between actual cultivar coefficient values and those generated by modelling tools underscore the need for further refinement in modelling techniques to accurately capture cassava phenology and yield dynamics.

The correlation and regression analyses provided deeper insights into the individual and collective impacts of climatic variables on cassava yield. Notably, wind speed emerged as a significant determinant, exhibiting a strong negative correlation with cassava yield (r = -0.519), followed by solar radiation, relative humidity, and other climatic factors. The regression analysis highlighted the significant positive effect of solar radiation on cassava yield, with a coefficient of approximately 2.2379 metric tons per unit increase in solar radiation (p-value < 0.001). However, other climatic variables such as temperature, rainfall, humidity, and wind speed did not show statistically significant effects on cassava yield in this analysis. The multi linear R-squared value of approximately 0.896 indicated that the included climate variables collectively explained about 89.6% of the variability in cassava yield in Anambra State.

5.0 Recommendation

Following a thorough investigation of how climate change affects Anambra State's cassava output, a number of thorough recommendations are put up for the benefit of farmers and the Anambra State administration. In view of the objectives and conclusions of the research, the evaluation of the MANIHOT-Cassava model, and the analysis of meteorological data, the following recommendations are made:

Based on our findings, several recommendations can be made to improve agricultural practices and enhance cassava yield in Anambra State:

1. Refinement of Modelling Techniques: Given the discrepancies between actual cultivar coefficient values and those generated by modelling tools, further refinement in modelling techniques is essential. This would enable more accurate capturing of cassava phenology and yield dynamics, thereby improving the reliability of yield predictions.
2. Holistic Approach to Agricultural Management: Agricultural management strategies should adopt a holistic approach that considers not only climatic variables but also other factors influencing cassava productivity. This includes soil quality, pest and disease management, crop rotation, and agronomic practices. Integrating these factors into management plans can help optimize yield and resilience against changing climatic conditions.
3. Investment in Climate-Resilient Varieties: Research and development efforts should focus on breeding and promoting climate-resilient cassava varieties. These varieties should be tailored to withstand the specific climatic challenges faced in Anambra State, such as temperature fluctuations, variable rainfall patterns, and humidity levels. By cultivating climate-resilient varieties, farmers can mitigate the adverse effects of climate change on cassava yield.

5.1 Limitations of Study/Suggestions for Further Work

However, it's important to acknowledge that there may be other factors beyond climate variables that influence cassava yield and contribute to the remaining percentage of unexplained variability. These could include soil fertility, nutrient availability, pest and disease pressure, crop management practices, genetic characteristics of cassava varieties, and socio-economic factors such as farmer knowledge and access to resources. Additionally, interactions between different environmental and agronomic factors may also play a role in determining cassava productivity. Therefore, while climate variables are significant determinants of cassava yield, considering these other factors is essential for a comprehensive understanding of the factors influencing cassava production and for developing effective strategies to enhance yield and agricultural sustainability.

Conflict of interest:

There is no conflict to declare

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