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**CLIMATE CHANGE IMPACT ASSESSMENT IN SOUTHEAST NIGERIA**

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**Abstract**

Climate change is a pressing global concern with far-reaching implications for regions like Southeast Nigeria. This assessment focused on long-term trends in temperature, precipitation patterns, and evaporation rate, revealing significant trends in Southeast Nigeria's climate. Increasing temperatures exhibit a high correlation coefficient of 82.9% with time, leading to heat stress, reduced crop yields, altered growing seasons, and potential impacts on water resources, public health, and ecosystems. The decrease in rainfall intensity during the rainy season raises concerns about water availability for domestic and agricultural use, while the consistent increase in evaporation highlights the growing risks of further disappearance of major freshwater sources. It is imperative that policymakers, researchers, and stakeholders develop strategies that promote sustainable development, enhance resilience, and ensure the well-being of the environment and society. We must take action to mitigate the impacts of climate change and ensure a sustainable future for generations to come in the Southeast region of Nigeria and in the indeed the entire nation.

**Keywords:** Climate change, Climate variables, Southeast Nigeria, Trend analysis, Mitigation and adaptation, Environment, Temperature, Rainfall, and evaporation.

**Introduction**

Climate change is a global phenomenon that has far-reaching implications for ecosystems, economies, and societies worldwide. As anthropogenic activities continue to release greenhouse gases into the atmosphere, the Earth's climate system is undergoing rapid and unprecedented changes (Haider, H. 2019). One region that is particularly vulnerable to the impacts of climate change is Southeast Nigeria. Situated in West Africa, Southeast Nigeria is characterized by its

diverse ecosystems, agricultural productivity, and vibrant communities, making it imperative to understand and assess the local consequences of a changing climate (Okon, et al., 2021).

Over the past century, the Earth's average surface temperature has risen, leading to shifts in weather patterns, sea-level rise, and more frequent and severe weather events (Dike, et al., 2020). The Intergovernmental Panel on Climate Change (IPCC) has underscored the urgent need for mitigation and adaptation strategies to keep global temperatures below 2 degrees Celsius above pre-industrial levels (Haider, H. 2019). As nations grapple with mitigating emissions, understanding the regional manifestations of climate change becomes crucial for informed decision-making and effective policy formulation.

While the global picture of climate change is critical, the effects of these changes are often experienced at the local and regional levels. With its unique geographic, ecological, and socio-economic characteristics, Southeast Nigeria faces distinct challenges that necessitate a localized assessment. The region's reliance on rain-fed agriculture, susceptibility to droughts and floods, and potential disruptions to water resources highlight the urgency of understanding how climate change affects this area (Tetteh, R. 2023).

Southeast Nigeria encompasses many ecosystems, including tropical rainforests, savannahs, wetlands, and coastal zones (Okon, et al., 2021). These ecosystems provide essential services such as carbon sequestration, biodiversity conservation, and water regulation, making them critical for the well-being of local communities and the broader global environment. Furthermore, the region has a rapidly growing population that depends on agriculture and natural resources for livelihood. This Climate Change Impact Assessment in Southeast Nigeria aims to address several key questions: How have temperature and precipitation patterns changed over time? Are extreme climate events becoming more frequent or severe? What are the potential implications of these changes for ecosystems, agriculture, and communities in the region? The assessment seeks to provide a comprehensive understanding of the evolving climate dynamics in Southeast Nigeria and equip stakeholders with the knowledge needed to develop effective adaptation and resilience strategies.

### **The Study Area**

The region of Southeast Nigeria shares borders with Cameroon to the east and the Atlantic Ocean to the south. It comprises five states: Anambra, Enugu, Imo, Abia, and Ebonyi (Nwankwo et al., 2017). Southeast Nigeria lies between latitude 4°47'35"N and 7°7'44"N and longitudes 7°54'26"E and 8°27'10"E and occupies a total land area of approximately 78,612 km<sup>2</sup>, representing 8.5% of the country's total land area (Olumba et al., 2021). The region is known for its urbanization, with highly urbanized settlements such as Enugu, Aba, Umuahia, Owerri, Awka, Orlu, Abakaliki, Okigwe, Onitsha, Nsukka, and Afikpo (Olumba et al., 2021). Urban agricultural activities, including crop production, occur in these urban towns. The region shares land borders with other Nigerian states, including Benue to the north, Kogi to the northwest, and Rivers to the south-south region. To the east, it shares a border with Cameroon. The Gulf of Guinea is located south of the region, a part of the Atlantic Ocean (Emeribeole & Iheaturu, 2016).

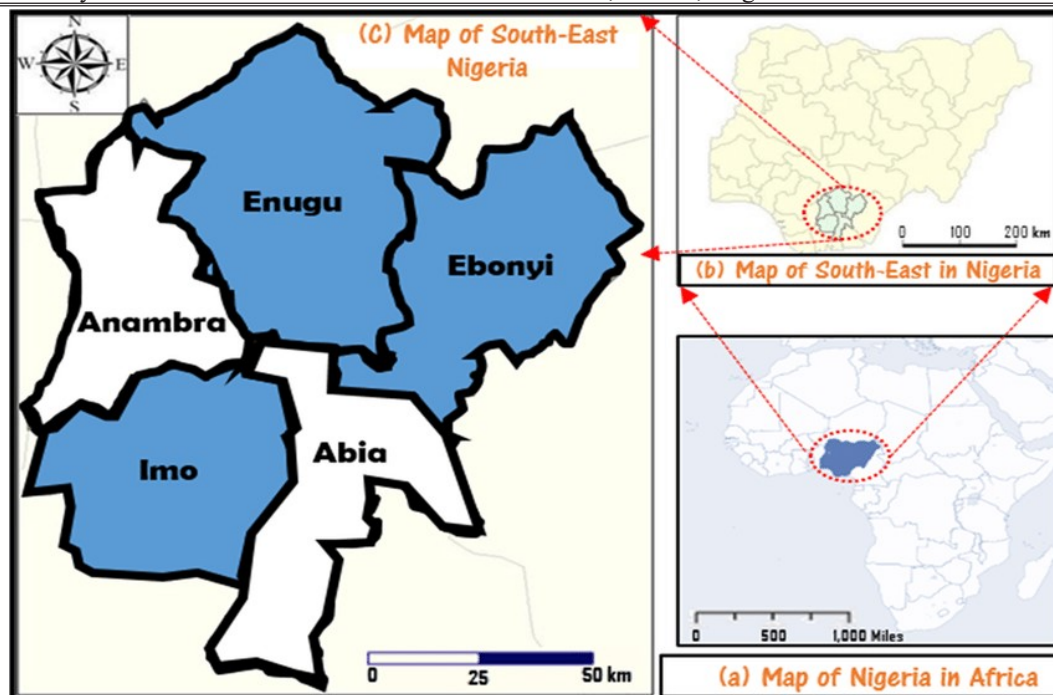


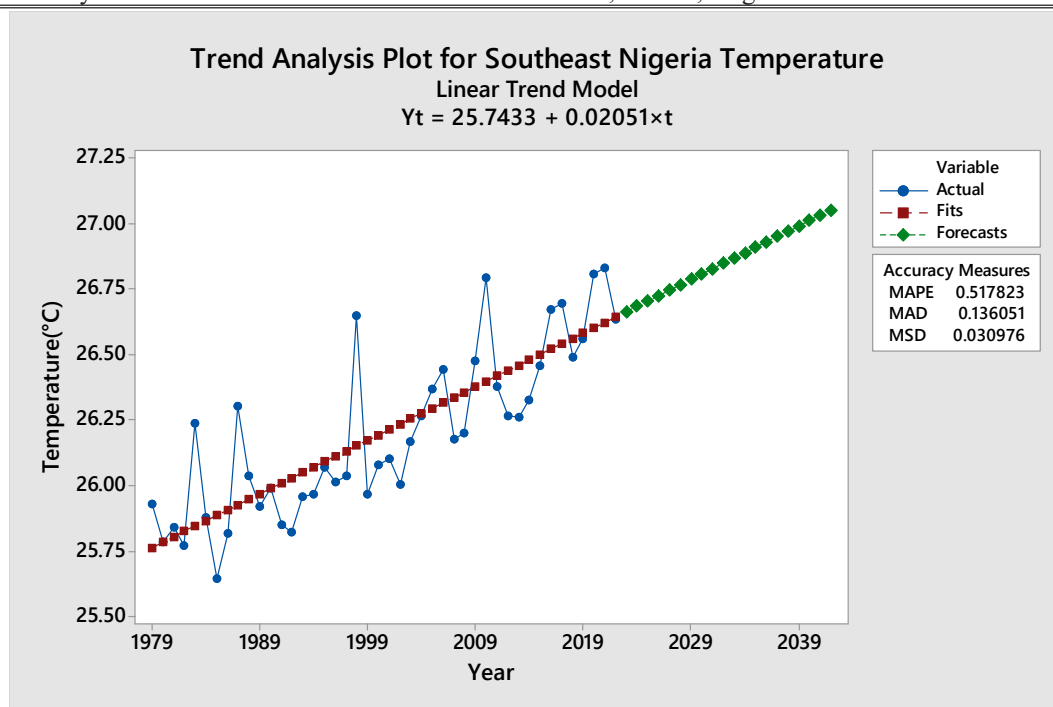
Figure 1. The Map of Southeast Region of Nigeria by (Olumba et al., 2021).

### Methodology

The study shows an in-depth assessment of climate change's impact on the Southeast region of Nigeria. Data spanning a period of 43 years, from 1979 to 2022, was collected to study changes in temperature, precipitation, and evaporation. This information was sourced from a reliable satellite platform called Climate Engine. Minitab and Excel, two advanced software programs, were then employed to analyze the data and predict future changes. The goal of this study was to gain a better understanding of how climate change is impacting the region in the long term. The daily data was converted to monthly and yearly data to enhance clarity and enable the identification of patterns.

### Material and Analysis

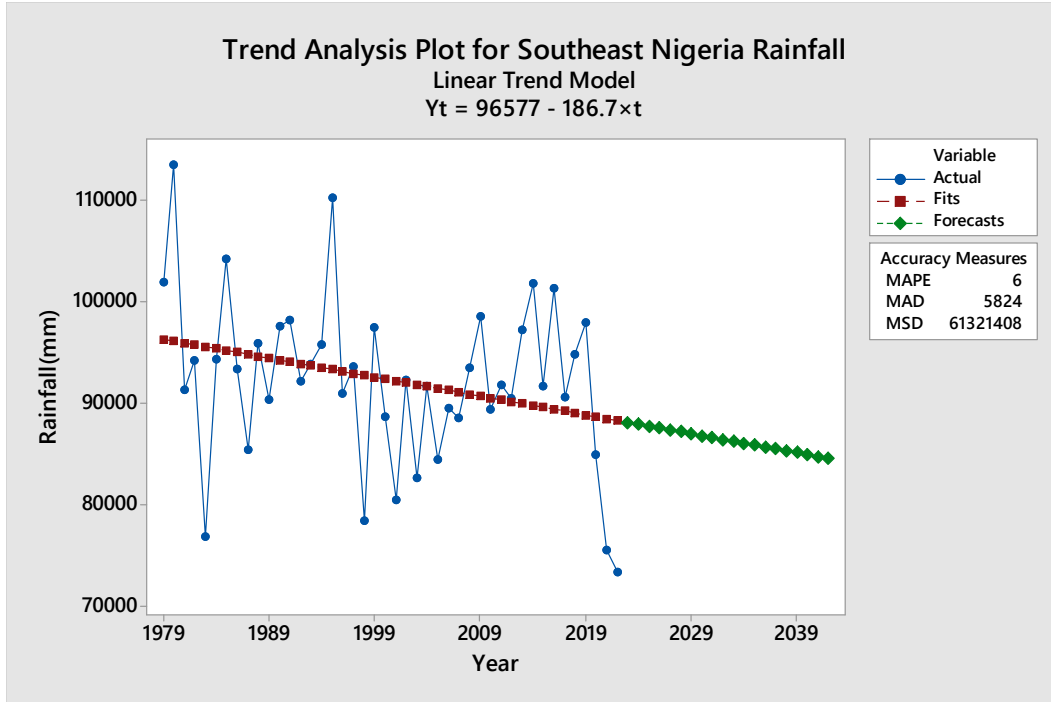
Having downloaded the dataset from Climate Engine, an Excel pivot table was employed for the data processing. Minitab was used to comprehensively analyse temperature trends, as shown in the figures below. From the analysis, the region shows a consistent increase in temperature across the years observed.



**Figure 2.** Trend result of Temperature in Southeast Nigeria from 1979-2022

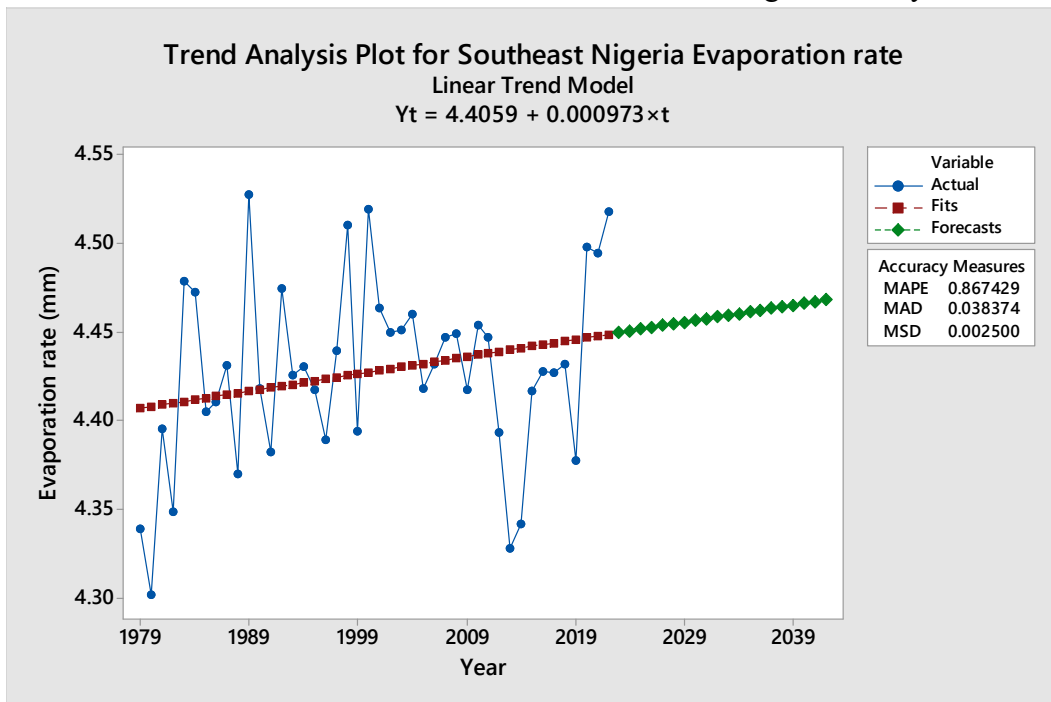
The upward trend of the temperature plot shows the drastic impact climate change has over the region across the period of consideration. From the average annual dataset and considering the descriptive statistics, the minimum temperature occurred in 1985 with the value of 25.64373°C, see Table 1. The portion of the trendline coloured green indicates the forecast for the next 20 years if there are no severe changes in climate factors. Temperatures (Y) show a robust positive correlation with Time(t). Below is the simple equation in its expressed form.

$Y_1 = f(t)$  (Where Y = Climate variable under consideration, and t = Year in Time).



**Figure 3.** Trend result of Rainfall in Southeast Nigeria from 1979-2022

The rainfall trend shows a negative correlation coefficient with time, as seen in Table 1. The amount of rainfall in the region has been consistently decreasing over the years. The overall plot shows a downward trendline, with the minimum value being the latest year, 2022.



**Figure 4.** Trend result of Evaporation rate in Southeast Nigeria from 1979-2022

Evaporation in the area is not left out of the effects of climate change in the area, as the trend shows over increase in the trendline. The disappearance of the famous river Niger along the Asaba-Onitsha bridge is undeniable and readily observable, a perfect example of the impact of evaporation. Evaporation also shows a positive correlation coefficient with time (year).

## Result and Discussion

|             | <i>Year</i> | <i>Temperature</i> | <i>Evaporation</i> | <i>Rainfall</i> |
|-------------|-------------|--------------------|--------------------|-----------------|
| Year        | 1           |                    |                    |                 |
| Temperature | 0.828539    | 1                  |                    |                 |
| Evaporation | 0.239955    | 0.344679           | 1                  |                 |
| Rainfall    | -0.28974    | -0.45291           | -0.69302           | 1               |

**Table 1.** Correlation coefficients of the climate variables with Time

### Temperature Trend

The positive temperature trend with time in Southeast Nigeria significantly impacts the environment, agriculture, and human health. The correlation coefficient shows a strong relationship with time, which is in tune with previous studies conducted in the region (Osugiri et al., 2019). Over the years, the Southeast region of Nigeria has been witnessing an increasing correlation coefficient at different periods. However, in this case, it was estimated to be 82.9% which is very strong (Haider, H. 2019). This situation nevertheless explains the continuous dependency on sources that emit greenhouse gases. It is also worth noting the high rate of deforestation in the region due to farming activities which contribute significantly to the impacts of climate change. In central and northern Nigeria, temperatures have been reaching above 40 °C, with some areas seeing an increase in the number of days with these extreme temperatures. More frequent high temperatures negatively impact people's health, farming, and water availability (Emeribeole & Iheaturu, 2016). Although this may differ from the region under consideration, the continued annual temperature increase will surely hit that target.

Temperature is a fundamental aspect of climate that influences various natural and human systems. In the context of Southeast Nigeria, where temperature-sensitive sectors like agriculture and health are prevalent, the escalating trend of increasing temperatures over the years raises concerns about potential consequences (Haider, H. 2019). Over the past decades, Southeast Nigeria has experienced a noticeable temperature increase, contributing to changes in the region's climate dynamics. These temperature increases are significant, as they can change various ecological and societal aspects (Chineke, et al., 2011).

| Descriptive Statistics |            |           |             |             |            |            |            |             |              |              |
|------------------------|------------|-----------|-------------|-------------|------------|------------|------------|-------------|--------------|--------------|
| Variabl<br>e           | Mea<br>n   | StD<br>ev | Coef<br>Var | Minim<br>um | Q1         | Medi<br>an | Q3         | Maxim<br>um | Skewn<br>ess | Kurt<br>osis |
| Temp<br>(OC)           | 26.2<br>05 | 0.31<br>8 | 1.21        | 25.644      | 25.9<br>61 | 26.17<br>3 | 26.4<br>54 | 26.832      | 0.38         | -0.83        |

|              |            |            |      |        |            |           |            |        |       |      |
|--------------|------------|------------|------|--------|------------|-----------|------------|--------|-------|------|
| Evap<br>(mm) | 4.42<br>78 | 0.05<br>21 | 1.18 | 4.3015 | 4.39<br>46 | 4.429     | 4.45<br>88 | 4.5273 | -0.23 | 0    |
| Rain<br>(mm) | 9237<br>7  | 8276       | 8.96 | 73362  | 8888<br>8  | 9232<br>0 | 9748<br>6  | 113606 | -0.05 | 0.77 |

**Table 2.** The descriptive statistics of the climate variables in Southeast Nigeria.

### Rainfall Trend

The warming trend in Southeast Nigeria has led to changes in rainfall patterns, including decreased durations and intensities (Diagi et al., 2017). The volume of rainfall across the region has shown a level of consistency but on the downward trend of the plot. A correlation coefficient of -0.3 shows a slight, consistent decrease in the intensity of the rainwater in the area (Osugiri et al., 2019). The decreasing rainfall intensity can lead to droughts in Southeast Nigeria (Shiru et al., 2020).

Rainfall is a vital climate system component that sustains ecosystems, agriculture, and communities (Ekwueme, B. N. 2021). In regions like Southeast Nigeria, where rain-fed agriculture plays a significant role in livelihoods, changes in rainfall patterns can have profound implications. Southeast Nigeria experiences a distinct wet and dry season climate pattern, with the rainy season typically extending from April to October, followed by a drier period influenced by the Harmattan winds from November to March. These seasonal variations in rainfall are crucial for agricultural productivity, water replenishment, and ecological balance.

This research is in line with the recent meteorological data analysis, which indicated a concerning trend of decreasing rainfall intensity in Southeast Nigeria over the years. This decline in rainfall intensity during the rainy season raises questions about its potential impact on various aspects of the region's socio-economic fabric (Dike, et al., 2020).

Rainfall, in general, has many impacts across various areas of life. Agriculture in Southeast Nigeria heavily depends on timely and sufficient rainfall (Merem et al., 2019). Decreased rainfall intensity can lead to water stress, affecting crop growth and yield potential. Maize, yam, and cassava are staple crops vulnerable to water deficits. Reduced crop yields could potentially jeopardize food security for the region's growing population, leading to increased dependence on external sources. Agriculture serves as a crucial means of sustenance for livelihood, and reduced crop productivity can impact the income and well-being of farming communities (Merem et al., 2019). Agriculture contributes significantly to the region's economy. Decreased agricultural productivity may hinder economic growth and development prospects. Lower rainfall intensity can impact forest ecosystems, leading to stress on vegetation, reduced tree growth, and potentially affecting biodiversity (Chineke, et al., 2011). Aquatic ecosystems, including rivers and wetlands, may suffer from reduced water flow, impacting fish populations and aquatic habitats (Chineke, et al., 2011).

### Evaporation Trends

Evaporation is a crucial component of the hydrological cycle, playing a significant role in the water balance of regions (Chineke, et al., 2011). In Southeast Nigeria, where water resources are essential for agriculture, industry, and domestic use, the observed increasing trend in evaporation over the years raises concerns about its potential implications. The above correlation coefficient shows that

evaporation has a positive coefficient of 24% with time (year). The trend also shows the average increment of evaporation in the region as seen across the decades by the plot, with the average minimum value occurring since 1980 with the average evaporation rate of 4.30mm and the next closest value occurring in the year 2013, with the average evaporation rate of 4.32mm.

Over recent decades, Southeast Nigeria has experienced a noticeable increase in evaporation rates, as shown in Figure 4, contributing to changes in the region's water dynamics. This trend can potentially disrupt water availability, influence agricultural productivity, and impact the region's ecological balance.

The Impact of evaporation in the region cuts across several areas, such as Water Resources (Increasing evaporation rates can lead to reduced water levels in rivers, lakes, and reservoirs, affecting water availability for various sectors, including agriculture and domestic use. Also, Elevated evaporation can contribute to faster groundwater depletion, potentially leading to reduced aquifer recharge and availability of potable water) (OKOYE & ELKIRAN, 2023)., Ecological and Agricultural sector (Higher evaporation rates can contribute to the drying of wetlands, affecting aquatic ecosystems, bird habitats, and overall biodiversity (Okon, et al., 2021). Agricultural Water Demand: Increased evaporation can escalate irrigation water requirements for agriculture, potentially straining already limited water resources.), and Socio-Economic Impacts (Elevated evaporation rates can lead to soil moisture deficits, negatively impacting crop growth, yield potential, and food security. Hydropower Generation: Reduced water availability due to higher evaporation can impact hydropower generation, affecting energy supply and economic activities).

### **Adaptation and Mitigation Strategies**

Climate change presents significant challenges to Southeast Nigeria and other regions globally. To effectively tackle its harmful effects, it is crucial to implement adaptation and mitigation strategies tailored to the region's specific impact assessment findings (Merem et al., 2019). Southeast Nigeria can establish a more climate-resilient future by adopting a range of approaches, including promoting sustainable development, reducing vulnerabilities, and enhancing resilience.

To address the impacts of climate change and encourage sustainable practices, it is essential to encourage the adoption of drought-resistant crop varieties, improved irrigation techniques, and agroforestry practices. These measures have proven to mitigate changing rainfall patterns and temperature fluctuations, ensuring consistent food production (Reddy, P. P. 2015). Enhancing water storage capacity by constructing reservoirs and rainwater harvesting systems can alleviate water scarcity during dry periods and support agricultural and domestic water needs. Given the region's susceptibility to frequent flooding during the wet season, this method can also aid in reducing the effects of floods (Gitz, et al., 2016).

Restoring and safeguarding wetlands, forests, and coastal ecosystems is also crucial. Healthy ecosystems provide natural buffers against extreme weather events and contribute to carbon sequestration and biodiversity conservation (Ahmed, et al., 2022). Additionally, designing and constructing infrastructure with climate resilience in mind can ensure that communities and buildings can withstand extreme weather events better.



Promoting energy-efficient technologies and practices across sectors is necessary to reduce overall energy consumption and associated emissions (OKOYE & ELKIRAN, 2022). Additionally, transitioning to cleaner energy options, such as solar, wind, and hydroelectric power, can decrease greenhouse gas emissions and mitigate the contribution to climate change. Encouraging large-scale afforestation and reforestation projects can also enhance carbon sequestration and mitigate deforestation (Rafindadi, A. A. 2016).

Implementing effective waste management practices, including recycling and composting, is vital. This implementation can reduce landfill emissions of methane, a potent greenhouse gas. Community engagement and capacity building are also essential aspects to consider (Reddy, P. P. 2015). Raising awareness about climate change among communities, schools, and local leaders can help promote sustainable practices and support climate-related policies. Establishing robust early warning systems for extreme weather events like floods can also help save lives and minimize damage to infrastructure and livelihoods (Ekwueme, B. N. 2021).

Incorporating climate resilience considerations into development plans and policies at all levels is vital. These policies can facilitate informed decision-making for a more climate-resilient future (Ajani, et al., 2023). It is equally essential to support climate-related research and innovation initiatives and raise awareness about climate change impacts and adaptation strategies through training programs, workshops, and educational campaigns. Stakeholders can inform targeted adaptation and mitigation measures by evaluating the consistency between adaptation provisions in the Nationally Determined Contributions (NDCs) and further federal guidelines in Nigeria (Dioha & Kumar, 2020).

Adaptation and mitigation strategies are indispensable for navigating Southeast Nigeria's complex challenges of climate change (Merem et al., 2019). Stakeholders can build a resilient and sustainable future through effective collaboration between government agencies, non-governmental organizations, academia, and local communities (Thornton, et al., 2014). By implementing a combination of measures tailored to the region's specific vulnerabilities and opportunities, Southeast Nigeria can ameliorate the influences of climate change and build a stronger ability to adapt to future changes.

### **Conclusion and Discussion**

Southeast Nigeria faces significant challenges due to climate change, significantly impacting agriculture, water resources, and the overall environment. The comprehensive study was conducted to identify the changes occurring and the potential consequences they may bring. The study analyzed various factors, such as the continuous rise in temperature, the decrease in rainfall, and the increase in evaporation rate. The findings showed that the situation is precarious, and immediate action is necessary (Okon, et al., 2021).

One of the most significant problems is the impact on farming. In Southeast Nigeria, agriculture is the primary income source for the people. However, the shifting weather patterns have made it more challenging to grow crops. The irregular rainfall, rising temperatures, and shifting growing seasons make it challenging for farmers to produce enough food (Reddy, P. P. 2015).

Another pressing issue is the adverse effects on water resources, which negatively impact the environment, including the flora and fauna that rely on water. Moreover, extreme weather events such as floods are occurring more frequently, posing a severe threat to humans, animals, and properties (Hoffmann, et al., 2019).

In conclusion, to address these climate change challenges, it is crucial for all stakeholders, including the government, research groups, and local communities, to collaborate and devise sustainable solutions for Southeast and, indeed, a template for the nation. Some of the potential solutions include innovative farming techniques, better water management, and the use of renewable energy sources. It is imperative to act now and work together to ensure a sustainable future for Southeast Nigeria.

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