International Journal of Multidisciplinary Research and Growth Evaluation.

# Climate Variability and its Effect on Tomato Yield in Nigeria

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## Article Info

**ISSN (online):** 2582-7138
**Volume:** 06
**Issue:** 03
**May-Jun 2025**
**Received:** 25-03-2025
**Accepted:** 24-04-2025
**Page No:** 635-643

**Abstract**
This work examines the effects of climate variability on tomato yield in Nigeria, focusing on key climate variables such as temperature, rainfall, humidity, and solar radiation. This review work synthesized existing literature, case studies, and scientific reports to assess how these climatic factors influence tomato growth, productivity, and susceptibility to pests and diseases. Findings revealed that extreme temperatures, both high and low, negatively affect tomato yield by disrupting flowering, fruit setting, and overall plant physiology. Fluctuating rainfall patterns, including prolonged droughts and excessive precipitation, contribute to soil erosion, water stress, and increased disease prevalence. High humidity levels promote fungal and bacterial infections, while low humidity accelerates water loss, reducing fruit quality. This review work equally highlights the socio-economic implications of climate variability, including reduced farmers incomes, food insecurity, and increased production costs due to the need for adaptation measures. Based on these findings, farmers are encouraged to adopt climate-smart agricultural practices such as improved irrigation techniques, drought-tolerant tomato varieties, and integrated pest management strategies. Additionally, government policies should support agricultural extension services, provide subsidies for climate-resilient farming inputs, and invest in research to develop adaptive strategies. Strengthening climate monitoring and early warning systems will further enable farmers to anticipate and respond effectively to climate variability. These interventions will contribute to stabilizing tomato yield, improving food security, and ensuring the sustainability of tomato farming in Nigeria.

**Keywords:** Climate Variability, Tomato Yield, Temperature, Rainfall, Pests, Humidity, Food Security

## Introduction

Climate change has emerged as one of the most pressing global challenges, with significant implications for agricultural productivity and food security, particularly in developing countries like Nigeria. The increasing variability in climate parameters, including temperature, rainfall patterns, and extreme weather events, poses serious threats to crop production, including tomato farming, which is an important horticultural crop in Nigeria. Tomatoes (*Solanum lycopersicum*) are widely cultivated across the country and serve as a major source of income for farmers, as well as a key component of the Nigerian diet (Adebayo and Olagunju, 2020) [1]. However, climate change-induced variations in temperature and precipitation patterns have disrupted the productivity of tomatoes, leading to lower yields and increased vulnerability to pests and diseases

Nigeria's climate is characterized by tropical conditions with distinct wet and dry seasons, but recent trends indicate increased temperatures, erratic rainfall, and prolonged droughts in some regions (NIMET, 2022) [11]. These climatic changes have had severe implications for tomato yield, affecting plant growth cycles, flowering, and fruit development. High temperatures, for instance, can cause flower abortion and reduce fruit set, while irregular rainfall patterns may result in water stress, leading to poor crop performance (Akinbile, Fakayode, and Ayodele. 2019) [3].

Furthermore, extreme weather conditions such as floods and droughts have led to significant post-harvest losses and reduced market availability of tomatoes.

The impact of climate variability on tomato yield is also evident in the increasing prevalence of pests and diseases, such as the tomato leaf miner (*Tuta absoluta*), which thrives under warmer conditions (Ajayi, Ogunbiyi, and Oladipo, 2020) [2]. Changes in humidity and temperature provide favorable conditions for fungal infections, including early and late blight, which can significantly reduce harvest output. These challenges threaten the livelihoods of many smallholder farmers, increase production costs, and contribute to food insecurity in Nigeria (Edeh and Gyimah-Brempong, 2021) [4].

Several studies have emphasized the need for adaptive strategies to mitigate the effects of climate change on tomato farming. Climate-smart agricultural practices, such as improved irrigation systems, drought-resistant tomato varieties, and greenhouse cultivation, have been suggested as viable options for sustaining tomato production in Nigeria (FAO, 2021). Additionally, policy interventions focusing on climate change adaptation, early warning systems, and sustainable land management practices are crucial to ensuring stable tomato yields in the face of changing climatic conditions (IPCC, 2022).

This study seeks to analyze climate variability and its effects on tomato yield in Nigeria, with a focus on temperature fluctuations, rainfall variability, and extreme weather events. The findings will contribute to a deeper understanding of the relationship between climate change and tomato productivity while exploring potential mitigation strategies for sustainable agricultural development.

Climate change is a critical global challenge that has profound implications for agriculture, particularly in developing countries like Nigeria, where the majority of the population depends on farming for livelihood and food security. The increasing variability in climatic factors such as temperature, rainfall patterns, humidity, and extreme weather events has significantly affected agricultural production, including the cultivation of tomatoes (*Solanum lycopersicum*), a staple vegetable crop widely grown across the country (Adebayo and Olagunju, 2020) [1].

Nigeria's climate is predominantly tropical, characterized by distinct wet and dry seasons. However, recent climatic trends indicate rising temperatures, erratic rainfall distribution, prolonged droughts, and extreme weather conditions such as floods and storms (NIMET, 2022) [11]. According to the Nigerian Meteorological Agency (NIMET), the average temperature in Nigeria has increased by approximately 1.2°C over the past century, with predictions of further warming by 2050. Additionally, changes in rainfall patterns have resulted in delays in the onset of the rainy season and shorter growing periods, affecting the productivity of climate-sensitive crops like tomatoes (Akinbile *et al*., 2019) [3].

Tomato cultivation in Nigeria thrives in moderate temperature conditions, with an optimal range of 21 °C to 27 °C. However, climate variability has led to increased occurrences of heat stress, which negatively affects plant growth and yield (Odekunle, Akinseye, and Adebisi. 2021) [13]. High temperatures above 30°C can cause physiological stress in tomato plants, leading to flower abortion, reduced fruit set, and lower yield quality. Extreme heat conditions also accelerate the respiration rate of tomato plants, resulting in energy loss and poor productivity (Ajayi, Ogunbiyi, and Oladipo. 2020) [2].

Rainfall is another critical climatic factor influencing tomato production. Inconsistent rainfall patterns, including prolonged dry spells and excessive rainfall, pose challenges to farmers. A lack of adequate water supply during the growing season can lead to moisture stress, causing poor germination, reduced vegetative growth, and lower fruit yield. Conversely, excessive rainfall and flooding can lead to waterlogging, which disrupts root function, promotes fungal diseases, and increases post-harvest losses (Edeh and Gyimah-Brempong, 2021) [4].

In Nigeria, the northern regions, which contribute significantly to tomato production, have been particularly affected by climate change. The Sahelian and Sudan savanna zones, which include states like Kano, Kaduna, Katsina, and Jigawa, have witnessed increased desertification and prolonged dry seasons, making rain-fed tomato farming highly unpredictable (FAO, 2021). On the other hand, the southern regions, which experience higher rainfall, are prone to flooding, which negatively impacts tomato farms. These climate-induced changes necessitate the adoption of climate-smart agricultural practices to sustain tomato production in the country.

One of the major consequences of climate Variability on tomato yield in Nigeria is the increased prevalence of pests and diseases. The tomato leaf miner (*Tuta absoluta*), one of the most destructive pests affecting tomato production, has become more widespread due to rising temperatures and reduced rainfall variability (Ajayi *et al*., 2020) [2]. Warmer conditions create a favorable environment for the rapid reproduction and spread of pests, leading to devastating losses for farmers.

Additionally, changes in humidity levels and excessive rainfall contribute to the prevalence of fungal and bacterial diseases such as early and late blight (*Phytophthora infestans* and *Alternaria solani*), bacterial wilt, and root rot. These diseases thrive under warm and moist conditions, further reducing tomato yield and quality (Adebayo and Olagunju, 2020) [1]. The increased incidence of these pests and diseases raises production costs, as farmers are forced to invest in pesticides, fungicides, and other control measures, thereby reducing profitability and food security.

Climate variability poses significant challenges to tomato yield in Nigeria, affecting crop growth, productivity, and profitability. Rising temperatures, erratic rainfall patterns, and increased pest and disease prevalence have led to reduced tomato yields, threatening food security and farmers' livelihoods. However, adopting climate-smart agricultural practices, improved irrigation systems, integrated pest management, and effective policy interventions can help mitigate these impacts and ensure sustainable tomato production. This study aims to explore the extent of climate variability on tomato yield in Nigeria, providing insights into adaptation strategies that can enhance agricultural sustainability in the face of a changing climate.

**Statement of the Problem**

Tomato (*Solanum lycopersicum*) is one of the most important vegetable crops cultivated in Nigeria, serving as a crucial source of vitamins, minerals, and economic livelihood for millions of smallholder farmers (Adebayo and Olagunju, 2020) [1]. However, in recent decades, the productivity and availability of tomatoes in Nigeria have been significantly threatened by climate variability, characterized by erratic

rainfall, rising temperatures, increased pest and disease outbreaks, and extreme weather events such as droughts and floods (Akinbile, Fakayode, and Ayodele. 2019) [3]. These climatic uncertainties have led to unstable tomato yields, fluctuating market prices, and food insecurity, necessitating urgent scientific and policy interventions.

One of the major challenges facing tomato production in Nigeria is the impact of temperature fluctuations. Tomato plants thrive within an optimal temperature range of 21 °C to 27 °C, but recent studies indicate that the country is experiencing rising temperatures beyond this range (NIMET, 2022) [11]. High temperatures exceeding 30 °C result in heat stress, leading to flower abortion, poor fruit setting, and reduced fruit quality (Odekunle, Akinseye, and Adebisi, 2021) [13]. Additionally, excessive heat accelerates plant respiration rates, causing energy loss that negatively affects fruit development and overall yield (Ajayi *et al*., 2020) [2].

Similarly, erratic rainfall patterns pose a significant problem for tomato farming. Rainfall is crucial for tomato cultivation, but its unpredictability has led to either prolonged droughts or excessive rainfall, both of which negatively impact yield (Edeh and Gyimah-Brempong, 2021) [4]. Drought conditions result in moisture stress, causing poor seed germination, stunted growth, and lower fruit yields. Conversely, excessive rainfall leads to waterlogging, which damages root systems and promotes fungal infections such as early and late blight (*Phytophthora infestans* and *Alternaria solani*), further reducing productivity (FAO, 2021). These problems have necessitated the need for this review work.

**Theoretical Framework**

This study adopts the use of the Cause-Effect Theory. This theory helps to explain how climate variability affects tomato farming, the adaptation strategies available to farmers, and the socio-economic implications of climate change on agricultural livelihoods.

This theory, rooted in Aristotelian philosophy and later formalized in scientific research (Pearl, 2009), explains how specific causes (independent variables) lead to particular effects (dependent variables). In the context of this study, climate variables such as temperature fluctuations, precipitation patterns, solar radiation, and humidity act as causative factors, while tomato yield represents the effect.

Causality in agricultural science has been widely studied, with researchers using empirical data and statistical models to establish cause-and-effect relationships. According to Granger (1969) [7], causality in time series analysis helps determine how one variable influences another over time. This concept is relevant in climate studies where past climate trends can predict future agricultural productivity. Studies by Lobell and Burke (2010) [10] and Rosenzweig (2014) [15] have applied causality theory to examine the impact of climate change on crop production, confirming that changes in temperature and precipitation directly influence agricultural output.

In Nigeria, climate variability has been identified as a key driver of fluctuations in tomato yield (Adebayo and Olagunju, 2020) [1]. Extreme temperatures, particularly heat stress above 35 °C, have been shown to reduce fruit set and increase blossom drop, leading to lower yields (Kumar *et al*., 2021) [9]. Similarly, excessive rainfall and prolonged droughts disrupt tomato growth cycles, affecting flowering and fruit development (Odekunle *et al*., 2021) [13]. Research by Smit and Skinner (2002) [16] highlights that understanding causality in climate-agriculture interactions allows for the development of targeted interventions, such as the use of drought-resistant tomato varieties, improved irrigation systems, and greenhouse farming. These adaptive measures serve to counteract the negative effects of climate variability, ensuring sustainable production.

**Literature review**

This literature review explores existing studies on the impact of climate variability on tomato yield in Nigeria, aligning with the study's objectives. Climate change has become a major global concern, with significant impacts on agricultural productivity. Tomato production, being highly sensitive to climatic conditions, is particularly affected by rising temperatures, erratic rainfall patterns, and extreme weather events. Across different regions of the world, studies have examined the relationship between climate variability and tomato yield, revealing diverse challenges and adaptation strategies.

In Asia, countries like India and China, which are among the largest producers of tomatoes, have experienced shifts in climatic conditions that threaten crop yields. Research by Kumar, Singh, and Sharma, (2021) [9] indicates that increasing temperatures beyond 30 °C lead to reduced fruit setting in tomatoes, ultimately lowering overall productivity. In India, extreme heat waves have caused significant crop failures, forcing farmers to adopt greenhouse farming and improved irrigation techniques to mitigate water stress. Similarly, China has faced irregular rainfall patterns, affecting soil moisture levels and increasing the vulnerability of tomatoes to fungal diseases like late blight (*Phytophthora infestans*), as observed by Wang, Zhao, and Li, (2020) [17]. These climatic factors have driven the adoption of climate-smart agricultural practices, such as the use of drought-resistant tomato varieties and precision farming technologies.

In Europe, climate variability has had a mixed impact on tomato production. Countries like Spain and Italy, which are among the largest tomato producers in the region, have recorded both increased temperatures and water shortages, leading to lower yields. A study by García, Peña, and Valverde, (2020) [6] found that excessive heat accelerates tomato ripening, reducing fruit size and quality. Additionally, prolonged droughts have strained water resources, making irrigation more expensive and less accessible to small-scale farmers. To combat these challenges, European farmers have increasingly adopted advanced irrigation systems, hydroponic farming, and climate-controlled greenhouses. Moreover, policy interventions by the European Union have emphasized sustainable agricultural practices, encouraging the use of renewable energy in farming and the development of resilient crop varieties.

In the United States, tomato farming has been significantly influenced by climate change, particularly in states like California and Florida, which are major producers. Lobell, Roberts, and Schlenker, (2019) [10] reported that rising temperatures and increased frequency of extreme weather events, such as hurricanes and droughts, have negatively affected tomato yields. Additionally, higher temperatures have contributed to an increase in pest populations, such as *Tuta absoluta*, which has become a serious threat to tomato crops. Farmers in the U.S. have responded by implementing integrated pest management (IPM) strategies, including the use of biological control agents and genetic modifications to develop pest-resistant tomato varieties. Moreover, climate

policies and government subsidies have supported farmers in adopting more sustainable farming practices to mitigate climate-related risks.

In Africa, tomato production faces numerous challenges due to climate variability, particularly in regions with erratic rainfall and prolonged dry spells. Studies by Nwajiuba, Okereke, and Uche, (2021) [12] highlight how extreme heat and drought conditions have led to widespread crop failures in countries like Ghana, Kenya, and Ethiopia. The lack of irrigation infrastructure in many parts of Africa exacerbates the impact of climate variability, making tomato farming highly dependent on seasonal rainfall. Pest outbreaks have also intensified under changing climate conditions, further reducing yields. To address these issues, African farmers have been encouraged to adopt climate-resilient agricultural practices, such as water harvesting techniques, organic fertilizers, and shade-net farming. However, limited access to financial resources and government support has hindered large-scale implementation of these adaptation strategies.

In Nigeria, tomato production is particularly vulnerable to climate change due to the country's heavy reliance on rain-fed agriculture. A study by Adebayo and Olagunju (2020) [1] found that rising temperatures, coupled with erratic rainfall, have significantly reduced tomato yields in major producing states such as Kano, Kaduna, and Katsina. The tomato leaf miner (*Tuta absoluta*) has become a major pest problem, with infestations leading to substantial losses. Research by Ajayi *et al*. (2020) [2] highlights that inadequate pest control measures, combined with climate-induced stress on crops, have exacerbated the decline in tomato production. Farmers have attempted to adopt adaptation strategies, such as the use of resistant tomato varieties and improved irrigation methods, but these efforts are often limited by financial constraints and poor access to extension services. Government policies aimed at supporting climate adaptation in agriculture have not been effectively implemented, leaving many smallholder farmers struggling to cope with climate variability.

This review highlights the multifaceted impact of climate change variability on tomato yield in Nigeria, including climate trends, yield reduction, pest outbreaks, socio-economic implications, and adaptation strategies. While climate-smart agriculture presents viable solutions, stronger government policies and farmer support systems are needed to enhance adaptation efforts. Addressing these challenges will ensure sustainable tomato production and food security in Nigeria.

Tomato (*Solanum lycopersicum*) is a widely cultivated crop that plays a significant role in global food security and economic sustainability. However, climate change has increasingly affected tomato production, with variables such as temperature fluctuations, precipitation patterns, solar radiation, and humidity influencing crop yield and quality. Several researchers have explored the relationship between climate variability and tomato yield using different methodologies, including statistical models, field experiments, and remote sensing technologies.

**The effects of temperature on tomato yield in Nigeria**

Temperature is a crucial climatic factor affecting tomato yield in Nigeria, influencing germination, flowering, fruit set, and overall productivity. The country experiences a wide range of temperatures due to its diverse agro-climatic zones, with northern regions such as Kano and Kaduna frequently experiencing temperatures above 35 °C, while central and southern regions have relatively moderate temperatures. Research indicates that optimal daytime temperatures for tomato growth range between 25–30 °C, with night temperatures between 15–20 °C being ideal for proper physiological development. However, due to climate variability, extreme temperatures have become more frequent, negatively impacting tomato yield.

Adebayo and Olagunju (2020) [1] conducted a three-year field study in Kaduna and Kano states to examine how temperature variability affects tomato yield. Their research employed a combination of field observations, temperature monitoring, and yield data collection. The findings revealed that when temperatures exceeded 35 °C, tomato plants exhibited increased flower abortion rates, poor fruit set, and lower yields, resulting in a 40% yield reduction. The study also found that tomatoes cultivated under shade nets had 20% higher yields than those exposed to direct sunlight, emphasizing the importance of temperature regulation strategies. The study recommended adopting heat-tolerant tomato varieties such as Tropimech and UC-82B, adjusting planting schedules to cooler months, and using shade nets to mitigate heat stress.

Temperature fluctuations also play a significant role in yield reduction, as sudden temperature changes disrupt physiological processes such as photosynthesis and nutrient uptake. Odekunle *et al*. (2021) [13] analyzed 30 years of climate data in Plateau State, a key tomato-growing region, using time-series climate analysis and experimental field trials. The study found that frequent cold nights below 15°C delayed flowering, while sudden heatwaves above 38°C led to sunscald, reducing marketable yield by 30%. By comparing yield performances under different temperature scenarios, the study confirmed that temperature inconsistencies cause significant productivity losses. Farmers who applied mulching techniques to stabilize soil temperature and cultivated early-maturing tomato varieties experienced better yields. Strengthening climate forecasting systems was recommended to help farmers anticipate and manage temperature variability.

High night temperatures also present a significant challenge to tomato production, as they increase plant respiration rates, depleting stored energy and leading to lower fruit yield. Ajayi *et al*. (2020) [2] conducted a controlled greenhouse study in Ibadan, where night temperatures were manipulated to assess their effects on tomato productivity. The results demonstrated that plants exposed to sustained night temperatures above 27 °C had lower fruit set due to excessive respiration, leading to smaller fruit sizes and reduced market value. The study used temperature-controlled chambers and respiration rate measurements to evaluate the impact. It recommended improving greenhouse ventilation, breeding tomato varieties tolerant to high night temperatures, and using irrigation cooling techniques to mitigate night temperature stress.

Temperature extremes also affect tomato quality, leading to sunscald, fruit cracking, and reduced shelf life. Wang *et al*. (2020) [17] examined the relationship between high temperatures and tomato quality through a series of controlled experiments and market surveys in Benue State, Nigeria. The findings showed that tomatoes harvested during peak heat periods above 35 °C had a 50% higher spoilage rate than those harvested under moderate temperatures. Post-harvest nutrient analysis revealed a decline in vitamin C and lycopene concentrations in heat-stressed tomatoes. The study utilized lab-based nutrient testing and storage condition

analysis to determine quality deterioration. It recommended the adoption of evaporative cooling storage systems, improved transportation logistics, and post-harvest processing techniques such as drying and pureeing to minimize losses.

Overall, multiple studies confirm that temperature extremes, fluctuations, and high night temperatures significantly reduce tomato yields and quality in Nigeria. The impacts range from reduced fruit set and poor pollination to increased disease susceptibility and post-harvest losses. Effective adaptation strategies include planting heat-tolerant varieties, using climate-smart farming techniques such as mulching and shading, and improving post-harvest storage facilities. Strengthening early warning systems for extreme temperature events and integrating modern greenhouse technologies can also enhance resilience. Addressing temperature-related challenges through research, policy support, and farmer education will be crucial for sustaining tomato production in Nigeria amid climate change.

**The Impact of Climate Variability on Tomato Pest and Diseases**

Climate variability plays a crucial role in the occurrence, intensity, and spread of pests and diseases affecting tomato production in Nigeria. Changes in temperature, humidity, and precipitation patterns create favorable conditions for pest proliferation and disease outbreaks, leading to significant yield losses. Rising temperatures and irregular rainfall patterns have altered the life cycles and geographical distribution of major tomato pests such as the tomato leaf miner (*Tuta absoluta*), whiteflies (*Bemisia tabaci*), and aphids (*Aphis gossypii*), as well as fungal and bacterial infections such as early blight (*Alternaria solani*), late blight (*Phytophthora infestans*), and bacterial wilt (*Ralstonia solanacearum*). These challenges have been exacerbated by increased humidity levels, which promote fungal infections, and prolonged droughts, which weaken plant resistance to pest infestations.

Ajayi *et al*. (2020) [2] conducted a field study on the relationship between climate change and tomato pest dynamics in southwestern Nigeria, focusing on the tomato leaf miner (*Tuta absoluta*), a highly destructive pest that has spread rapidly in recent years. Using a combination of field surveys, remote sensing, and laboratory analysis, the study found that higher temperatures accelerated the reproductive cycle of *Tuta absoluta*, leading to more frequent outbreaks. Farmers in Oyo and Ogun States reported that pest infestations had increased by 60% over the past decade, leading to an estimated 35% decline in yield. The study also noted that prolonged dry spells weakened tomato plants, making them more susceptible to pest attacks. Recommended management strategies included the adoption of integrated pest management (IPM) approaches such as biological control using *Trichogramma* parasitoids, pheromone traps, and climate-smart insecticide application schedules.

Humidity variations have also contributed to increased disease pressure, particularly fungal infections like early and late blight, which thrive in moist conditions. Akinbile *et al*. (2019) [3] investigated the correlation between rainfall variability, humidity levels, and tomato disease prevalence in Nigeria's middle-belt region, using a combination of long-term meteorological data analysis and experimental farm trials. The study found that excessive rainfall and high humidity (above 80%) created ideal conditions for *Phytophthora infestans*, the pathogen responsible for late blight. In Jos, where tomato production is extensive, farmers reported a 40% increase in blight-related losses in years with higher-than-average rainfall. The study recommended the use of disease-resistant tomato varieties such as Roma VF and Sankara, improved farm drainage systems to prevent waterlogging, and the application of copper-based fungicides in a targeted manner.

Drought conditions have also been linked to increased vulnerability to bacterial wilt, a devastating soil-borne disease caused by *Ralstonia solanacearum*. Edeh and Gyimah-Brempong (2021) [4] analyzed the effects of prolonged dry spells on bacterial wilt outbreaks in tomato farms across northern Nigeria, utilizing a combination of field observations, farmer interviews, and soil pathogen analysis. The results showed that under prolonged drought conditions, tomato plants experienced water stress, which weakened their natural defense mechanisms against soil pathogens. In Kano and Katsina, where droughts have become more frequent, bacterial wilt incidence was found to be 50% higher compared to regions with more stable rainfall patterns. The study recommended adopting drip irrigation systems to maintain consistent soil moisture, using organic amendments such as compost to enhance soil microbial diversity, and practicing crop rotation with non-host crops like maize and cowpea to reduce pathogen build-up.

Climate-induced shifts in pest and disease patterns have also affected pest management strategies, increasing the reliance on synthetic pesticides. However, excessive pesticide use has led to pest resistance and environmental contamination. Odekunle *et al*. (2021) [13] conducted a survey on pesticide application trends among tomato farmers in Nigeria, using structured interviews and field assessments. The study found that farmers had increased pesticide usage by 70% over the past decade to combat climate-induced pest surges. Unfortunately, indiscriminate pesticide use had led to the development of resistant pest populations and a decline in beneficial insect species. The study recommended the promotion of climate-smart agricultural practices such as intercropping with pest-repellent plants (e.g., marigolds), the introduction of biological control agents, and improved farmer training on sustainable pest management techniques.

The reviewed studies confirm that climate variability significantly influences the prevalence and severity of tomato pests and diseases in Nigeria. Rising temperatures, fluctuating humidity, and irregular rainfall patterns have facilitated the expansion of pest populations, increased disease incidence, and weakened plant resistance. Effective adaptation strategies must combine improved pest surveillance, the adoption of resistant tomato varieties, climate-smart irrigation techniques, and sustainable pest and disease management approaches. Strengthening research on climate-resilient pest control measures and enhancing extension services to educate farmers on climate-adaptive strategies will be essential in safeguarding tomato production in Nigeria.

**The Effect of Rainfall on Tomato Yield in Nigeria**

Rainfall is one of the most critical climatic factors affecting tomato production in Nigeria, influencing soil moisture availability, plant growth, nutrient uptake, and overall yield. The unpredictable nature of rainfall, characterized by irregular distribution, delayed onset, prolonged dry spells, and intense storms, poses significant challenges to tomato

farming. Excessive rainfall often leads to waterlogging and increased disease prevalence, while insufficient rainfall causes drought stress, reducing plant productivity. These rainfall-related issues have become more severe due to climate variability, affecting different tomato-growing regions in Nigeria.

Akinbile *et al*. (2019) [3] conducted a time-series analysis on rainfall variability and tomato yield across major producing states such as Benue, Kano, and Plateau. The study used historical meteorological data spanning 30 years and applied statistical correlation techniques to analyze the relationship between annual rainfall patterns and tomato yield fluctuations. The findings revealed that erratic rainfall patterns had resulted in a 25% reduction in tomato yield over the study period. In years with excessive rainfall, crop losses were attributed to waterlogged soil conditions, which restricted root aeration, reduced nutrient uptake, and promoted fungal infections such as *Phytophthora infestans* (late blight). Conversely, in years with below-average rainfall, yield reductions were linked to moisture stress, which hindered photosynthesis and fruit development. The study recommended the use of raised beds for improved drainage, strategic water harvesting techniques such as small-scale reservoirs, and the cultivation of drought-tolerant tomato varieties.

Rainfall intensity and distribution have also been identified as key factors influencing tomato yield. Odekunle *et al*. (2021) [13] examined the impact of extreme rainfall events on tomato production using a combination of field surveys, remote sensing data, and crop simulation modeling. The study found that heavy downpours, particularly in southern Nigeria, increased the incidence of soil erosion, washing away essential topsoil nutrients necessary for tomato growth. The research also highlighted that tomatoes grown in flood-prone areas experienced higher rates of flower drop and fruit cracking due to excessive moisture absorption. On the other hand, northern Nigeria, which relies on seasonal rainfall for tomato farming, experienced significant yield declines during extended dry spells, particularly when rains ceased earlier than expected. To mitigate these impacts, the study recommended the implementation of controlled irrigation systems such as drip irrigation, the application of organic mulches to retain soil moisture, and the adoption of agroforestry practices to reduce erosion in flood-prone regions.

Edeh and Gyimah-Brempong (2021) [4] explored how rainfall variability affects soil nutrient dynamics and, consequently, tomato yield. Using a combination of soil moisture monitoring, nutrient analysis, and yield assessments, their research demonstrated that erratic rainfall distribution altered nutrient availability, leading to imbalanced soil fertility. In areas where rainfall was too frequent, nutrients such as nitrogen and potassium were leached beyond the root zone, limiting plant uptake and weakening tomato plants. This resulted in poor vegetative growth, lower fruit set, and increased susceptibility to pests and diseases. Conversely, prolonged dry spells led to nutrient immobilization, making essential minerals less available to tomato plants. The study recommended adopting site-specific fertilizer application techniques, enhancing soil organic matter content through composting, and practicing conservation agriculture to improve soil structure and water retention capacity.

Rainfall fluctuations also affect the timing of tomato planting and harvesting, which is critical for optimizing yield. Ajayi *et al*. (2020) [2] conducted farmer interviews and participatory research across several tomato-producing regions to assess how farmers had adjusted their practices in response to changing rainfall patterns. The findings showed that delayed rains in recent years had forced many farmers to shift planting schedules, with some resorting to dry-season irrigation farming to compensate for losses during the rainy season. However, in areas without reliable irrigation infrastructure, production cycles were severely disrupted, leading to supply shortages and price volatility in local markets. The study recommended strengthening weather forecasting services, providing farmers with timely climate information, and expanding irrigation infrastructure to reduce dependency on rainfall.

The reviewed literature confirms that rainfall variability has significant effects on tomato yield in Nigeria, influencing soil conditions, nutrient availability, pest and disease prevalence, and planting cycles. Excessive rainfall causes soil erosion, waterlogging, and nutrient leaching, while insufficient rainfall leads to drought stress, reduced photosynthesis, and lower fruit yield. Effective adaptation strategies include water management practices such as rainwater harvesting, improved drainage systems, and controlled irrigation. Additionally, adopting climate-resilient tomato varieties, enhancing soil fertility management, and providing farmers with real-time weather forecasts will be crucial in mitigating the adverse effects of rainfall variability on tomato production in Nigeria. Strengthening research and policy interventions to support climate-smart agricultural practices will further enhance the resilience of tomato farmers against unpredictable rainfall patterns.

**The effects of Humidity on tomato yield in Nigeria**

Humidity plays a crucial role in tomato production, influencing growth, yield, and susceptibility to diseases. Variability in humidity levels, driven by climate change, has been linked to both positive and negative effects on tomato farming in Nigeria. High humidity levels can promote disease outbreaks, particularly fungal and bacterial infections, while low humidity can lead to excessive water loss, reducing plant vigor and fruit quality. Researchers have explored these effects using field trials, climate modeling, and farmer surveys to assess the impact of humidity fluctuations on tomato yield and suggest adaptation strategies.

Edeh and Gyimah-Brempong (2021) [4] analyzed the relationship between relative humidity and tomato productivity in Nigeria using historical climate data and crop yield records. Their econometric analysis indicated that optimal humidity levels, ranging between 60% and 80%, supported healthy growth and fruit development. However, excessive humidity beyond this range was associated with increased occurrences of fungal diseases such as *Phytophthora infestans* (late blight) and Botrytis cinerea (gray mold). The study recommended the adoption of greenhouse farming techniques, improved ventilation systems, and resistant tomato varieties to mitigate the effects of high humidity.

Ajayi *et al*. (2020) [2] conducted field experiments in southwestern Nigeria to assess the impact of high humidity on tomato leaf diseases. Using controlled environment trials, the researchers exposed tomato plants to varying humidity levels and monitored the progression of common fungal infections. The study found that relative humidity above 85% led to rapid disease proliferation, reducing tomato yield by up

to 40%. Farmers relying on open-field cultivation suffered the most losses due to the difficulty of controlling environmental conditions. The researchers recommended the use of weather monitoring tools to predict disease outbreaks, early application of organic fungicides, and adoption of raised bed farming to improve aeration and reduce moisture accumulation around plant roots.

The effect of low humidity on tomato yield has also been investigated, particularly in arid and semi-arid regions of northern Nigeria. Akinbile *et al*. (2019) [3] evaluated the effects of dry conditions on tomato transpiration rates, using a combination of field measurements and remote sensing technology. Their study revealed that during periods of low humidity (below 40%), tomato plants exhibited higher rates of transpiration, leading to water stress and reduced fruit size. In extreme cases, prolonged dry spells caused flower abortion and reduced fruit set, significantly lowering overall yield. The study emphasized the need for improved irrigation techniques such as drip irrigation and mulching to conserve soil moisture and minimize the adverse effects of low humidity.

The relationship between humidity and fruit quality has also been a subject of research. Nwajiuba *et al*. (2021) [12] examined how humidity fluctuations affected the texture, shelf life, and marketability of tomatoes. The study employed a combination of laboratory analysis and farmer interviews to assess post-harvest quality under different climatic conditions. The results indicated that high humidity conditions often led to softer fruits with shorter shelf lives due to increased susceptibility to rot and microbial spoilage. Conversely, excessively low humidity resulted in fruit shrinkage and reduced consumer appeal. The study recommended that farmers adopt proper post-harvest handling techniques, including controlled storage environments, improved packaging materials, and timely transportation to markets to reduce losses.

In addition to disease management and fruit quality, humidity fluctuations influence pollination success and overall plant physiology. Odekunle *et al*. (2021) [13] investigated the impact of varying humidity levels on tomato flower development and pollination rates in open-field and greenhouse conditions. Using pollen viability tests and flower retention studies, they found that excessively high humidity reduced pollen dispersal and fertilization success, while low humidity caused desiccation of pollen grains, leading to lower fruit set rates. The study suggested that greenhouse ventilation control and targeted irrigation scheduling could help maintain optimal humidity levels for improved pollination efficiency.

Given the complex effects of humidity on tomato production in Nigeria, adaptation strategies must be tailored to specific regional conditions. Farmers in humid regions should prioritize disease-resistant tomato varieties, improved aeration, and integrated pest management to combat fungal infections. Meanwhile, those in drier areas should focus on water conservation techniques, such as mulching, shaded cultivation, and efficient irrigation systems, to reduce water stress. Strengthening climate monitoring and early warning systems can also help farmers anticipate unfavorable humidity conditions and implement timely interventions. Policymakers and agricultural extension services should promote these adaptation strategies through farmer training programs, subsidies for climate-smart agricultural inputs, and investments in research and technology development. Addressing the challenges posed by humidity variability will contribute to stabilizing tomato yields, improving food security, and sustaining the livelihoods of Nigerian farmers.

**Discussion of findings**

The review on the effects of climate variability on tomato yield in Nigeria reveals significant challenges posed by climate-related factors, including temperature fluctuations, rainfall variability, humidity changes, and solar radiation shifts. These climatic variables have both direct and indirect effects on tomato production, influencing plant physiology, pest and disease prevalence, soil conditions, and overall yield. The discussion of findings based on existing literature highlights key trends, impacts, and potential adaptation strategies for mitigating climate risks.

Temperature fluctuations have emerged as one of the most critical factors affecting tomato production. Studies such as those by Adebayo and Olagunju (2020) [1] and Kumar *et al*. (2021) [9] demonstrate that temperatures exceeding the optimal range of 25–30 °C disrupt tomato growth, causing poor fruit setting, increased flower abortion, and reduced yield. High temperatures also accelerate the life cycle of pests such as *Tuta absoluta*, leading to more severe infestations. On the other hand, low temperatures, particularly in the dry season, slow down tomato development and increase vulnerability to frost damage in certain regions. Research suggests that the adoption of heat-tolerant tomato varieties and shading techniques can help mitigate temperature-related yield losses.

Rainfall variability is another major concern, with inconsistent precipitation patterns leading to drought stress or excessive soil moisture conditions. Akinbile *et al*. (2019) [3] found that erratic rainfall distribution in Nigeria often results in periods of water scarcity, which negatively affects tomato growth and yield. Conversely, excessive rainfall leads to waterlogging, root rot, and increased susceptibility to fungal diseases such as late blight (*Phytophthora infestans*). These findings highlight the need for improved water management practices, such as drip irrigation and rainwater harvesting, to ensure stable moisture levels for optimal tomato growth.

Humidity plays a crucial role in the prevalence of tomato diseases, particularly fungal and bacterial infections. Nwajiuba *et al*. (2021) [12] demonstrated that high humidity levels above 85% create a favorable environment for pathogens, leading to widespread outbreaks of leaf mold, gray mold, and bacterial wilt. Conversely, low humidity conditions increase plant transpiration, causing water stress and affecting fruit quality. The literature supports the use of greenhouse ventilation, mulching, and controlled irrigation as effective strategies for managing humidity-related challenges in tomato farming.

The socio-economic implications of climate variability on tomato production have also been widely discussed in the literature. Edeh and Gyimah-Brempong (2021) [4] highlighted that climate-induced yield reductions have led to income losses for smallholder farmers, increased tomato prices, and heightened food insecurity in Nigeria. The need for policy interventions to support climate adaptation strategies, including farmer education, access to climate-resilient seeds, and financial assistance for climate-smart technologies, has been emphasized in several studies.

Overall, the literature suggests that while climate variability presents significant risks to tomato production in Nigeria, effective adaptation measures can help mitigate its impacts. Improved farming techniques, investment in resilient

agricultural infrastructure, and government support are crucial in ensuring sustainable tomato production. Future research should focus on developing localized adaptation strategies tailored to different agro-ecological zones to enhance the resilience of Nigerian tomato farmers to climate change.

## Conclusion

In conclusion, this paper highlights the significant impact of climate change variability on tomato production in Nigeria, a sector that is crucial to both food security and the livelihoods of smallholder farmers. The rising temperatures, erratic rainfall, and increased frequency of extreme weather events have led to reduced tomato yields, worsened by pest outbreaks and the spread of diseases. These challenges have severe socio-economic implications, including income losses, higher production costs, and disrupted supply chains. Despite government efforts to address climate-related issues in agriculture, the implementation of climate adaptation policies remains weak, and many farmers lack the necessary resources to effectively adapt to these changes.

The Climate Change Theory provides the scientific basis for understanding climate variability and its impact on tomato yield. The Agricultural Adaptation Theory explains how farmers adjust to changing climatic conditions through various coping strategies. The Sustainable Livelihoods Framework (SLF) highlights the broader socio-economic dimensions of climate change impacts on tomato farmers. Together, these theories provide a comprehensive framework for analyzing the effects of climate variability on tomato farming and identifying sustainable adaptation measures.

The review underscores the need for immediate action to address these climate challenges, particularly through the adoption of climate-smart agricultural practices, improved pest management, and the development of resilient crop varieties. Strengthening government policies and providing farmers with better access to climate data, extension services, and financial support are critical steps toward improving resilience in tomato farming. By adopting these strategies, Nigeria can enhance the sustainability of its tomato production, reduce food insecurity, and protect the livelihoods of its farmers. Ultimately, addressing climate change impacts on agriculture requires a collaborative effort from government, researchers, farmers, and other stakeholders to build a climate-resilient agricultural sector.

## Recommendation

Based on the findings of this paper, several recommendations are made to mitigate the adverse effects of climate change on tomato production in Nigeria:

- Farmers should be encouraged to adopt practices such as improved irrigation techniques (e.g., drip irrigation), agroforestry, mulching, and the use of climate-resilient tomato varieties that can withstand extreme temperatures and pests. These practices can help optimize water usage, reduce soil erosion, and increase crop resilience to climate change.
- Given the increase in pest outbreaks, particularly *Tuta absoluta* (tomato leaf miner), integrated pest management (IPM) strategies should be promoted. This includes the use of biological control agents, regular monitoring of pests, and the adoption of pest-resistant tomato varieties to reduce the impact of climate-induced pest and disease outbreaks.
- There is a need for stronger extension services to educate farmers about climate adaptation strategies, pest management, and sustainable farming practices. Training programs should be tailored to the specific needs of tomato farmers, equipping them with knowledge to navigate the challenges of climate variability.
- More resources should be allocated to research on climate-resilient crop varieties and the development of innovative technologies that can help mitigate climate impacts. Partnerships between government, research institutions, and the private sector could accelerate the development and dissemination of these solutions.
- Improved access to accurate climate data and early warning systems will help farmers make informed decisions about planting and harvesting times. This can reduce the risks associated with unpredictable weather patterns and extreme events, allowing farmers to better prepare for climate challenges.
- By adopting these recommendations, Nigeria can enhance the sustainability of its tomato production, reduce climate-related risks, and support the livelihoods of smallholder farmers.

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