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A Correlation Analysis of Vapour Pressure Deficit (VPD) and Selected Crop Yield in Nigeria

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Abstract

The study examined the correlation between vapour pressure deficit (VPD) and selected crop yields in Nigeria. To accomplish this, annual temperature, relative humidity, rice, maize and cassava yield data were collected using the ex-post facto research approach. The climate data was extracted from the NASA POWER DAV V2.4.6. Employing the VPD formula using the Excel sheet, the annual VPD was calculated using the mean relative humidity and mean temperature. The crop yield from the Nigerian Bureau of Statistics was accessed to obtain the yields of rice, maize, and cassava from 2000 to 2021. Correlation analysis was used in the study to examine the association between climatic variables and crop yields. The outcome of the study showed that in the past twenty-one (21) years, rice had a weak positive relationship with temperature (0.1037) and vapour pressure deficit (0.2415) and a weak negative relationship with relative humidity (-0.2662). The implication is that rice yields increase with increasing VPD, and maize and cassava require a minimum VPD. Accordingly, the study suggests that farmers should modify their irrigation regimens according to the VPD needs of each crop. Also, farmers should choose crops adapted to local VPD conditions.

Keywords: ***correlation, crop yields, climate change, relative humidity, vapour pressure deficit (VPD)***

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Introduction

Arguably, vapour pressure deficiency (VPD) is the most acutely significant external weather variable that has significant effects on the atmosphere, hydrology, and ecology. The potential effects and ramifications regarding the physical and human surroundings, including plant development, water utilisation effectiveness, net ecosystem production, atmospheric carbon dioxide (CO2) growth rate, etc., can be evaluated by comprehending the processes underlying the fluctuation and trend of the VPD (Noguera et al., 2023). The term "vapour pressure deficit" (VPD) refers to the variation between the air moisture content and its saturation capacity, and a lower VPD indicates a colder, humid environment, whereas a higher VPD denotes a hotter, drier one, while the variation is expressed in pressure units known as kilopascals (kPa) because it generally corresponds to the rate at which plants transpire (the loss of water through the leaf stomata), the vapour pressure deficit is an important indicator in horticulture (Mah, 2024). Vapour pressure deficit (VPD) has emerged as a crucial environmental element that affects stomatal functioning, photosynthesis, and plant growth in crop and horticulture plants (Inoue et al., 2021).

One of the few meteorological variables that significantly affect cloud cover and rainfall frequency is vapour pressure deficit (VPD), which, when complemented by air temperature, is crucial to the evaporation process (Kalbarczyk & Kalbarczyk, 2014). The primary predictor of transpiration, which subsequently determines the effect of drought-related problems on agricultural output, is VPD, followed by light and air temperature (Kalbarczyk & Kalbarczyk, 2014).

A growing body of research conducted across various landmasses worldwide has demonstrated that because of an upward trend in the water vapour in the atmosphere pressure deficit (VPD), the Earth is presently passing through what is known as global "atmospheric drying." For instance, according to Qin et al. (2024), effective utilisation of water resources in the context of climate change requires a comprehension of spatial and temporal trends and variability in vapour pressure deficit (VPD). They went on to say that VPD is a key measure of atmospheric dryness that has an immediate effect on plant evapotranspiration rates, which in turn affects how well an ecosystem functions as a whole. Related research has found that the global vapour pressure deficit (VPD) has increased significantly since the 1990s, resulting in increasing atmospheric water demand for forests (Grossiord et al., 2020). A widespread rise in the atmospheric vapour pressure deficit (VPD) has been connected to climate change (Grossiord et al., 2020; Schönbeck et al., 2022). Global temperature rises during the past 15-20 years have caused the vapour pressure deficit (VPD) to increase exponentially. A significant factor in the current trend of drought-induced plant death rates, although traditionally when considered separately, VPD is a significant determinant of plant viability in terrestrial ecological systems, especially associated with other climate change-related variables (Sperry et al., 2017; Oksanen et al., 2018; Grossiord et al., 2020). This observed trend is predicted to intensify more deeply as climate change continues (López et al., 2021). Two primary factors are believed to be responsible for this effect: (i) an upward trend in saturated vapour pressure brought due to an increase in global temperature; and (ii) a downward trend in actual vapour pressure, which is partly caused due to different hydrological phenomena and partly influenced by the amount of air moisture present at the time (López et al., 2021).

Vapour pressure deficit (VPD) is a critical meteorological variable influencing atmospheric, hydrological, and ecological systems (Noguera et al., 2023). It represents the difference between air moisture content and its saturation capacity, measured in kilopascals (kPa). Lower VPD indicates a cooler, humid environment, while higher VPD signifies hotter, drier conditions, directly affecting plant transpiration, water use efficiency, and crop growth (Mah, 2024; Inoue et al., 2021). VPD also plays a significant role in cloud formation, rainfall patterns, and evaporation (Kalbarczyk &

Kalbarczyk, 2014). It is a primary determinant of transpiration, impacting drought-induced agricultural challenges (Kalbarczyk & Kalbarczyk, 2014).

Recent studies indicate a global increase in VPD, leading to "atmospheric drying" and heightened plant water stress (Grossiord et al., 2020). This trend is attributed to rising global temperatures and declining actual vapour pressure due to hydrological changes (López et al., 2021). Understanding VPD trends is essential for effective water resource management in the context of climate change (Qin et al., 2024). Increased VPD affects plant evapotranspiration, influencing ecosystem functioning and forest water demand (Grossiord et al., 2020; Schönbeck et al., 2022). It is also linked to drought-induced plant mortality, exacerbating climate change's impact on terrestrial ecosystems (Sperry et al., 2017; Oksanen et al., 2018; Grossiord et al., 2020).

Changes in VPD values are impacting crop yields because of changing rainfall patterns and rising temperatures caused by climate change. Water stress from increased VPD reduces agricultural productivity, particularly for crops like maize, rice, and soybeans (Grossiord et al., 2020; García-García et al., 2023; Novick et al., 2024; Han & Leng, 2024). High VPD leads to poor grain quality, increased susceptibility to pests and diseases, and disrupted pollination (Lobell et al., 2014; AghaKouchak et al., 2020; The Intergovernmental Panel on Climate Change [IPCC], 2021; Wang et al., 2024). A VPD of 2.2 kPa can cause significant plant stress, affecting yield and quality, such as fruit cracking in tomatoes (Leonardi et al., 2000; Noh & Lee, 2022).

Despite the importance of VPD in agriculture, water resources management, and climate studies, there is inadequate knowledge of the interaction between VPD and crop yields, particularly as it relates to rice, maize, and cassava yields. This knowledge gap hinders the advancement of effective techniques for handling water resources, optimising crop yields, and mitigating the effects of environmental crises. Most studies undertaken in Nigeria are on the variability and trends of temperature and relative humidity, and their impact on agriculture, water resources and ecological systems. For example, Emaziye (2015) conducted a study to examine the impact of temperature and rainfall on the productivity of yam, maize, and cassava crops in rural areas of Delta State, Nigeria. Obateru et al. (2019) investigated how climate variability affected the yields of certain tuber crops in the Federal Capital Territory (FCT), Nigeria. Sule et al. (2020) investigated how crop yield was affected by climate variability and what that meant for Nigeria's Guinea Savanna's smallholder farmers and precision agriculture. According to data from a few chosen areas in Nigeria's Rivers State, Asogwa et al. (2022) investigate how crop productivity is impacted by climatic variability. Ideki et al. (2024) looked at how Nigeria's agricultural yield was affected by climate variability over the four decades from 1980 to 2020. Expect for Ajetomobi (2016), who analyses the relationship between VPD, cassava and maize yields in Nigeria. However, there are several studies on the consequences of a vapour pressure deficit (VPD) on crop yields in different regions of the world. For instance, the physiology and productivity of protected vegetables in China were investigated by Yu et al. (2023). They discovered that high VPD significantly lowers the yield and water use efficiency of protected vegetables while improving the colour and flavour of the fruit; on the other hand, in addition to altering the anatomical structure of crops and promoting crop photosynthesis, reduced VPD can increase crop output by facilitating better water and nutrient circulation in protected vegetables and boost crops yield, nutritional value, and water usage productivity. Zhang et al. (2017) investigated the consequences of China's shifting vapour pressure imbalance from 1980 to 2008, both spatially and temporally, on crop yields. The study found that VPD grew by more than 0.10 kPa (10 yr)–1 in northeastern and southeast China over the growing seasons of rice, maize, and soybeans. Variations in VPD have varying effects on agricultural yields depending on the crop and the area. Generally, crop yields fell as VPD grew, except for wheat in southeast China. Compared to other crops, maize yields appeared to be more VPD-sensitive in the surrounding regions. Among the major crops, soybeans were shown to be more susceptible to VPD across the most prominent crops, whereas rice proved to be the least susceptible in China.

Crop yields are greatly impacted by climatic conditions, which also affect distribution, quality, and yield. For instance, ideal temperatures promote crop growth, but excessive heat can harm or even kill crops. Sufficient moisture is necessary for crop growth, but too much rain can cause soggy soil and lower yields. In addition, a drought can negatively affect both crop yields and quality. Crop productivity is impacted by the interactions of these climatic conditions with soil, topography, and management techniques. Crop breeding and selection, agricultural planning and management, and precision agriculture acknowledging this relationship are essential for reducing and preparing for the consequences of environmental crises. These components could benefit farmers, scientists, and policymakers in creating plans to maximise crop yield, enhance food security, and adjust to shifting weather patterns.

It is becoming more widely acknowledged that vapour pressure, a crucial element of the atmospheric water balance, plays a significant role in determining agricultural yields and output. Crop water stress, photosynthesis, and transpiration can all be strongly impacted by variations in vapour pressure deficit (VPD), which in turn can impact crop development and output. Nevertheless, the intricate connections between crop yields and vapour pressure deficit (VPD) remain incompletely comprehended, impeding the creation of practical approaches to lessen the negative effects of water stress on agricultural output. The need for a study on VPD and crop yield in Nigeria is evident due to climate change, which has led to rising temperatures and changing rainfall patterns, which have altered VPD values and impacted crop yields. Understanding the effects of VPD on crop yields can help improve agricultural productivity and food security. There is a lack of research on the specific effects of VPD on crop yields in Nigeria, making it essential to conduct studies to fill this knowledge gap. A study on the effects of VPD on crop yields can provide valuable insights for developing climate-resilient agricultural practices, such as irrigation management, crop selection, and breeding for drought tolerance. More importantly, Nigeria's growing population and increasing food demand make it essential to optimise crop yields and guarantee the availability of food; thus, understanding the effects of VPD on crop yields can help achieve this goal. Therefore, this study aims to investigate the relationship between vapour pressure deficit (VPD) and selected crop yields in Nigeria, to understand the impact of VPD on crop productivity.

Objectives of the Study

1. To examine the spatial patterns of VPD and selected crop yields (Maize, Rice, and Cassava) in Nigeria.
2. To investigate the relationship between VPD and selected crop yields (Maize, Rice, and Cassava) in Nigeria.
3. To identify the optimal VPD ranges for selected crop yields (Maize, Rice, and Cassava) in Nigeria.
4. To provide recommendations for managing VPD to improve Maize, Rice, and Cassava yields.

Methodology

Study Area

Nigeria, a country in West Africa, is surrounded by several nations, including Niger to the north, Benin to the west, Chad and Cameroon to the east, and the Gulf of Guinea to the south. Nigeria is positioned between longitudes 3^{o}E and 15^{o}E of the Greenwich meridian and latitudes 4^{o}N and 14^{o}N of the Equator (Figure 1). Nigeria's diverse geography is divided into three climate zones, with rainfall decreasing significantly from south to north. The northern region has a hot and dry Sahelian climate, while the southern region experiences a tropical monsoon climate, and the central regions have a tropical savannah climate (World Bank Group, 2021). Nigeria's relative humidity has an annual mean of 88% in the Lagos area and declines from the south to the north. Nigeria has an average yearly temperature of 26.9°C, with typical monthly temperatures ranging from 24°C in December and January to 30°C in April. The country also experiences 1,165.0 mm of rainfall on a yearly average.

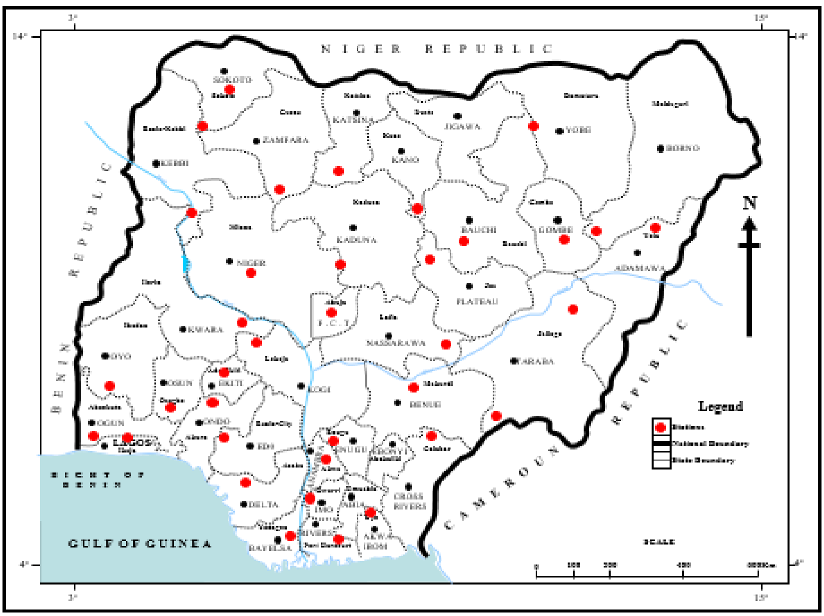

Fig. 1: ***Nigeria map showing climatic data and crop yields stations. Source: Researcher (2025)***

Data Collection

The Clouds and the Earth's Radiant Energy System (CERES)/Modern-Era Retrospective Analysis for Research and Applications, Version 2 (MERRA-2) Native Resolution monthly and annual temperatures and relative humidity data were accessed from the POWER website via the Data Access Viewer (DAV) with 0.5 x 0.625-degree latitude/longitude region from January 1, 2000 to December 31, 2021 (National Aeronautics and Space Administration

(NASA) Prediction of Worldwide Energy Resources (POWER) Data Access Viewer (DAV) Version 2.4.6. 2024/10/01). Annual crop yields of rice, maize, and cassava were obtained from the Nigerian Bureau of Statistics bulletin from 2000 to 2021(Nigerian Bureau of Statistics, 2024).

Data Analysis

The data on VPD and crop yields were analysed using statistical tools such as the Mean, Standard Deviation, Minimum and Maximum values, and Pearson Correlation with the help of STATA 14.2. Also, the results were presented in Tables, and the graphs were used to depict the spatial variations of temperature, relative humidity, VPD (Vapour Pressure Deficit), maize, rice, and cassava yields. Pearson correlation analysis is commonly used for VPD studies because it helps to assume a linear relationship between variables, which is often the case with VPD and crop yield. VPD and related variables (e.g., temperature, humidity) are typically continuous, making Pearson Correlation suitable. By calculating correlation coefficients for different variables, researchers can compare the strength of relationships between VPD and various crop yields.

Results and Discussion

The annual variations of temperature, relative humidity, and vapour pressure are presented in Figure 2, indicating that temperature has been relatively stable over the past twenty-one (21) years, with a mean of 26.13°C and a narrow range from 22°C to 29°C. This suggests a consistent climate across the years covered in the dataset. The relative humidity shows slight fluctuations but remains generally consistent with a wider range of 33% - 90% and a mean of 68.60%. This indicates variability in moisture levels, which could impact agricultural production, particularly for crops sensitive to humidity changes. VPD exhibits minor variations over time with a mean of 1.09 and a range of 0.34 - 2.68, which reflects the atmospheric moisture demand. Higher VPD values can stress plants by increasing transpiration rates, potentially affecting crop yields.

The yields of rice show significant variability, with some years showing higher yields, with a mean of 154,894 metric tons and a wide range. This suggests that rice yields are influenced by various factors, possibly including climate conditions and agricultural practices. Maize yields also vary widely, with noticeable increases in certain years and a mean of 223,587 metric tons. The variability indicates that maize is similarly affected by climatic and possibly economic factors. Cassava has the highest mean yields of 1,245,684 metric tons and shows significant variability.

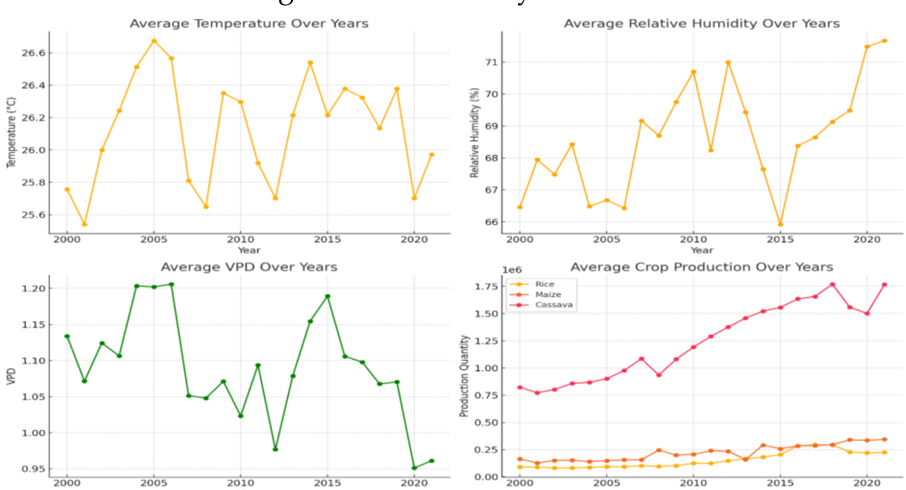

Fig. 2: ***Average temperature, relative humidity, vapour pressure deficit (VPD), rice, maize and cassava yield in Nigeria from 2000 – 2021. Source: Researcher's computation (2025)***

Figure 3 revealed that Borno State has the highest mean temperature of 28.5°C, followed by Adamawa State (28°C), Yobe State and Kebbi States (27.8°C) and Kwara State (27.2°C). Figure 3 shows that Borno State has relatively low humidity of 38.4%, indicating dry conditions, with Delta (88.3%), Bayelsa (88.1%), Rivers (87.8%), Ogun (87.5%), Cross River States (87.4%), Edo (87.3%), and Akwa Ibom (87.0%), followed by Abia and Imo

States (86.2%) and Lagos (86.1%) maintain moderately higher humidity levels compared to the other hotter states.

Figure 3 indicates that Delta, Bayelsa, Rivers, Edo, Ogun Cross River, and Akwa Ibom State had the lower VPD of 0.4kPa, followed by Abia, Imo, Oyo, Lagos, Anambra, Ondo, and Ekiti States with lower VPD of 0.5 kPa, while Enugu, Ebonyi and Osun had lower VPD of 0.6 kPa. The lower VPD amounts recorded in these states imply that these states may experience relatively more moisture retention. On the other hand, the highest mean VPD of 2.4kPa was recorded in Borno State, followed by a mean VPD of 2.3kPa (Yobe), 2.2kPa (Jigawa State), 2.1kPa (Sokoto and Katsina States), and 2.0kPa (Kano and Kebbi States). The highest mean VPD recorded in these states indicates a strong capacity for evaporation and dryness. According to Elbeltagi et al. (2023), high VPD ratios suggest an increased requirement for water in the atmosphere, suggesting that plants may require additional moisture since they release moisture to the surrounding environment faster than usual.

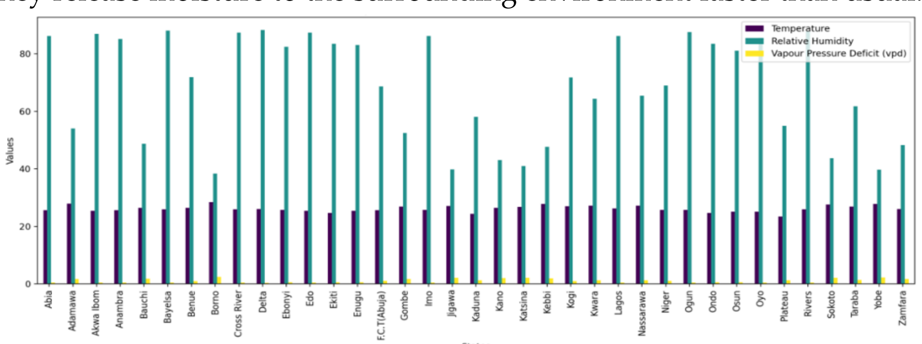

Fig. 3: ***Spatial variations of temperature, relative humidity and vapour pressure deficit (VPD) in Nigeria from 2000 – 2021. Source: Researcher's computation (2025)***

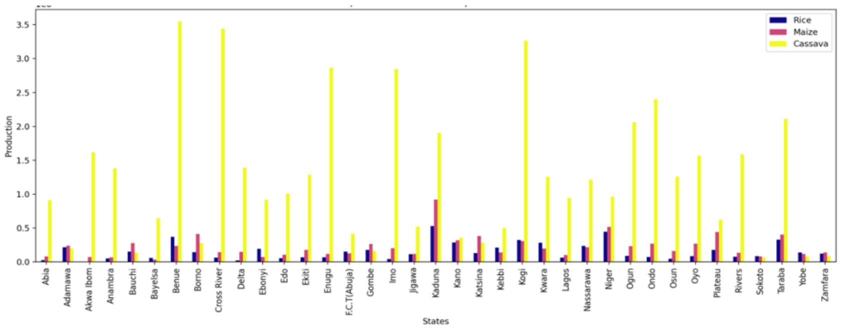

Fig. 4: ***Spatial variations of rice, maize and cassava in Nigeria from 2000 – 2021. Source: Researcher's computation (2025)***

Figure 4 shows the spatial variations of crop yields in Nigeria. The figure revealed that Rice had a mean of 154,894 metric tons, the highest yield of 530,946 metric tons (Kaduna State) and the lowest yield of 5,136 metric tons (Akwa Ibom). Figure 4 indicates that Maize had a mean of 223,588 metric tons, the highest yield of 918,209 metric tons (Kaduna), and the lowest yield of 33,443 metric tons (Bayelsa). Cassava, on the other hand, had a mean of 1,245,684 metric tons, the highest yield of 3,547,324 metric tons (Benue), and the lowest yield of 68,887 metric tons (Sokoto). The figure revealed that cassava shows much higher yield values overall compared to rice and maize.

The figure also shows that Kaduna (530,945); Niger (444,774); Benue (372,405); Taraba (329,364); and Kogi (326,065) are the top rice-producing states in Nigeria. On maize: Kaduna (918,209); Niger (517,052); Plateau (442,517); Borno (411,192); and Taraba (405,208) are the top producing states. Cassava: Benue (3,547,324); Cross River (3,443,549); Kogi (3,263,818); Enugu (2,865,283); and Imo (2,844,840) are the top-producing states in Nigeria. Additionally, Kaduna and Benue are dominant states for rice, maize, and cassava yields, respectively (See Figure 4).

Table 1: Summary of descriptive results for climatic variables and crop yields in Nigeria

Variable	Obs	Mean	Std. dev.	Min	Max
temperature	37	26.13243	1.087059	23.5	28.5
relativehu-y	37	68.60811	18.06003	38.4	88.3
vapourpres-d	37	1.097297	.6767925	.4	2.4
rice	37	154894.1	123881.1	5136.3	530945.9
maize	37	223587.7	165946.5	33443.7	918208.7
cassava	37	1245684	1002362	68887.4	3547324

**(6 variables, 37 observations pasted into data editor); summarize temperature relativehumidity vapourpressuredeficitvpd rice maize cassava. Source: Researcher's computation via STATA 14.2 (2025)*

The descriptive statistics for rice, maize, and cassava as presented in Table 1, indicate that the mean temperature is 26.1°C with a Standard Deviation of 1.1°C which indicates that temperature is still relatively stable. The mean of relative humidity is 68.6%, with a Standard Deviation of 18.1%, indicating substantial fluctuation. With a Standard Deviation of .68kPa and a Mean of 1.1 kPa, vapour pressure exhibits a moderate range. Table 1 demonstrates that rice has a mean of 154,894.12 metric tons with a standard deviation of 123,881.16 metric tons. The table shows that there's a wide range in rice yields, from 5,136 to 530,946, suggesting a significant variation among states. This suggests that rice yields are influenced by various factors, possibly including climate conditions and agricultural practices.

The mean of maize is 223, 587.7 metric tons with a standard deviation of 165,946.49 metric tons. Maize yields range from 33,443 to 918,209, which shows even more variability compared to Rice. The variability indicates that maize is similarly affected by climate-related factors and possibly economic factors. The mean of cassava is 1,245,684 metric tons with a Standard Deviation of 1,002,362.12 metric tons. Cassava yields span an extremely large range, from 68,887 to 3,547,324. Table 1 indicates that all three crops exhibit right-skewed distributions, meaning a few states produce disproportionately high quantities compared to others, while Cassava shows the highest variability due to its much larger range. The standard deviation is largest for Cassava (1,002,362), followed by Maize (165,946) and Rice (123,881), indicating a more uneven distribution of yields in Cassava. The yields of rice show significant variability, with a mean of 154,894 units and a wide range.

Table 2: Pearson correlation matrix

	rice	maize	cassava	temper-e	relati-y	vapour-d
rice	1.0000					
maize	0.6101	1.0000				
cassava	0.1760	0.1635	1.0000			
temperature	0.1037	-0.1113	-0.2284	1.0000		
relativehu-y	-0.2662	-0.2279	0.4931	-0.5457	1.0000	
vapourpres-d	0.2415	0.1827	-0.4883	0.6424	-0.9912	1.0000

**(8 variables, 887 observations pasted into data editor); correlate rice maize cassava temperature relativehumidity vapourpressuredeficitvpd (obs=814). Source: Researcher's computation via STATA 14.2 (2025)*

Table 2 indicates the results for the crop yields (dependent) and climate-related factors (independent) variables; the correlation analysis reveals that rice had a weak positive relationship with temperature (0.1037) and vapour pressure deficit (0.2415), and a weak negative relationship with relative humidity (-0.2662). Maize had a weak negative relationship with temperature (-0.1113) and relative humidity (-0.2279), and a weak positive relationship with vapour pressure deficit (0.1827). Cassava had a weak negative relationship with Temperature (-0.2284), a moderate negative relationship with vapour pressure deficit (-0.4883), and a moderate positive relationship with relative humidity (0.4931).

Overall, the correlations are generally weak to moderate, indicating that while there are some relationships, they are not particularly strong. Also, temperature and rice yield show no clear pattern. Relative humidity and cassava yields suggest that higher humidity may favour cassava yields. VPD and Maize yields indicate that VPD might have a slight influence on maize yields. The moderate positive correlation with relative humidity suggests that cassava yields may benefit from higher humidity levels. The result is in tandem with Ajetomobi (2016), who found that a negative relationship exists between VPD and cassava yield. But, in contrast, Ajetomobi (2016) observed that maize had a negative relationship with VPD.

The Optimal VPD Range for Maize, Rice, and Cassava Yields in Nigeria

VPD is a key factor in crop growth, influencing transpiration, water use efficiency, and overall yield. Low VPD values (below 1.0 kPa) generally indicate high humidity, which can reduce plant water loss but may also increase disease risks. Higher VPD values (above 1.5 kPa) suggest drier air, which can enhance transpiration but may stress crops if the water supply is insufficient.

Table 3: The optimal VPD range for maize, rice, and cassava yields in Nigeria

State	Vapour pressure deficit (VPD)
Abia	0.5
Adamawa	1.7
Akwa Ibom	0.4
Anambra	0.5
Bauchi	1.8
Bayelsa	0.4
Benue	1.0

State	Vapour pressure deficit (VPD)
Borno	2.4
Cross River	0.4
Delta	0.4
Ebonyi	0.6
Edo	0.4
Ekiti	0.5
Enugu	0.6
Gombe	1.7
Imo	0.5
Jigawa	2.2
Kaduna	1.3
Kano	2.0
Katsina	2.1
Kebbi	2.0
Kogi	1.0
Kwara	1.3
Lagos	0.5
Nasarawa	1.2
Niger	1.0
Ogun	0.4
Ondo	0.5
Osun	0.6
Oyo	0.5
Plateau	1.3
Rivers	0.4
Sokoto	2.1
Taraba	1.4
Yobe	2.3
Zamfara	1.7
F.C.T(Abuja)	1.0

Source: Researcher's computation (2025)

The results of the optimal VPD range for crop yields (maize, rice, cassava) in Nigeria are presented in Table 3. The results show that Abia (0.5), Akwa Ibom

(0.4), Bayelsa (0.4), Cross River (0.4), Delta (0.4), Edo (0.4), Rivers (0.4), Abia (0.5), Anambra (0.5), Ekiti (0.5), Imo (0.5), Lagos (0.5), Ondo (0.5), Oyo (0.5), Ebonyi (0.6), Enugu (0.6), Osun (0.6), Benue (1), Kogi (1), Niger (1), F.C.T(1), Nasarawa (1.2), Kaduna (1.3), Kwara (1.3), Plateau (1.3), and Taraba (1.4) have the optimal VPD for rice, the results have suggest that these regions are more favourable for rice production which prefers low VPD of 0.5 – 1.5 kPa. Also, rice thrives in humid conditions with low VPD, as excessive transpiration can reduce grain filling and increase water demand. While high VPD states like Borno (2.4) and Yobe (2.3), Jigawa (2.2), Katsina (2.1), Sokoto (2.1), Kano (2), Kebbi (2), Bauchi (1.8), Adamawa (1.7), Gombe (1.7), and Zamfara (1.7) may experience lower yields due to increased water stress, requiring irrigation. **Maize** prefers a moderate VPD of 1.0 – 2.0 kPa and performs best under moderate VPD, where transpiration aids nutrient transport without excessive water loss. The results show that Bauchi (1.8), Adamawa (1.7), Gombe (1.7), Zamfara (1.7), Taraba (1.4), Kaduna (1.3), Kwara (1.3), Plateau (1.3), Nasarawa (1.2), Benue (1), Kogi (1), Niger (1), and F.C.T (1) are states with favourable conditions for maize. Extremely low VPD areas (below 0.5) may experience poor pollination, while high VPD states (above 2.0) like Kano (2.0), Jigawa (2.2), and Katsina (2.1) may require irrigation (See Figure 5).

Cassava prefers low to moderate VPD of 0.5 – 1.5 kPa, states with ideal VPD for cassava include Abia (0.5), Anambra (0.5), Ekiti (0.5), Imo (0.5), Lagos (0.5), Ondo (0.5), Oyo (0.5), Ebonyi (0.6), Enugu (0.6), Osun (0.6), and Taraba (1.4). States with higher VPD and above 1.5, such as Sokoto (2.1) and Zamfara (1.7), may experience lower yields unless supplemented with irrigation. Cassava is more drought-tolerant but still benefits from moderate humidity. Rice yields are likely highest in humid, low VPD states in the South (e.g., Rivers, Delta, and Cross River), with maize performing best in the Middle Belt and Northern regions with moderate VPD (e.g., Benue, Kwara, and Kaduna). While cassava grows well in both humid and semi-humid areas, favouring states like Ogun, Osun, and Enugu, overall irrigation is necessary for northern states with high VPD to maintain crop productivity (See Figure 5).

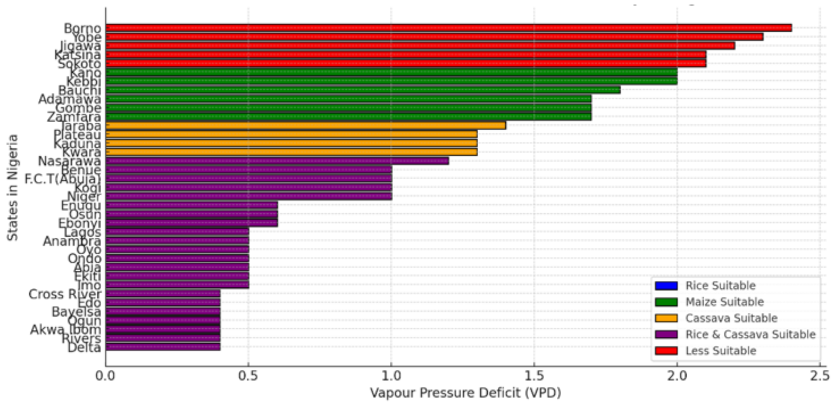

Fig. 5: ***The optimal VPD range for maize, rice, and cassava in Nigeria from 2000 – 2021. Source: Researcher's computation (2025)***

This finding implies that the best places to plant maize are Kaduna, Niger, Taraba, Kogi, Nasarawa, Plateau, Borno, and Taraba. Maize is to be planted in April – June (rainy season) and August – September (second planting in some regions). The best places to plant rice are Kaduna, Niger, Kogi, Abuja (FCT), Benue, Enugu, Taraba, and Kogi. Rain-fed rice is to be planted in May–July (planted at the beginning of the rainy season) and irrigated rice in November – February (dry season with irrigation). The best places to plant cassava are Benue, Niger, Taraba, Nasarawa, Cross River, Kogi, Enugu, and Imo. The best season to plant cassava is March-May for early planting (before the peak of the rainy season), and August-October for late planting (if soil moisture is adequate).

Conclusion

In this study, climatic variables such as temperature, relative humidity and vapour pressure deficiency (VPD) and crop yields such as rice, maize and cassava were employed to determine the effects of VPD on crop yields in Nigeria. The findings indicate that temperature remained relatively stable over the years, and relative humidity exhibited fluctuations, which could impact agricultural productivity. The study revealed that higher VPD values are recorded in northern states of the country, which suggests drier conditions that may increase crop water demands, leading to potential yield reductions. The findings of the study indicate that cassava exhibited the highest mean yield among the three crops, while maize and rice yields varied significantly across states, with northern regions experiencing higher VPD levels, which negatively affected crop growth. The study revealed that weak to moderate correlations were found between climatic variables and crop yields, with cassava showing a moderate positive relationship with relative humidity and a negative correlation with VPD. These results align with previous research indicating that VPD contributes significantly to plant water stress and productivity. Overall, the study underscores the significant impact of climate conditions on agricultural yields, with variations in temperature, humidity, and VPD influencing crop performance differently across regions.

Based on the study's findings, tailored recommendations are provided for different regions in Nigeria to address climate-related challenges affecting crop yields. Northern Region (sahel and Sudan savanna zones: Borno, Yobe, Sokoto, Katsina, Jigawa, Kano, Kebbi, Zamfara, Adamawa, Gombe, Bauchi), given the high VPD and low humidity, farmers should adopt drought-tolerant rice, maize, and cassava varieties that can withstand water stress. Central Region (Guinea savanna zone: Niger, Kwara, Kogi, Benue, Nasarawa, Taraba, Plateau, FCT Abuja, Kaduna), smallholder farmers should be encouraged to adopt water conservation techniques, such as rainwater harvesting and efficient irrigation, which will help maintain soil moisture levels. Southern Region (humid and rainforest zones: Lagos, Ogun, Oyo, Osun, Ekiti, Ondo, Edo, Delta, Bayelsa, Rivers, Cross River, Akwa Ibom, Abia, Imo, Ebonyi, Enugu, Anambra), due to high humidity and low VPD in these regions, investments in better drainage infrastructure are necessary to prevent waterlogging, which affects crop yields. By implementing these recommendations, Nigeria can enhance agricultural productivity while addressing climate-related challenges unique to each geographical zone.

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