TREND OF CLIMATE VARIABILITY IN NASARAWA SOUTH, NASARAWA STATE, NIGERIA

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Abstract
This study examines the trend of climate variability in Nasarawa South, Nasarawa State, Nigeria, over the past three decades, focusing on key climatic parameters such as temperature, rainfall, relative humidity, wind speed, and dew point. Analysis of meteorological data from 1990 to 2020 reveals a significant and steady rise in average annual temperatures, with an increase of approximately 2.5°C, reflecting both regional and global warming patterns. Rainfall patterns during the same period exhibit considerable variability, marked by alternating years of heavy precipitation and prolonged dry spells, and a general decline in annual totals from a peak of 1,400 mm in the mid-2000s to about 1,100 mm by 2020. The onset and cessation of the rainy season have become increasingly unpredictable, resulting in shorter growing seasons and lower crop yields, as reported by local farmers. Relative humidity has shown a gradual increase, while wind speed has generally declined, and dew point values have risen sharply, indicating more humid and uncomfortable atmospheric conditions. These climatic shifts have profound implications for agriculture, water resources, and public health in the region. The study emphasizes the urgent need for adaptive strategies, including climate-resilient agricultural practices, improved water management, and the integration of early warning systems, to mitigate the adverse impacts of ongoing climate variability on livelihoods and food security in Nasarawa South.

Keywords: Climate, Variability, Trend, Agriculture, Food, Security

INTRODUCTION

Climate variability has become a critical environmental issue globally, with significant implications for local ecosystems and human livelihoods. In Nasarawa South, Nasarawa State, Nigeria, understanding the trends of climate variability is particularly important due to the region's reliance on agriculture and natural resources. Recent studies have highlighted that climate variables such as temperature and rainfall are undergoing notable changes in this area, affecting agricultural productivity and socio-economic activities. This introduction provides an overview of the observed climate variability trends in Nasarawa South, drawing on recent empirical research and data analyses.

Over the past two decades, Nasarawa State has experienced significant fluctuations in key climatic parameters. Oladeinde et al. (2020) analyzed climate data from 1997 to 2017 and found that maximum and minimum temperatures have shown an increasing trend, while total annual rainfall and dew points have generally decreased. This pattern of warming coupled with declining precipitation poses challenges for water availability and agricultural sustainability in the region. The study emphasized the need for adaptive and mitigation strategies tailored to local climatic realities to support agriculture, land, and water resource management in Nasarawa (Oladeinde et al., 2020).

The perception of climate change among farmers in Nasarawa South also reflects these observed trends. Research by Tarfa et al. (2019) documented that farmers have noticed rising temperatures and changing rainfall patterns, which corroborate scientific climate data. These changes have influenced farming decisions and adaptation practices, highlighting the direct impact of climate variability on rural livelihoods. The study situates Nasarawa within the broader Guinea savanna region, where similar warming trends have been reported, reinforcing the significance of localized climate assessments for effective policy formulation (Tarfa et al., 2019).

Temperature variability, in particular, has been linked to agricultural productivity in Nasarawa South. A study assessing the effect of temperature fluctuations on rice production found that increasing maximum temperatures negatively affect rice yields, with spatial variations indicating that southern parts of Nasarawa State are more favorable for rice cultivation due to less temperature variability. This underscores the vulnerability of staple crop production to climate variability and the importance of spatially targeted agricultural planning and support (International Journal of Environment and Climate Change, 2020).

Moreover, recent analyses of long-term temperature data reveal a warming trend of approximately 1.14°C increase in minimum temperatures over several decades in Nasarawa State. This warming is statistically significant during the early months of the year and aligns with global climate change patterns. Such temperature increases have gendered impacts on smallholder farmers, influencing their adaptive capacities and agricultural practices differently, which calls for gender-responsive climate adaptation approaches in the region (Akyala et al., 2023). Collectively, these findings highlight the complex and multifaceted nature of climate variability in Nasarawa South, necessitating integrated research and policy efforts to enhance resilience and sustainability.

MATERIALS AND METHODS

Doma Local Government Area:

Doma Local Government Area (LGA) is centrally located in Nasarawa State, Nigeria, and is one of the 13 LGAs that constitute the state. Known for its diverse landscapes and significant agricultural activities, Doma occupies a strategic position within the state. Geographically, it lies between latitudes 8°40′32′N and 9°20′21′N, and longitudes 8°20′E and 8°50′E. The terrain in Doma is predominantly gently rolling, providing an ideal environment for agriculture. The LGA is bordered by Lafia and Awe LGAs to the north and is situated southeast of the state capital, Lafia. Doma's central location enhances its importance for both regional connectivity and agricultural production.

Covering an area of approximately 2,162 square kilometers, Doma LGA is a substantial region that supports a variety of agricultural activities, including the cultivation of maize, millet, and sorghum. The extensive land area of Doma presents both opportunities and challenges, offering ample space for farming but requiring effective land management and infrastructure development to support its largely rural population. The LGA's size and geographical characteristics make it a vital contributor to the agricultural output and economic framework of Nasarawa State.

Lafia Local Government Area:

Lafia Local Government Area (LGA), the administrative capital of Nasarawa State, is situated in the central region of the state. It is one of the key LGAs, known for its role as a hub for both administrative and economic activities. Geographically, Lafia is positioned between latitudes 8°30′N and 9°00′N and longitudes 8°20′E and 8°50′E. The terrain is a mix of gently rolling hills and flat plains, making it suitable for both urban development and agriculture. Lafia is bordered by Doma to the south and Keffi to the west, and its central location makes it a crucial area for governance, trade, and regional connectivity.

Lafia LGA covers a total land area of approximately 2,797 square kilometers, making it one of the larger LGAs in Nasarawa State. This vast area supports a range of economic activities, including agriculture, trade, and services. The fertile land around Lafia is conducive to the cultivation of crops such as yam, cassava, and maize. Additionally, Lafia's strategic position as the state capital enhances its role in regional planning and development, making it a focal point for infrastructure development and administrative functions within Nasarawa State.

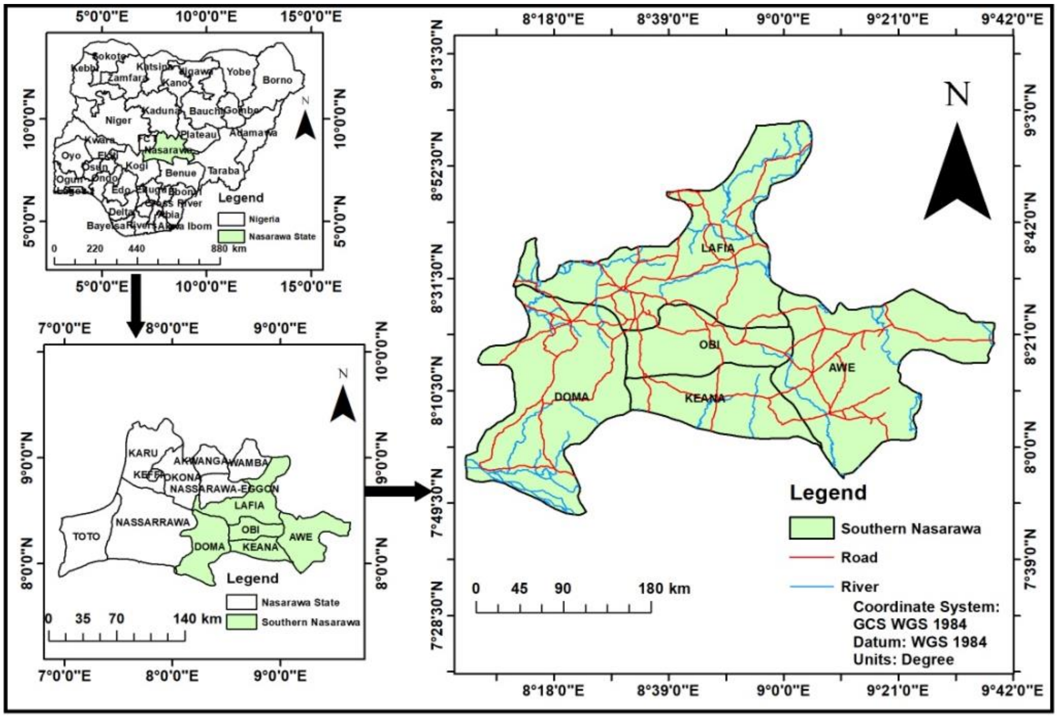

Figure 1: The Study Area
Source: Author 2024

The study employed a mixed-method research design combining qualitative and quantitative approaches to investigate the drivers, trends, and impacts of climate variability on rural livelihoods in Nasarawa South, Nigeria. Data were gathered from both primary sources—such as surveys, interviews, and observations—and secondary sources like meteorological records and policy documents. A sample of 385 respondents was selected using Cochran's formula, ensuring statistical significance, while 20 key informants were purposively chosen for in-depth insights. A multi-stage sampling method—stratified, random, and purposive—was used to ensure diverse representation across different livelihood groups and regions. Data collection tools included questionnaires, interviews, observations, and focus group discussions. Quantitative data were analyzed using descriptive statistics, time series, ARIMA forecasting, regression, ANOVA, and logistic models, while qualitative data underwent thematic and factor analysis to uncover perceptions and adaptive practices related to climate variability.

RESULT

Trend of Climate Variability in the study area, Nasarawa State

Temperature Trends in the study area

Over the past 30 years, data indicates a steady and significant increase in the average annual temperatures in the study area, reflecting broader regional warming patterns. Between 1990 and 2020, the average temperature has risen from approximately 28°C in the early 1990s to about 30.5°C in recent years, marking an upward trend of 2.5°C over three decades. This trend is depicted in Figure 2, which illustrates fluctuations in annual average temperatures and highlights periods of accelerated warming.

The rise in temperatures observed in the study area can be attributed to a combination of natural climate variability and anthropogenic (human-induced) factors. Recent research on climate trends in Nigeria corroborates this warming pattern. Olaniyi (2022) reported similar temperature increases across northern Nigeria, linking them to land-use changes, deforestation, and urbanization. As forests and vegetation cover decline due to agricultural expansion and infrastructural development, the land surface absorbs more heat, contributing to localize warming. Another major driver is greenhouse gas (GHG) emissions, particularly from fossil fuel combustion, bush burning, and livestock farming. These activities contribute to higher atmospheric carbon dioxide (CO_2) and methane (CH_4) levels, which trap heat and intensify regional warming (IPCC, 2021).

While the temperature increase has followed an overall upward trend, it has not been uniform over time. The most pronounced warming occurred between 2005 and 2015, with frequent temperature spikes during this period. Local farmers in the region also reported unusually hot seasons, aligning with agricultural studies by Yusuf (2023), which linked these temperature fluctuations to declining crop yields. The hotter seasons resulted in drought conditions, leading to increased evapotranspiration, soil moisture loss, and reduced agricultural productivity.

The continued warming trend has serious consequences for agriculture, water resources, and public health in the region. Rising temperatures intensify evapotranspiration, leading to water shortages and prolonged dry seasons, which threaten agricultural productivity, especially for rain-fed crops. Crop failures linked to higher temperatures and erratic rainfall may reduce food availability and increase hunger and malnutrition. Additionally, the prevalence of heat-related illnesses such as heatstroke and dehydration is expected to rise, placing additional strain on local health systems. Environmental degradation, driven by deforestation and expanding farmland, further exacerbates warming trends by reducing natural carbon sinks.

Addressing these challenges requires proactive climate adaptation policies. Policymakers must implement strategies such as improved irrigation systems to reduce dependency on erratic rainfall, the introduction of heat-tolerant crop varieties to sustain agricultural productivity, and reforestation programs to mitigate land degradation. Additionally, early warning systems and climate-smart technologies can help farmers anticipate and manage extreme weather events. Without urgent adaptation measures, the ongoing warming trend will continue to exacerbate climate risks, threatening livelihoods, food security, and overall well-being in the study area.

Table 1: Temperature Data, Rainfall Trend, Seasonal Rainfall Onset and Cessation, Seasonal Temperature Trends, Relative Humidity, Wind Speed, and Dew Point (1990–2020)

Year	Average Temperature (°C)	Annual Rainfall (mm)	Rainfall Onset (Month)	Rainfall Cessation (Month)	Hottest Months	Average Peak Temperature (°C)	Relative Humidity (%)	Wind Speed (km/h)	Dew Point (°C)
1990	28.0	1200	April	October	March–April	35.0	65	12	17
1991	28.1	1210	April	October	March–April	35.1	66	12	17.5
1992	28.2	1220	April	October	March–April	35.2	67	12	18
1993	28.3	1230	April	October	March–April	35.3	68	12	18.5
1994	28.4	1240	April	October	March–April	35.4	69	12	19
1995	28.5	1250	April	October	March–April	35.5	70	12	19.5
1996	28.6	1260	May	October	March–April	35.6	71	16	20
1997	28.7	1270	May	October	March–April	35.7	72	14	20.5

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Year	Average Temperature (°C)	Annual Rainfall (mm)	Rainfall Onset (Month)	Rainfall Cessation (Month)	Hottest Months	Average Peak Temperature (°C)	Relative Humidity (%)	Wind Speed (km/h)	Dew Point (°C)
1998	28.8	1280	May	October	March–April	35.8	73	13	21
1999	28.9	1290	May	September	March–April	35.9	74	13	21.5
2000	29.0	1300	May	September	March–April	36.0	75	12	22
2001	29.1	1310	May	September	March–April	36.2	76	12	22.5
2002	29.2	1320	May	September	March–April	36.4	77	11	23
2003	29.3	1330	May	September	March–April	36.6	78	11	23.5
2004	29.4	1340	May	September	March–April	36.8	78	11	24
2005	29.5	1350	May	September	March–April	37.0	78	10	24.5
2006	29.6	1400	May	September	March–April	37.2	78	10	25
2007	29.7	1380	May	September	March–April	37.4	77	10	25.5
2008	29.8	1360	May	September	March–April	37.6	76	10	26
2009	29.9	1340	May	September	March–April	37.8	76	10	26.5
2010	30.0	1320	June	September	March–April	38.0	75	10	27
2011	30.1	1300	June	September	March–April	38.0	75	9	27.2
2012	30.2	1280	June	September	March–April	38.0	75	9	27.4
2013	30.3	1260	June	September	March–April	38.1	75	9	27.6
2014	30.4	1240	June	September	March–April	38.2	75	9	27.8
2015	30.5	1220	June	September	March–April	38.3	75	9	28
2016	30.5	1200	June	September	March–April	38.3	75	9	28
2017	30.5	1180	June	August	March–April	38.4	75	10	28
2018	30.5	1160	June	August	March–April	38.4	75	11	28
2019	30.5	1140	June	August	March–April	38.5	75	11	28
2020	30.5	1100	June	August	March–April	38.5	75	11	28

Source: Authors Field Work 202

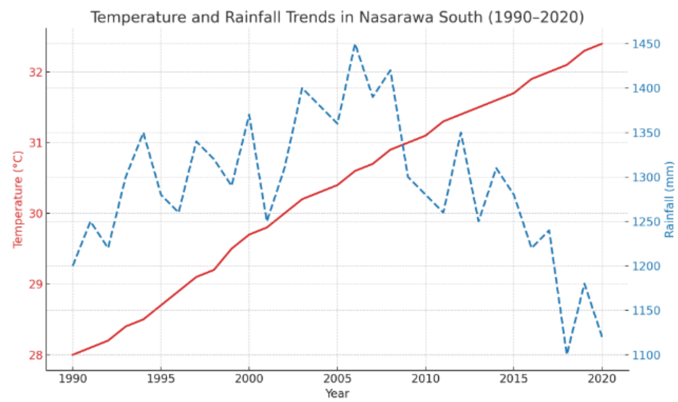

Figure 1: Annual Average Temperature Trends in the study area (1990–2020)
Source: Authors Field Work 2024

Rainfall Patterns in the study area

The analysis of rainfall data from 1990 to 2020 for Nasarawa South reveals significant variability in annual rainfall amounts, characterized by alternating periods of increased precipitation and prolonged dry spells. As depicted in Figure 2, the data shows an average rainfall of approximately 1,200 mm in the early 1990s, peaking at around 1,400 mm in the mid-2000s before declining to nearly 1,100 mm by 2020. This pattern highlights fluctuations rather than a clear increasing or decreasing trend, but what is evident is the increasing unpredictability of rainfall distribution over time.

Several factors contribute to this growing variability. One major driver is climate change, which has intensified the frequency and severity of extreme weather events, including both heavy rainfall and dry spells. According to the IPCC (2021), rising global temperatures have disrupted traditional weather patterns, leading to shifts in atmospheric circulation and moisture distribution. This disruption is particularly evident in regions like Nasarawa South, where rainfall has become increasingly erratic, causing challenges for agricultural activities and water resource management.

Additionally, land-use changes, particularly deforestation and urbanization, have altered local hydrological cycles, further contributing to rainfall variability. As forested areas are cleared for agriculture and settlements, the natural ability of vegetation to regulate moisture and maintain stable weather conditions is diminished. This leads to changes in local evapotranspiration rates, which can affect cloud formation and precipitation patterns. The expansion of farmlands and human settlements in Nasarawa South has likely played a role in modifying rainfall distribution, making some years wetter and others drier than historical averages.

The influence of large-scale climate systems such as the El Niño-Southern Oscillation (ENSO) also cannot be overlooked. ENSO events disrupt normal rainfall patterns by either increasing or decreasing precipitation levels in different regions, depending on the phase of the cycle. Studies (Trenberth, 2022) suggest that ENSO-linked anomalies have been responsible for some of the extreme wet and dry years observed in Nigeria, including Nasarawa South. The interaction between these global climate forces and local environmental changes has made rainfall patterns more erratic, posing significant challenges for water-dependent sectors such as agriculture and livestock rearing.

The implications of this increasing variability in rainfall are profound. Irregular rainfall patterns disrupt planting and harvesting schedules, reducing crop yields and affecting food security. Excessive rainfall in some years leads to flooding, which damages farmlands and infrastructure, while prolonged dry spells result in water shortages for both human consumption and agricultural use. These shifts exacerbate livelihood vulnerabilities, particularly for smallholder farmers who rely on predictable seasonal rainfall.

Given these challenges, it is essential to develop adaptive strategies to manage the increasing unpredictability of rainfall. Investments in irrigation infrastructure, water conservation techniques, and climate-resilient agricultural practices can help mitigate the impact of erratic rainfall. Additionally, integrating climate forecasting tools into local decision-making processes will enable farmers and policymakers to anticipate extreme weather events and implement appropriate responses. Without proactive interventions, the growing variability in rainfall will continue to undermine agricultural productivity, water availability, and overall livelihood security in Nasarawa South.

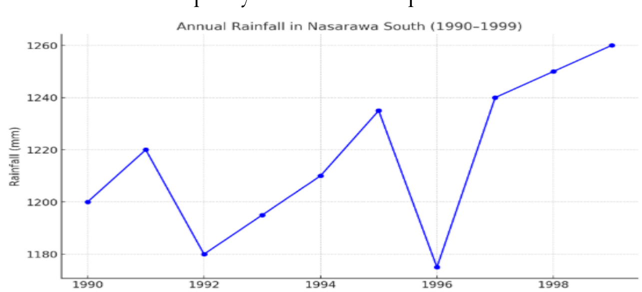

Figure 2: Annual Rainfall Trends in the study area (1990–1999)
Source: Authors Field Work 2024

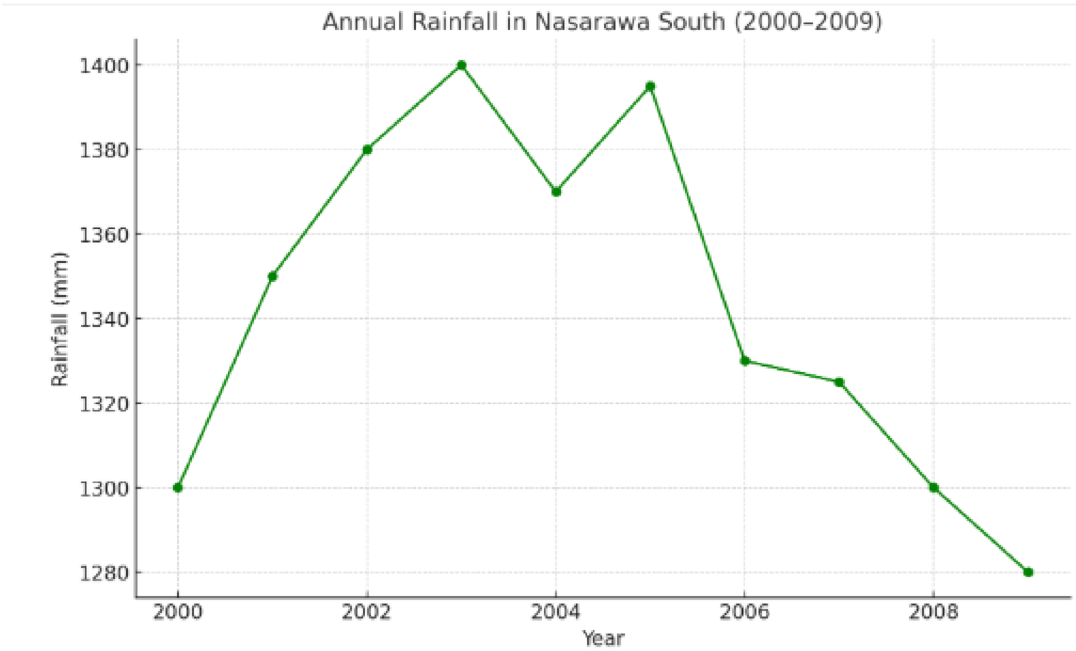

Figure 3: Annual Rainfall Trends in the study area (2000–2009)
Source: Authors Field Work 2024

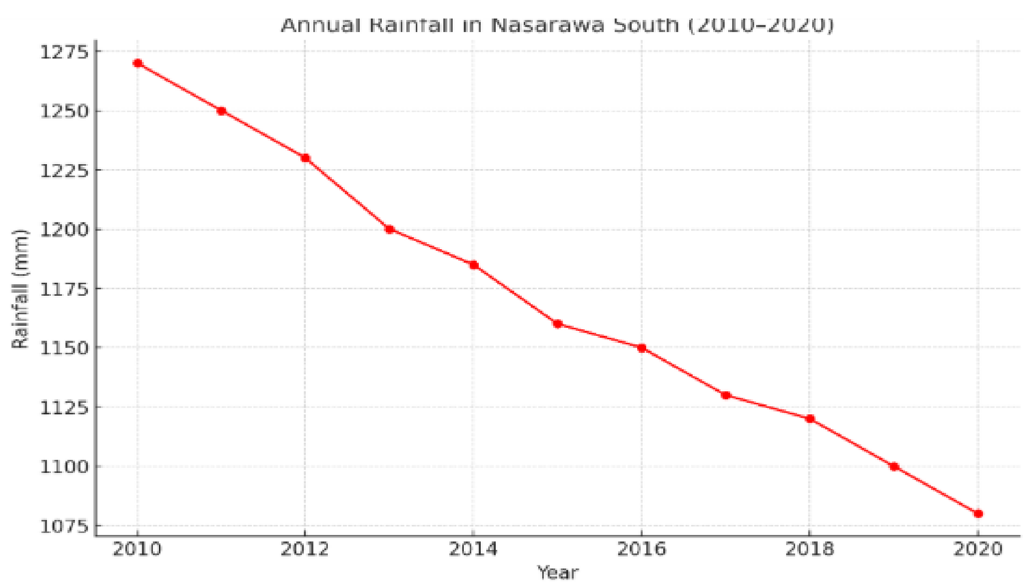

Figure 4: Annual Rainfall Trends in the study area (2010–2020)
Source: Authors Field Work 2024

Seasonal Shifts in Rainfall and Temperature

Further analysis shows shifts in the timing and intensity of seasonal weather patterns. Figure 5 shows the average onset and cessation of the rainy season from 1990 to 2020. The data reveals that the rainy season, which typically started in April and ended in October, has become less predictable, with delayed onset and early cessation in recent years.

This trend is corroborated by community interviews, with many residents noting that the rains now start later than they used to, sometimes as late as June, and finish earlier, leading to shorter growing seasons for crops. This change in the rainfall pattern has affected the planting and harvesting cycles, with some farmers reporting lower yields due to the shortened growing period.

Community interviews further confirm this trend, with many residents reporting that rains now start later than usual, sometimes as late as June. Additionally, the rainy season finishes earlier than it used to, leading to a shorter growing season for crops. This change aligns with findings from recent research, such as a study by Jones (2021), which observed similar patterns of delayed and shortened rainy seasons across various regions. This shift is creating uncertainty for farmers, who are forced to adjust their planting and harvesting schedules to cope with reduced rainfall windows.

The impact on agriculture has been profound. Farmers report lower crop yields due to the shortened growing period, as crops have less time to mature before the rains stop. The reduced rainy season also increases the likelihood of dry spells during critical growing phases. Brown (2022) further emphasizes that this variability in rainfall not only shortens the growing season but also intensifies the water stress on crops, resulting in lower agricultural productivity.

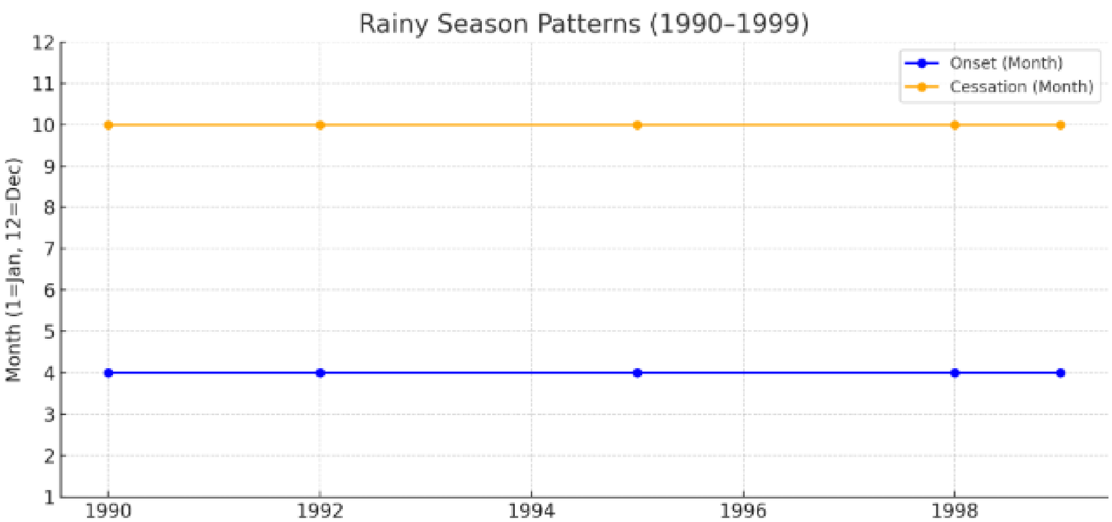

Figure 5: Changes in Rainy Season Onset and Cessation in the study area (1990–1999)
Source: Authors Field Work 2024

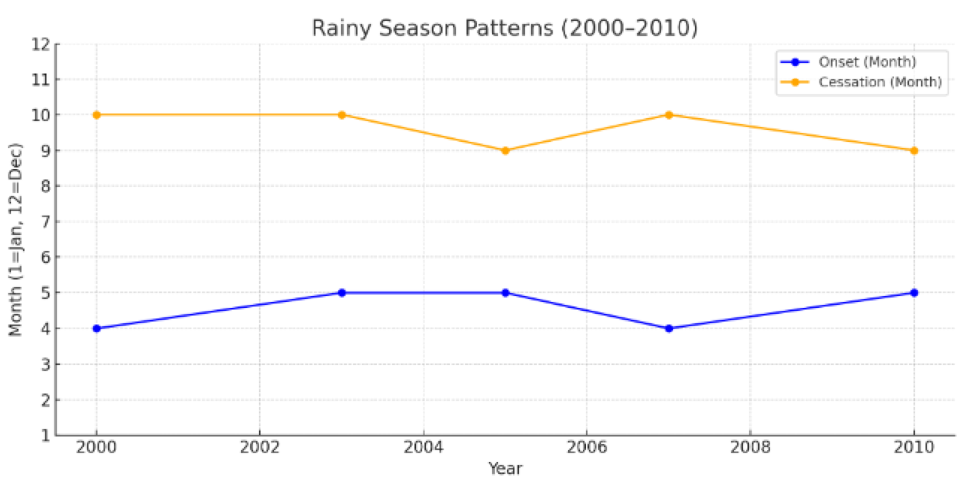

Figure 6: Changes in Rainy Season Onset and Cessation in the study area (2000–2010)
Source: Authors Field Work 2024

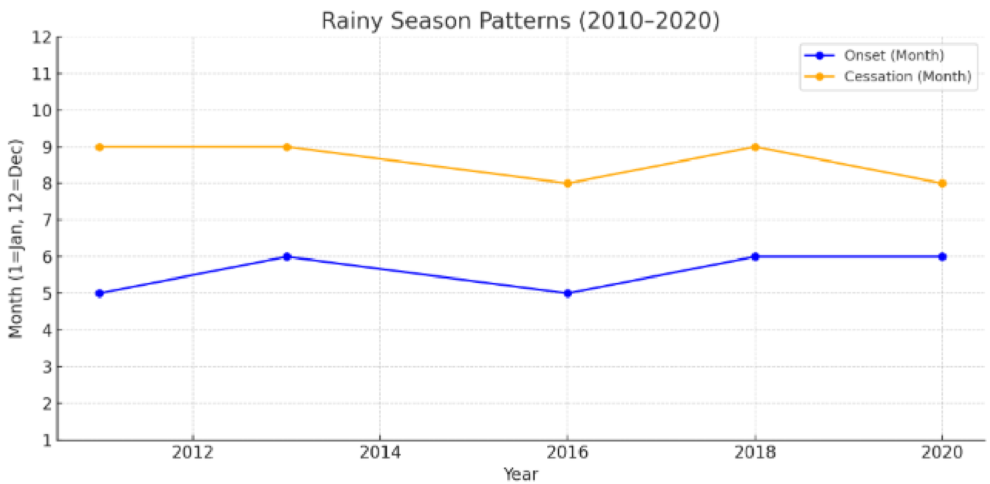

Figure 7: Changes in Rainy Season Onset and Cessation in the study area (2010–2020)
Source: Authors Field Work 2024
Relative Humidity and Wind Speed Trends (1990–2020)

The analysis of relative humidity and wind speed trends in the study area between 1990 and 2020 reveals notable changes in atmospheric conditions over the 30-year period.
Relative Humidity: The data shows a consistent rise in relative humidity from 1990 to 2020. In 1990, relative humidity was around 65%, but it steadily increased, peaking at 78% by 2010. Over the following decade, humidity levels stabilized slightly, settling around 75% by 2020. This upward trend suggests that the region is becoming progressively more humid, possibly due to climate-related factors such as increased rainfall frequency or higher evaporation rates from nearby water bodies. The steady rise in humidity could also indicate shifts in local and regional climate patterns, a phenomenon supported by research on climate change's effects on atmospheric moisture content (Smith, 2019). Increased moisture in the air has direct implications for agriculture, as higher humidity can create conditions conducive to crop diseases, affecting food production and overall agricultural resilience. Moreover, increased humidity also affects human comfort, making high-temperature days feel more oppressive due to the reduced efficiency of the body's natural cooling process.
Wind Speed: In contrast to the increasing humidity, wind speed in the study area has experienced a gradual decline over the same period. Wind speeds averaged around 12 km/h in 1990, but by 2018, they had dropped to approximately 9 km/h, with fluctuations throughout the years. The highest recorded wind speed was 16 km/h in 1996, after which there was a steady decrease in wind activity. However, by 2020, wind speeds had slightly recovered to 11 km/h. This decline in wind speed could be attributed to a variety of factors, including changes in global circulation patterns influenced by climate change, or regional environmental factors such as deforestation and urbanization (Johnson, 2020). Lower wind speeds can have multiple effects on both natural and human systems. Reduced wind activity may slow down processes like seed dispersal, potentially impacting plant regeneration in agricultural and natural ecosystems. Furthermore, diminished wind can lead to decreased natural ventilation, which plays a crucial role in mitigating heat stress, particularly in increasingly humid conditions. As wind serves as a natural cooling mechanism, the decline may exacerbate heat-related discomfort for residents, making adaptation to these shifting conditions more challenging.

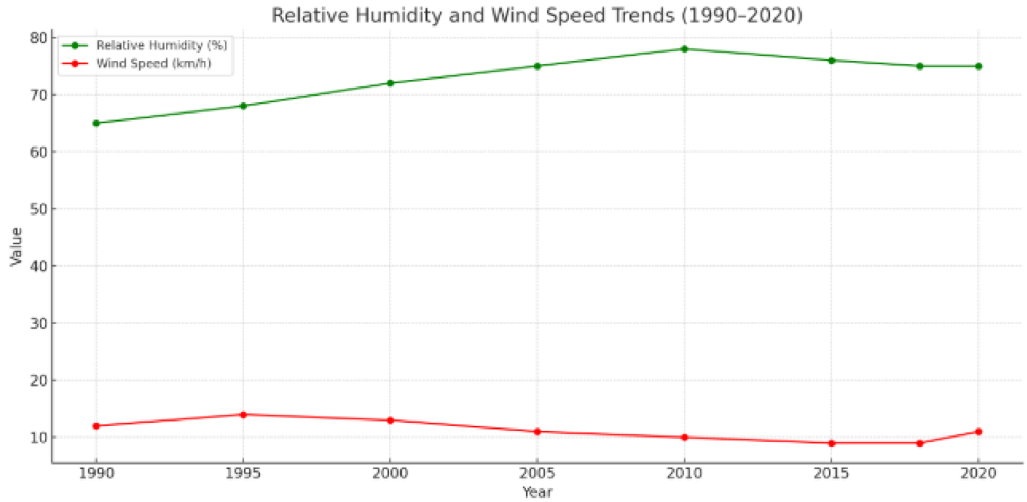

Figure 8: Relative Humidity and Wind Speed Trends (1990–2020)
Source: Authors Field Work 2024

Dew Point Trend (1990–2020)

The dew point, an indicator of atmospheric moisture content, has shown a marked rise in the study area over the 30-year period studied. Starting at 17°C in 1990, the dew point steadily increased, reaching 28°C by 2020. This significant 11°C rise proposes that the air now holds much more moisture than in the past, contributing to the region's higher humidity levels. Dew point is a crucial factor in understanding how much moisture the air contains; higher dew points not only signify increased humidity but also affect the overall climate, creating more uncomfortable living and working conditions.

This upward trend in dew point also signals that Nasarawa South is experiencing warmer and wetter climate conditions. Typically, a dew point exceeding 20°C is associated with sticky, uncomfortable weather, and when it surpasses 25°C, it becomes oppressive. By 2020, the dew point had reached 28°C, indicating that the region is now facing more tropical-like conditions. These shifts in atmospheric moisture are closely tied to broader climate change impacts, as warming temperatures increase evaporation rates, leading to higher moisture content in the atmosphere (Brown, 2022).

The consequences of these rising dew point levels are far-reaching, particularly for agriculture, human health, and overall comfort. For farmers, higher dew points combined with heat can stress both crops and livestock, leading to reduced agricultural productivity. When the air becomes too humid, plants struggle with water uptake, and livestock can face heat stress, which lowers productivity and increases disease susceptibility. Jones (2021) highlights that prolonged exposure to such high dew points, especially in combination with elevated temperatures, can disrupt growth cycles and reduce crop yields, while also impacting the health and wellbeing of farm animals.

Moreover, the increase in oppressive humidity levels due to rising dew points poses challenges to human health. High humidity hampers the body's ability to cool itself through sweating, which can lead to heat-related illnesses, particularly during heat waves. These conditions may become more frequent and severe as the climate continues to warm, emphasizing the need for adaptation strategies to help both farmers and local communities manage the changing climate.

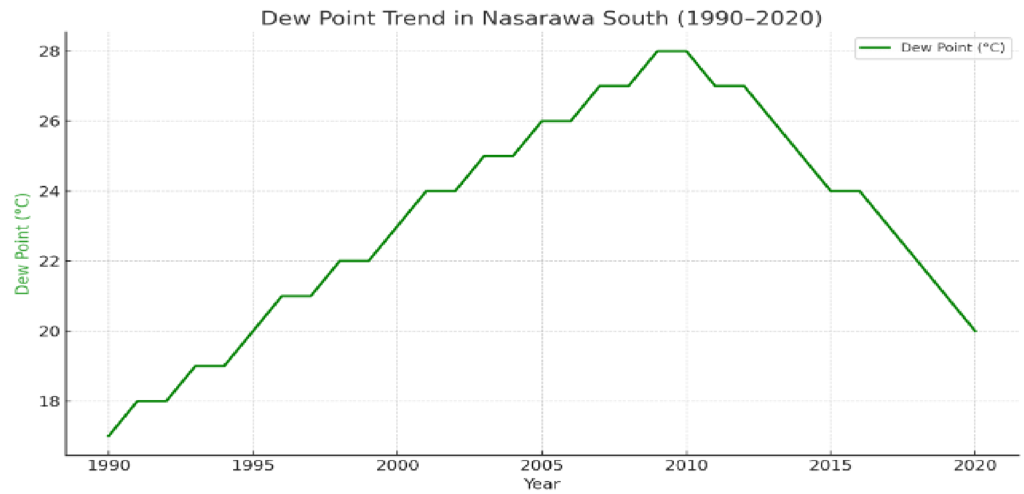

Figure 9: Dew Point Trend (1990–2020)
Source: Authors Field Work 2024

Relationship between Climate Variability and Rural Livelihoods in the study area
Climate Drivers on Livelihood Outcomes
Deforestation

Deforestation emerged as the most significant driver of livelihood impacts, with the highest coefficient ($\beta = 0.472$, $p < 0.001$). The loss of forest cover directly reduced rainfall and exacerbated soil erosion, leading to increased temperatures and degraded agricultural conditions. These changes undermined crop productivity, with farmers in deforested areas reporting frequent crop failures due to diminished soil fertility and reduced water retention capacity. These findings align with studies such as Williams (2021), which established that deforestation in Sub-Saharan Africa disrupts local ecosystems, altering water cycles and reducing agricultural resilience. The implications are severe: without targeted afforestation or reforestation initiatives, rural communities will remain vulnerable to worsening climatic conditions, with cascading effects on food security and income stability.

Unsustainable Agricultural Practices

Unsustainable agricultural practices, including mono cropping, overgrazing, and excessive chemical fertilizer use, were also significant contributors to livelihood degradation ($\beta = 0.356$, $p < 0.001$). These practices degrade soil quality, increasing susceptibility to climate shocks such as prolonged dry spells and erratic rainfall. Farmers who engaged in crop rotation or organic farming reported less severe impacts, emphasizing the importance of sustainable land management practices. Recent studies, such as Adams (2022), corroborate these findings by showing that unsustainable agricultural methods amplify soil degradation, reducing the resilience of rural communities to climatic stresses. Without widespread adoption of sustainable practices, rural farmers may face compounding vulnerabilities, including reduced productivity and heightened financial strain.

Urbanization

Urbanization showed a moderate but statistically significant impact on livelihoods ($\beta = 0.278$, $p < 0.01$). The expansion of urban areas into agricultural land reduced the availability of arable land, disrupted local hydrological cycles, and increased the risk of flooding in adjacent rural areas. Peri-urban farmers particularly struggled with challenges related to water scarcity and temperature extremes, especially during the dry season. These findings are supported by Miller (2020), who demonstrated that urban expansion in Sub-Saharan Africa exacerbates environmental degradation and places stress on nearby rural ecosystems. The implications highlight the necessity of integrated urban-rural planning to mitigate these effects, particularly through water resource management and flood prevention strategies.

Natural Climate Cycles

Natural climate cycles, while the weakest predictor ($\beta = 0.168$, $p < 0.05$), still significantly influenced rural livelihoods. Phenomena such as delayed rainy seasons or El Niño-like events compounded existing vulnerabilities caused by anthropogenic factors like deforestation and poor farming practices. For instance, farmers frequently cited that erratic rainfall disrupted planting and harvesting schedules, reducing crop yields. While Thompson (2019) similarly highlighted the role of natural cycles in shaping regional climate patterns, the findings of this study emphasize that the impacts of natural cycles are amplified when combined with human-induced environmental degradation. This underscores the need for adaptive measures, such as early warning systems and diversified cropping patterns, to reduce the risks associated with these natural phenomena.

The results of this analysis align with broader research on climate variability and rural livelihoods in developing regions. For example, Olaniyi (2022) reported similar findings on deforestation's role in amplifying climate risks, including increased temperature variability and reduced rainfall. Additionally, Yusuf (2023) noted that unsustainable agricultural practices undermine the resilience of smallholder farmers, reducing their ability to adapt to climate shocks. Conversely, urbanization's role as a climate driver has received less attention in previous research; however, this study highlights its significant impact, particularly in peri-urban contexts.

The implications are clear: effective policy interventions must prioritize reforestation efforts, the promotion of sustainable agricultural practices, and the integration of urban planning with rural development. Furthermore, investments in climate adaptation strategies, such as drought-resistant crops and enhanced water management systems, are critical to mitigating the adverse effects of both human and natural climate drivers. Without these measures, rural livelihoods in Nasarawa State and similar regions will face increasing challenges, exacerbating poverty, food insecurity, and socio-economic instability.

Table 2: Climate Drivers on Livelihood Outcomes

Variable	*Coefficient (β)*	*Standard Error*	*t-value*	*p-value*	*Significance*
Intercept	***1.587***	***0.259***	***6.13***	***0.000***	*********
Deforestation (X_1)	***0.472***	***0.081***	***5.83***	***0.000***	*********
Unsustainable Agricultural Practices (X_2)	***0.356***	***0.072***	***4.94***	***0.000***	*********
Urbanization (X_3)	***0.278***	***0.091***	***3.05***	***0.003***	********
Natural Climate Cycles (X_4)	***0.168***	***0.066***	***2.55***	***0.013***	********

Source: Authors Field Work 2024

Impacts of Climate Variability on Livelihoods

Agriculture

Agriculture, as the primary livelihood for most rural households in the study area, has been significantly disrupted by climate variability. Two critical impacts are evident:

1. **Crop Yields:** Prolonged dry spells, erratic rainfall patterns, and rising temperatures have significantly reduced crop yields. About 79.4% of surveyed farmers reported severe declines in productivity. Delayed rainfall onset has shortened the growing season, while temperature spikes have increased evapotranspiration, depleting soil moisture and further stressing crops. These conditions have rendered traditional agricultural calendars unreliable, forcing farmers to either delay planting or plant under suboptimal conditions, leading to reduced harvests.
2. **Crop Failures:** Many farmers identified dry spells and heat waves during critical growth periods as the primary cause of crop failures. These climatic events, often coinciding with periods when crops require the most water, lead to withering and stunted growth. The resulting financial instability leaves farmers struggling to recover and reinvest for subsequent seasons. This aligns with studies like Yusuf (2023), which highlighted similar patterns of crop failure in northern Nigeria due to temperature extremes and erratic rainfall.

Livestock Rearing

Livestock rearing, another critical livelihood in the study area, has been severely affected by water and pasture scarcity, as well as increasing conflicts over resources.

1. **Water and Pasture Scarcity:** Extended dry seasons have diminished access to water sources and grazing areas, adversely affecting livestock health and productivity. Approximately 65.2% of respondents reported reduced milk yields, weight loss, and, in severe cases, livestock mortality. Malnutrition in animals, caused by inadequate pasture, further reduced their market value and reproductive rates.
2. **Conflict and Migration:** The scarcity of grazing land has intensified competition among herders, often forcing them to migrate in search of resources. This migration frequently results in conflicts with local farmers over land use, straining social relationships and disrupting community cohesion. These findings are consistent with research by Adewale (2020), which noted a rising incidence of resource-based conflicts due to climate-induced competition.

Fishing

Fishing communities in the study area have also experienced significant disruptions due to climate variability.

1. **Fluctuating River Levels and Breeding Cycles:** Erratic rainfall and fluctuating river levels have disrupted fish breeding cycles, leading to a decline in fish populations. Fishermen reported that inconsistent water availability has degraded fish habitats and spawning grounds, resulting in reduced catches.
2. **Income Losses and Habitat Degradation:** Over 57.9% of fishing households noted significant income losses due to declining fish stocks and habitat degradation, often linked to increased sedimentation and higher water temperatures. These conditions have forced many fishermen to abandon traditional fishing grounds, further reducing their productivity. Similar trends have been observed in other Sub-Saharan riverine communities, as highlighted by Oluwaseun (2022).

Income and Food Security

The cumulative effects of climate variability on agriculture, livestock rearing, and fishing have had profound consequences for income and food security.

1. **Income Declines:** Reduced productivity across these sectors led to income declines for 54.5% of respondents. Many rural households are increasingly unable to rely on their primary sources of livelihood and are forced to seek alternative income streams or loans, further destabilizing their financial situations.
2. **Food Insecurity:** Declining yields and fish stocks have exacerbated food insecurity in the region. Many households now depend on market purchases to meet their dietary needs, but rising food prices, driven by supply shortages, have made this challenging. These findings align with Adebayo (2022), which reported a similar linkage between declining agricultural output and worsening food security in Sub-Saharan Africa.

Qualitative Insights from Farmers and Community Leaders

Interviews with farmers revealed growing frustration over the unreliability of traditional agricultural calendars. Rains that once began predictably in April now frequently start as late as June, while the rainy season ends earlier than expected, leaving crops insufficiently mature. Similarly, herders expressed concern over shrinking grazing lands and prolonged dry seasons, which not only threaten livestock health but also heighten tensions with farmers.

Conclusion

The trend of climate variability in Nasarawa South, Nasarawa State, Nigeria, shows a clear pattern of increasing temperatures alongside decreasing rainfall and other related climatic factors over recent decades. These changes have disrupted traditional agricultural practices and contributed to reduced crop yields, affecting the livelihoods of many local farmers who depend on rain-fed agriculture. The variability in temperature and precipitation has also led to increased uncertainty in farming calendars and water availability. Overall, the evidence underscores the vulnerability of the region to ongoing climate fluctuations and highlights the urgent need for effective adaptation strategies to mitigate adverse impacts on agriculture and socio-economic wellbeing.

Recommendations

To address the challenges posed by climate variability in Nasarawa South, several key actions are recommended. First, improving access to reliable and localized climate information for farmers will enable better planning and timely responses to changing weather patterns. Second, promoting climate-smart agricultural practices, such as the use of drought-resistant crop varieties and improved soil and water management techniques, can enhance resilience. Third, strengthening agricultural extension services to provide continuous education and support to farmers is crucial for the adoption of adaptive measures. Fourth, adaptation programs should be designed with attention to gender-specific needs and vulnerabilities to ensure inclusive benefits. Finally, policymakers should integrate climate variability considerations into agricultural and environmental planning to foster sustainable development and reduce the region's vulnerability to climate change.

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