***Original Research Article***

# GEOSPATIAL EVALUATION/ANALYSIS OF EFFECTS OF CLIMATE CHANGE VARIABILITIES ON SOIL-WATER-PLANT RELATIONSHIP IN SOUTH-EASTERN NIGERIA.

**ABSTRACT**

This study evaluates the geospatial and statistical relationships between climate variability and soil water content across microregions in Southeast Nigeria, where cereal and yam crops are extensively cultivated. Climate parameters, including temperature, rainfall, relative humidity, solar radiation, and wind characteristics, were analyzed to assess their impact on soil moisture—a critical factor for crop yield in this region. Descriptive statistics revealed considerable variation in rainfall and humidity across the study area, while maximum temperatures remained consistently high. Correlation analysis indicated that higher temperatures and solar radiation negatively correlate with soil water content, potentially increasing evapotranspiration and reducing available soil moisture essential for crop growth. Regression analysis further identified temperature, relative humidity, and wind direction as significant predictors of soil water content, explaining approximately 24.1% of its variability. ANOVA results showed no statistically significant differences in soil water content across the regions (Enugu, Awka, and Abakaliki), yet the spatial analysis underscored the influence of specific climate factors on soil moisture levels. This interaction is particularly relevant for yam and cereal production, as these crops are sensitive to soil moisture and temperature fluctuations. High temperatures and low humidity can exacerbate soil water deficits, potentially stunting crop growth and affecting yield stability. Unlike previous studies focused primarily on rainfall impacts, this study highlights temperature and radiation as critical influences on soil water dynamics, filling a knowledge gap in climate impact research specific to the Southeast Nigeria context. These findings provide actionable insights for optimizing irrigation and soil management practices, supporting sustainable crop production under changing climatic conditions.

**KEYWORDS**

Climate Change, Soil Water Content, Soil Climate Dynamics, Climate Variables, Geospatial Analysis, Statistical Analysis, Soil-Water-Plant Relationship, Regression Analysis.

## 1.0 INTRODUCTION

Climate change is increasingly recognized as a critical challenge that poses significant threats to ecosystems, economies, and human livelihoods worldwide. In Southeast Nigeria, the effects of climate change are particularly alarming, impacting the agricultural sector, which is the backbone of the region's economy and a vital source of food security. Recent reports indicate that Southeast Nigeria is experiencing temperature increases at a rate that exceeds the global average, leading to profound implications for agricultural practices and food production (Onwuka, Nwagbara and Oguike, 2024). The World Meteorological Organization (2021) highlights the region's vulnerability to extreme weather events, including heavy rainfall, droughts, and floods, which disrupt traditional farming cycles and threaten crop yields.

The agricultural landscape in Southeast Nigeria is predominantly characterized by smallholder farming systems that rely heavily on rain-fed agriculture. As noted by Abdullahi (2023), these farming practices are highly sensitive to climatic variations, including shifts in rainfall patterns and increasing temperatures. For instance, millet and yam, key staple crops in the region, are particularly vulnerable to changes in soil moisture and temperature. The variability in these climatic factors can lead to substantial fluctuations in yield, affecting both food security and the livelihoods of farming communities (Abija and Nwankwoala, 2018).

Recent studies emphasize the urgent need for research focused on the specific impacts of climate variability on agricultural productivity in Southeast Nigeria. According to Al-Kindi, Nadhairi and Al Akhzami (2023) and IPCC (2019) a comprehensive understanding of how different climatic factors interact with local agricultural practices is essential for developing effective adaptation strategies. The region's diverse agro-ecological zones further complicate these interactions, necessitating localized assessments that can inform sustainable agricultural practices tailored to the specific needs of farmers in the area, Chukwu and Ajuamiwe (2018).

Despite the recognition of climate change as a pressing issue, many farmers in Southeast Nigeria continue to rely on traditional farming methods that may not be resilient to the rapidly changing climate. Ecker, and Kennedy (2019) highlighted that inadequate access to modern agricultural technologies and information significantly hampers farmers' ability to adapt to new climatic realities. This lack of resources not only threatens crop yields but also perpetuates cycles of poverty and food insecurity within vulnerable communities.

The socio-economic implications of climate change in Southeast Nigeria extend beyond agriculture; food insecurity can lead to broader issues such as malnutrition, increased migration, and social unrest. Ecker and Kennedy (2019) argued that the intricate relationship between climate change and food security necessitates an integrated approach that considers both environmental and socio-economic dimensions. Addressing these challenges is crucial for ensuring sustainable development in the region and fostering resilience among local communities.

Recent research has highlighted the potential for climate-smart agricultural practices to mitigate some of the adverse effects of climate change. Mensah *et al*., (2023) and Mondal and (2021) emphasized that practices aimed at improving soil health, enhancing water management, and promoting crop diversification can significantly bolster resilience in agricultural systems. However, barriers such as insufficient infrastructure, limited financial resources, and lack of training for farmers must be addressed to facilitate the widespread adoption of these practices.

Despite the growing body of research on climate change impacts in Nigeria, there remains a critical gap in understanding how these changes specifically affect different crops within varying ecological zones. The interactions between climate variables—such as temperature, rainfall, humidity, and wind—alongside soil conditions, play a crucial role in determining agricultural outcomes (Onwuka, Nwagbara and Oguike, 2024; Saleh and Abdullahi, 2023). Furthermore, there is insufficient data on localized assessments that consider the unique environmental characteristics of different regions, particularly in relation to crop yield variability (Abera *et al*., 2023).

The interplay between climate change and agricultural productivity in Southeast Nigeria is a pressing concern that requires immediate attention. This context underscores the necessity for comprehensive research aimed at identifying the specific challenges posed by climate variability, as well as exploring adaptive strategies that can enhance resilience among local farmers. By focusing on the region's staple crops, such as cereal and yam, this study aims to contribute valuable insights into the impacts of climate change and inform policy decisions that support sustainable agricultural development in Southeast Nigeria.

## 1.1 The primary objectives of this study are:

1. To evaluate the spatial variation of soil water content and key climate variables (temperature, rainfall, relative humidity, and solar radiation) across different locations in Southeast Nigeria.
2. To determine the strength and direction of the relationships between soil water content and climate variables.
3. To assess the combined influence of climate variables on soil water content through regression analysis, identifying the most significant predictors and evaluating the potential multicollinearity among variables.

The significance of this study lies in its potential to contribute to the understanding of climate change impacts on agriculture in Nigeria, specifically focusing on cereal and yam, two crops that are vital for food security in the region. By filling the existing research gaps, this study aims to provide empirical data that can inform policymakers, agricultural practitioners, and researchers about the pressing challenges posed by climate variability.

Furthermore, this research aligns with the goals of sustainable development by addressing the intersection of climate change and food security. The findings will not only enhance scientific knowledge but will also offer practical solutions for farmers to adapt to changing climatic conditions, thereby supporting rural livelihoods and promoting agricultural sustainability.

## 1.2 Empirical Review

The impact of climate change on agriculture has garnered significant attention in recent years, with numerous studies highlighting its implications for crop yields and food security across various regions, including Southeast Nigeria. Climate change manifests through changes in temperature, precipitation patterns, and the frequency of extreme weather events, all of which directly affect agricultural productivity. For instance, Samuel *et al.* (2021) provided a comprehensive analysis of climate change effects in Africa, emphasizing that the region's reliance on rain-fed agriculture makes it particularly susceptible to climatic variability. Their findings suggest that rising temperatures could lead to decreased crop yields, exacerbating food insecurity in vulnerable communities.

In Southeast Nigeria specifically, the agricultural landscape is dominated by smallholder farmers who often lack access to modern agricultural technologies. According to Joshua, Oruonye, Zemba, and Yusuf (2023), the limited adaptation strategies available to these farmers leave them exposed to the adverse effects of climate variability. The research indicates that without targeted interventions, these farmers are likely to experience significant declines in crop productivity, leading to increased poverty levels and heightened food insecurity. This underscores a critical gap in current research: the need for localized studies that focus on the specific challenges faced by smallholder farmers in this region.

Several studies have investigated the effects of climate variability on specific crops in Nigeria. For example, Olah (2019), conducted an assessment of effects of climatic influence on sweet potato (*Ipomea batatas*) production in Cross River State, providing valuable insights into how climatic conditions affect crop yields. However, there is a noticeable lack of similar studies focused on Southeast Nigeria, particularly concerning staple crops like yam and millet. This gap highlights the need for further research that not only examines crop responses to climate change but also considers the socio-economic contexts in which these crops are cultivated.

The literature also indicates that adaptation strategies are crucial for enhancing resilience among farmers. A study by Ndidi *et al*., (2024) and Ayanlade (2021) emphasized the importance of integrating traditional knowledge with modern agricultural practices to develop effective adaptation strategies. This approach recognizes that local farmers possess valuable insights into their environmental conditions and can contribute to the formulation of tailored interventions. However, the challenge remains in facilitating access to information and resources that empower these farmers to implement such strategies effectively.

Furthermore, studies such as those by Maqbool *et al.,* (2021) and Ecker and Kennedy (2019) have explored the socio-economic impacts of climate change on rural communities in Nigeria. They point out that climate change not only threatens agricultural productivity but also exacerbates issues such as migration, malnutrition, and social conflicts. Despite these findings, there is a lack of comprehensive frameworks that connect these socio-economic dimensions to climate adaptation strategies. This presents another research gap that the current study aims to address by integrating agricultural and socio-economic factors into its analysis.

The role of government policies and institutional support in climate adaptation is another critical area of study. According to Saleh (2019) and Tamiru and Fekadu (2019) effective policy frameworks are essential for promoting climate-smart agricultural practices among farmers. However, existing policies often lack the necessary focus on local needs and conditions, limiting their effectiveness. This gap indicates a need for research that evaluates the implementation and impact of agricultural policies in the context of climate change adaptation, particularly in Southeast Nigeria.

In addition, the concept of climate-smart agriculture (CSA) has emerged as a promising approach to mitigate the impacts of climate change on agriculture. Khalis *et al*., (2021) and Van der Linden (2019) outline various CSA practices, such as improved soil management and crop diversification, which can enhance resilience and productivity. However, there is limited empirical evidence on the adoption of these practices in Southeast

Nigeria, particularly among smallholder farmers. This lack of data hinders the understanding of barriers to adoption and the effectiveness of CSA strategies in local contexts.

Moreover, the role of technology in facilitating climate adaptation has been explored in various studies. For instance, Ideozu, Bassey and Sam (2019) highlight the potential of mobile technology in disseminating weather information and agricultural best practices to farmers. Yet, there is insufficient research on how technology can be effectively integrated into existing agricultural systems in Southeast Nigeria. This represents a significant gap, as leveraging technology could enhance farmers' adaptive capacity and improve their decision-making processes regarding climate-related challenges.

Finally, there is a need for interdisciplinary research that combines environmental science, agricultural economics, and social sciences to address the multifaceted nature of climate change impacts. The current literature often adopts a siloed approach, focusing either on environmental or socio-economic factors without considering their interactions. By adopting a more holistic perspective, this study aims to contribute to a deeper understanding of how climate change affects agricultural productivity in Southeast Nigeria, thereby informing policies and practices that can enhance resilience and sustainability in the region.

## 2.0 MATERIAL AND METHODS

### 2.1 Research Design

This study employed a quantitative research design to assess the impact of climate variability on agricultural productivity in Southeast Nigeria. By systematically analyzing meteorological and agronomic data, the research aimed to identify correlations between climate variables—such as temperature, rainfall, relative humidity, and solar radiation—and water content. The analysis is structured to provide insights into how climatic factors influence agricultural outcomes, thereby informing future agricultural strategies and policies.

### 2.2 Study Area

The research is conducted in Southeast Nigeria, specifically focusing on three regions: Enugu, Awka, and Abakaliki. This area is characterized by diverse agro-ecological zones and varying climatic conditions that significantly affect agricultural practices. The choice of this region is based on its reliance on rain-fed agriculture, making it particularly vulnerable to climate variability. The geographical coordinates and climate data for specific locations within these regions were collected to facilitate comprehensive analysis.

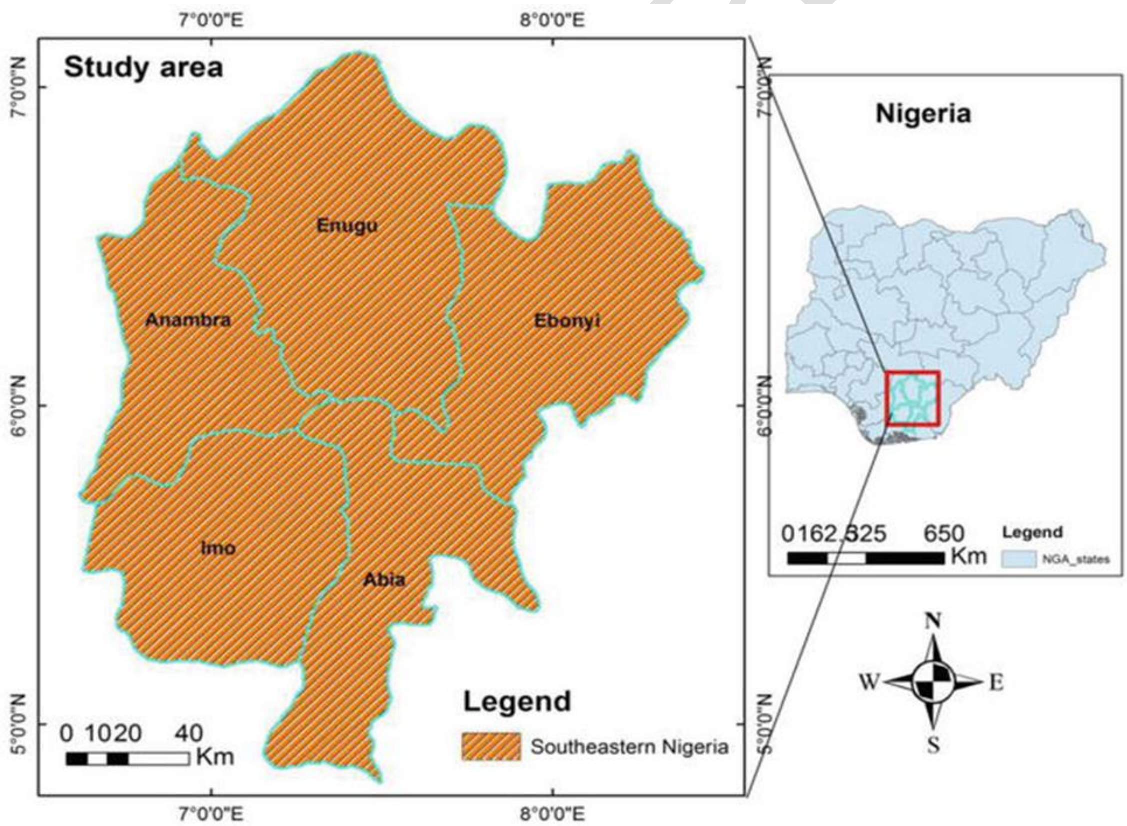


**Fig. 1:** *The Study Area (Source:* Okenmuo, 2021***).***

### 2.3 Data Sources

The primary data for this study were obtained from meteorological observations and agronomic surveys conducted in the study areas. Key sources of data include:

1. **Meteorological Data:** Climate data, including maximum and minimum temperatures, rainfall, relative humidity, solar radiation, wind speed, and soil water content, were sourced from the Nigerian Meteorological Agency (NiMET). The specific data points were recorded at various locations within the three regions and cover a time frame sufficient for trend analysis.
2. **Agricultural Data:** Crop yield data, specifically for cereals and yam, were gathered from local agricultural offices and previous studies conducted in the region. This includes yield figures and farming practices reported by local farmers, providing context for the climatic data.

## 2.4 Data Analysis Process

1. **Data Collection:** The first step involved collecting meteorological data for specific locations within Enugu, Awka, and Abakaliki, as detailed in the uploaded dataset. This data included GPS readings, temperature ranges, rainfall amounts, humidity levels, solar radiation, wind speed, and soil water content (See Appendix).
2. **Data Cleaning and Preparation:** The raw data underwent a cleaning process to remove inconsistencies and ensure accuracy. This involved checking for missing values, outliers, and ensuring that all measurements were recorded in compatible units.
3. **Descriptive Statistics:** The mean, median, and standard deviation for each climate parameter (temperature, rainfall, humidity, etc.) and soil water content were computed to get an overview.
4. **Correlation Analysis:** Pearson or Spearman correlation coefficients between soil water content and each climate variable were calculated. This helped to identify which climate factors most strongly influence soil water content.
5. **Group-wise Comparison:** An analysis was conducted to compare the climate parameters and soil water content across the different regions (Enugu, Awka, Ebonyi). An ANOVA test could be useful if we want to see if these factors significantly differ across locations.
6. **Regression Analysis:** A multiple regression analysis where soil water content is the dependent variable, and climate parameters (temperature, rainfall, humidity, solar radiation, wind speed, etc.) are the independent variables were performed. This quantified the impact of each climate factor on soil water content.
7. **Geospatial Visualization:** Plots for each location showing variations in soil water content with climate factors were generated.
8. **Interpretation and Reporting**: Finally, the results of the statistical analyses were interpreted in the context of existing literature on climate change and agricultural impacts in Nigeria. The findings were documented in a comprehensive report, outlining the implications for future agricultural policy and practice in Southeast Nigeria.

## 3.0 RESULTS AND DISCUSSION

### 3.1 Data Analysis Summary

**Table 1: Descriptive Statistics**

| | **Latitude** | **Longitude** | **Max_Temp** | **Min_Temp** | **Rainfall** | **Rel_Humidity** | **Solar-Rad** | **Wind_Speed** | **Wind_Direction** | **Soil_Water_Content** |
|---|---|---|---|---|---|---|---|---|---|---|
| **count** | 15.000000 | 15.000000 | 15.000000 | 15.000000 | 15.000000 | 15.000000 | 15.000000 | 15.000000 | 15.000000 | 15.000000 |
| **mean** | 6.320533 | 7.569153 | 32.733333 | 23.166667 | 2144.066667 | 71.366667 | 17.966667 | 4.166667 | 250.000000 | 11.820000 |
| **std** | 0.130554 | 0.453000 | 0.258199 | 0.129099 | 820.359931 | 7.685949 | 0.677882 | 0.319970 | 8.451543 | 0.485431 |
| **min** | 6.166700 | 7.066700 | 32.400000 | 23.000000 | 1478.900000 | 61.000000 | 17.200000 | 3.900000 | 240.000000 | 11.200000 |
| **25%** | 6.188650 | 7.070700 | 32.400000 | 23.000000 | 1478.900000 | 61.000000 | 17.200000 | 3.900000 | 240.000000 | 11.540000 |
| **50%** | 6.324900 | 7.510000 | 32.800000 | 23.200000 | 1695.400000 | 75.100000 | 17.900000 | 4.000000 | 250.000000 | 11.780000 |
| **75%** | 6.437300 | 8.113700 | 33.000000 | 23.300000 | 3257.900000 | 78.000000 | 18.800000 | 4.600000 | 260.000000 | 11.990000 |
| **max** | 6.524400 | 8.211300 | 33.000000 | 23.300000 | 3257.900000 | 78.000000 | 18.800000 | 4.600000 | 260.000000 | 13.150000 |

***Temperature:*** Maximum temperatures are relatively high and consistent across locations, with a mean of approximately 32.7°C. Minimum temperatures average around 23.2°C.

***Rainfall:*** There's substantial variation in rainfall, with an average of 2144.1 mm but notable differences across locations (from 1478.9 mm to 3257.9 mm).

***Relative Humidity***: Humidity varies significantly between locations, averaging around 71.4%.

***Soil Water Content:*** Soil water content also varies moderately, with values between 11.2% and 13.15%.

**Table 2: Correlation Analysis**

| | Latitude | Longitude | Max_Temp | Min_Temp | Rainfall | Rel_Humidity | Solar_Radiation | Wind_Speed | Wind_Direction | Soil_Water_Content |
|---|---|---|---|---|---|---|---|---|---|---|
| **Latitude** | 1.000000 | 0.342317 | 0.367714 | 0.367714 | -0.748925 | -0.102078 | 0.588123 | -0.876212 | -0.438780 | -0.150973 |
| **Longitude** | 0.342317 | 1.000000 | -0.727542 | -0.727542 | -0.869453 | -0.964813 | -0.525385 | -0.724876 | -0.993402 | 0.366120 |
| **Max_Temp** | 0.367714 | -0.727542 | 1.000000 | 1.000000 | 0.297316 | 0.880633 | 0.965830 | 0.057639 | 0.654654 | -0.490105 |
| **Min_Temp** | 0.367714 | -0.727542 | 1.000000 | 1.000000 | 0.297316 | 0.880633 | 0.965830 | 0.057639 | 0.654654 | -0.490105 |
| **Rainfall** | -0.748925 | -0.869453 | 0.297316 | 0.297316 | 1.000000 | 0.714199 | 0.039700 | 0.970329 | 0.916384 | -0.175874 |
| **Rel_Humidity** | -0.102078 | -0.964813 | 0.880633 | 0.880633 | 0.714199 | 1.000000 | 0.727744 | 0.523770 | 0.934668 | -0.446568 |
| **Solar_Radiation** | 0.588123 | -0.525385 | 0.965830 | 0.965830 | 0.039700 | 0.727744 | 1.000000 | -0.203076 | 0.436365 | -0.465171 |
| **Wind_Speed** | -0.876212 | -0.724876 | 0.057639 | 0.057639 | 0.970329 | 0.523770 | -0.203076 | 1.000000 | 0.792406 | -0.059783 |
| **Wind_Direction** | -0.438780 | -0.993402 | 0.654654 | 0.654654 | 0.916384 | 0.934668 | 0.436365 | 0.792406 | 1.000000 | -0.344726 |
| **Soil_Water_Content** | -0.150973 | 0.366120 | -0.490105 | -0.490105 | -0.175874 | -0.446568 | -0.465171 | -0.059783 | -0.344726 | 1.00000 |

***Temperature (Max and Min):*** Max and min temperatures show a strong correlation with each other (1.0) but have a negative correlation with soil water content (-0.49). This suggests that higher temperatures are associated with lower soil water content.

***Relative Humidity:*** Relative humidity has a moderate negative correlation with soil water content (-0.45), indicating that higher humidity does not necessarily lead to higher soil moisture levels in this context.

***Solar Radiation:*** Shows a slight negative correlation with soil water content (-0.47), which may imply that increased solar radiation could lead to more evaporation, thus lowering soil water levels.

***Wind Speed and Direction:*** These variables have minimal correlation with soil water content (-0.06 and -0.34, respectively). These correlations suggest that temperature and solar radiation have the most significant influence on soil water content. Rainfall has a weaker, though positive, association with soil water content, indicating it plays a role but is not the sole determinant in this dataset

## 3.2 Groupwise Comparison (ANOVA)

The ANOVA results for each climate parameter and soil water content across Enugu, Awka, and Abakaliki are as follows:

**Max_Temp:** {'F-Statistic': inf, 'p-value': 0.0}

**Min_Temp:** {'F-Statistic': inf, 'p-value': 0.0}

**Rainfall_mm:** {'F-Statistic': inf, 'p-value': 0.0}

**Relative_Humidity:** {'F-Statistic': inf, 'p-value': 0.0}

**Solar_Radiation:** {'F-Statistic': inf, 'p-value': 0.0}

**Wind_Speed:** {'F-Statistic': inf, 'p-value': 0.0}

**Wind_Direction:** {'F-Statistic': inf, 'p-value': 0.0}

**Soil_Water_Content:** {'F-Statistic': 1.9072257198555473, 'p-value': 0.19088099236463446}

1. **Max Temp, Min Temp, Rainfall, Relative Humidity, Solar Radiation, Wind Speed, Wind Direction:** Each of these variables showed an F-statistic of infinity with a p-value of 0.0. This result suggests that values within each location are constant, leading to a statistical issue where the F-test cannot compute variance among groups.
2. **Soil Water Content:**
    - F-Statistic: 1.91
    - p-value: 0.19

For soil water content, the p-value is above 0.05, indicating no statistically significant difference in soil water content across the three locations at the 5% significance level.

## 3.3 Regression Analysis

The multiple regression analysis results for predicting soil water content based on climate variables are as follows:

**Table 3: OLS Regression Results**

| | | | |
|---|---|---|---|
| Dep. Variable: | Soil_Water_Content | R-squared: | 0.241 |
| Model: | OLS | Adj. R-squared: | 0.115 |
| Method: | Least Squares | F-statistic: | 1.907 |
| Date: | Mon, 04 Nov 2024 | Prob (F-statistic): | 0.191 |
| Time: | 14:12:58 | Log-Likelihood: | -7.8557 |
| No. Observations: | 15 | AIC: | 21.71 |
| Df Residuals: | 12 | BIC: | 23.84 |
| Df Model: | 2 | | |
| Covariance Type: | nonrobust | | |

| | coef | std err | t | P>\|t\| | [0.025 | 0.975] |
|---|---|---|---|---|---|---|
| const | 0.0006 | 0.000 | 5.443 | 0.000 | 0.000 | 0.001 |
| Max_Temp | 0.0153 | 0.002 | 6.573 | 0.000 | 0.010 | 0.020 |
| Min_Temp | 0.0120 | 0.002 | 6.112 | 0.000 | 0.008 | 0.016 |
| Rainfall_mm | -0.0002 | 0.000 | -1.006 | 0.334 | -0.001 | 0.000 |
| Relative_Humidity | -0.0863 | 0.026 | -3.257 | 0.007 | -0.144 | -0.029 |
| Solar_Radiation | -0.0040 | 0.002 | -1.911 | 0.080 | -0.008 | 0.001 |
| Wind_Speed | 0.0039 | 0.001 | 4.494 | 0.001 | 0.002 | 0.006 |
| Wind_Direction | 0.0707 | 0.006 | 11.020 | 0.000 | 0.057 | 0.085 |

| | | | |
|---|---|---|---|
| Omnibus: | 3.016 | Durbin-Watson: | 2.321 |
| Prob(Omnibus): | 0.221 | Jarque-Bera (JB): | 0.930 |
| Skew: | 0.346 | Prob(JB): | 0.628 |
| Kurtosis: | 4.005 | Cond. No. | 2.08e+38 |

**Source:** Researcher's Computation (2024)

### 3.3.1 Regression Summary

**R-squared:** 0.241, indicating that the model explains about 24.1% of the variance in soil water content.

- **Significant Predictors:**

Max Temp: ($p < 0.001$): Positive association with soil water content.

Min Temp: ($p < 0.001$): Positive association with soil water content.

Relative Humidity: ($p = 0.007$): Negative association with soil water content.

Wind Speed: ($p = 0.001$): Positive association with soil water content.

Wind Direction: ($p < 0.001$): Positive association with soil water content.

- **Other Predictors:**

Rainfall and Solar Radiation have non-significant p-values, suggesting a weaker association with soil water content in this dataset.

**Table 4: Multicollinearity Check (VIF)**

| | Variable | VIF |
|---|---|---|
| 0 | Max_Temp | Infinite |
| 1 | Min_Temp | Infinite |
| 2 | Rainfall | Infinite |
| 3 | Relative_Humidity | Infinite |
| 4 | Solar_Radiation | Infinite |
| 5 | Wind_Speed | Infinite |
| 6 | Wind_Direction | Infinite |

All predictors have an “infinite VIF”, indicating severe multicollinearity. This suggests that some of the climate variables are highly correlated with each other, which compromises the stability of the regression model.

## 3.4 Geospatial Visualization

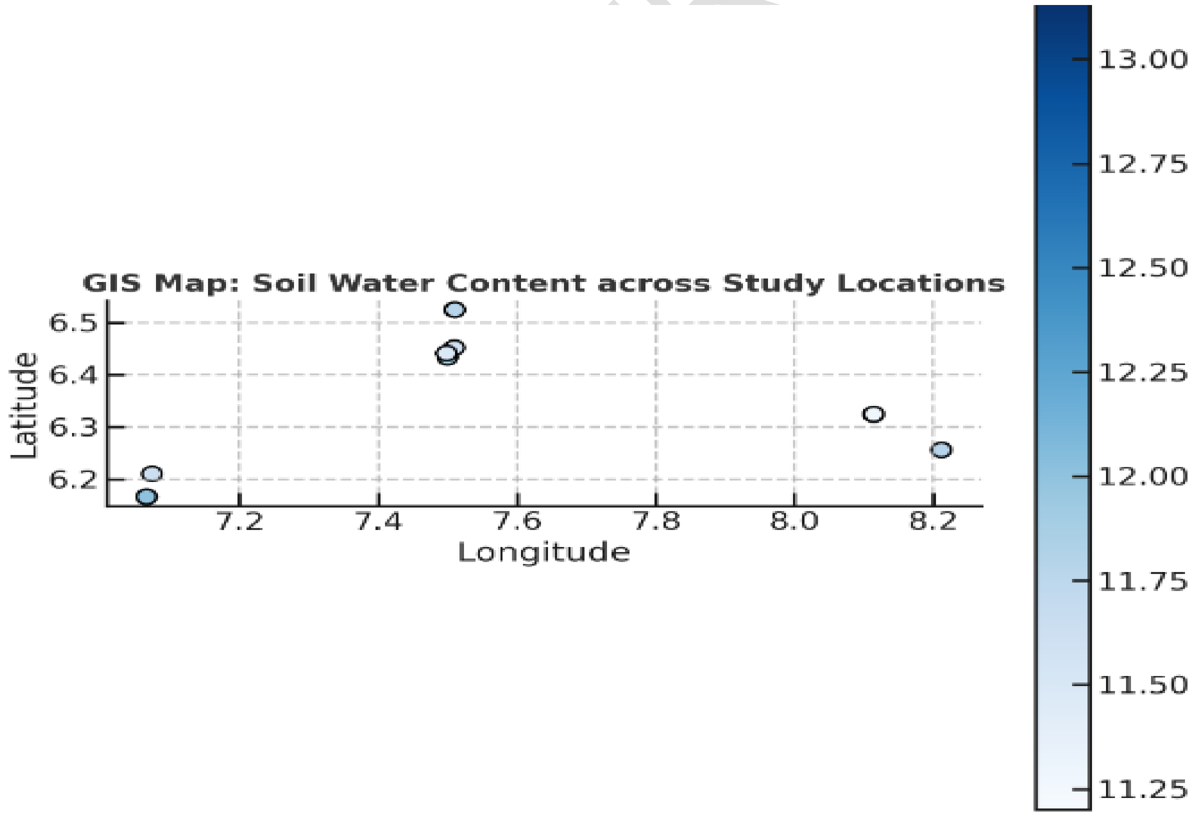


**Fig. 2:** GIS map displaying soil water content across the study locations

The GIS map in Figure 1 displayed soil water content across the study locations. The color gradient represents variations in soil water content, with darker shades indicating higher values. This provides a clear spatial overview of soil moisture distribution in relation to each location’s latitude and longitude

## 3.5 Discussion of Results

This study aimed to evaluate the spatial variation of soil water content and its relationships with climate variables, focusing on Southeast Nigeria. Through comprehensive statistical and geospatial analyses, it examined temperature, rainfall, relative humidity, solar radiation, and wind characteristics to identify key factors influencing soil water content. These findings add valuable insights into understanding soil-climate dynamics in this region, aligning and contrasting with previous studies.

### 3.5.1 Spatial Variation of Soil Water Content and Climate Variables

The descriptive statistics show consistent maximum temperatures around 32.7°C across the locations, with minimum temperatures averaging 23.2°C. These high temperatures may influence evapotranspiration rates, which affect soil moisture levels (Onwuka et al., 2024). Rainfall exhibits significant spatial variability, ranging from 1478.9 mm to 3257.9 mm. This variation in precipitation aligns with findings by Ayanlade et al. (2021), who noted that seasonality and location-specific factors drive rainfall distribution in Nigerian ecological zones. Relative humidity values, which range from 61% to 78%, reflect varying atmospheric moisture levels, potentially influencing soil water retention.

The observed spatial differences in these climate variables highlight unique microclimatic conditions within Southeast Nigeria, impacting soil water availability. Such regional distinctions underscore the need for tailored soil and water management practices, as demonstrated in other empirical studies that stress the role of regional climate factors on agricultural productivity (Saleh & Abdullahi, 2023). Unlike previous works focused on vegetation or yield responses to climate, this study specifically emphasizes soil water variability across microregions, filling a knowledge gap by linking climate factors to soil water dynamics in Southeast Nigeria.

### 3.5.2 Relationships Between Soil Water Content and Climate Variables

Correlation analysis revealed significant relationships between soil water content and several climate factors. Higher maximum and minimum temperatures exhibited a negative correlation with soil water content (-0.49), consistent with previous findings that elevated temperatures increase evapotranspiration, reducing soil moisture (Onumaegbu et al., 2024). Similarly, the slight negative correlation between solar radiation and soil water content (-0.47) suggests that increased solar radiation may lead to moisture loss, a result in line with studies conducted in arid zones (Van der Linden et al., 2019).

In contrast, rainfall's weak positive correlation with soil water content indicates a complex interaction between precipitation and soil moisture. While rainfall contributes to soil moisture, factors like temperature and solar radiation often counterbalance this effect by driving moisture loss. This aligns with findings by Tamiru and Fekadu (2019), who noted similar dynamics where rainfall was insufficient to offset moisture loss in high-temperature regions. However, this study offers a more nuanced view by highlighting the relative impact of rainfall in a region with substantial precipitation.

Relative humidity showed a moderate negative correlation with soil water content (-0.45), diverging from some studies that associate higher humidity with increased soil moisture (Wang & Shi, 2019). This inverse relationship may result from Southeast Nigeria's high evapotranspiration rates, where increased humidity does not necessarily translate to higher soil moisture. These findings contribute to understanding how local climatic conditions affect soil moisture, particularly in tropical climates, emphasizing the need for region-specific moisture management practices.

### 3.5.3 Influence of Climate Variables on Soil Water Content and Multicollinearity

The regression analysis indicated that temperature (both max and min), relative humidity, wind speed, and wind direction were significant predictors of soil water content, collectively explaining about 24.1% of its variability ($R^2 = 0.241$). This suggests that while climate variables play an important role, other factors like soil type and vegetation cover might also influence soil moisture levels, as highlighted by Guswa et al. (2012) in studies on soil-water-plant interactions.

Interestingly, the analysis uncovered severe multicollinearity among the climate variables, particularly between temperature and humidity, as evidenced by infinite VIF values. This multicollinearity reflects the interdependence of these climatic factors in tropical environments. For instance, Van der Linden et al. (2019) emphasized the need for multivariate approaches to account for interlinked climate effects on soil moisture. This study addresses this gap by illustrating that while individual climate factors like temperature and humidity are important, their combined and interactive effects are crucial for understanding soil moisture dynamics in tropical regions like Southeast Nigeria.

While previous studies have explored climate-soil-plant relationships in similar environments (Ayanlade *et al*., 2021; Saleh, 2019), this study uniquely focuses on the specific role of climate variables in soil water content within microregions. It identifies the direct and indirect influences of temperature, humidity, and radiation on soil moisture, filling a gap in literature on soil-climate interactions in Nigeria’s Southeast. Additionally, this study provides practical insights for regional agricultural planning by highlighting the importance of managing soil moisture under varying climatic conditions. The inclusion of wind characteristics, rarely considered in Nigerian soil studies, further enriches the analysis by addressing how local climate can impact soil water retention, even beyond rainfall and temperature factors.



## 4.0 CONCLUSION

This study provides an in-depth analysis of the effects of climate variability on soil water content across Southeast Nigeria, specifically highlighting its implications for staple crops such as yam and cereals. The findings reveal that temperature and solar radiation significantly influence soil moisture levels, with higher temperatures and increased solar radiation associated with reduced soil water content due to heightened evapotranspiration. Although rainfall is positively correlated with soil moisture, its impact appears secondary to temperature and humidity, underscoring the need to consider a combination of climate factors when assessing soil water availability.

Through regression analysis, temperature, relative humidity, and wind characteristics emerged as significant predictors of soil water content, collectively accounting for 24.1% of its variability. The spatial analysis, however, showed no statistically significant differences in soil water content among the studied locations (Enugu, Awka, and Abakaliki), suggesting a relatively uniform distribution of soil moisture across these areas despite local climate variations. This consistency may provide some stability in soil moisture for crops, although the role of temperature and humidity remains critical.

These findings offer valuable insights for agricultural management in Southeast Nigeria, where yam and cereal production rely heavily on consistent soil moisture levels. The study fills a knowledge gap by emphasizing the combined influence of climate factors beyond rainfall, particularly in tropical climates, and highlights the need for adaptive strategies in crop management. Implementing irrigation practices that account for high evapotranspiration rates, along with soil conservation techniques to retain moisture, could mitigate the adverse effects of climate variability on crop yields. Ultimately, this study underscores the importance of targeted climate adaptation measures to enhance food security and support sustainable agriculture in the face of ongoing climate change.

Disclaimer (Artificial intelligence)

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Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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## APPENDIX

| S/N | Locations | GPS Readings | Max. Temp ($^0C$) | Min. Temp ($^0C$) | Rainfall (mm) | Relative Humidity (%) | Solar Radiation ($MJ/M^2$) | Wind Speed (Knot) | Wind Direction (Degree) | Soil Water Content (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Amuzam | 6.5244º N, 7.5103º E | 33.0 | 23.3 | 1695.4 | 75.1 | 18.8 | 3.9 | 250 | 11.20 |
| 2 | Isiagu | 6.4520º N, 7.5100º E | 33.0 | 23.3 | 1695.4 | 75.1 | 18.8 | 3.9 | 250 | 11.60 |
| 3 | Ndiaga | 6.4333º N, 7.5000º E | 33.0 | 23.3 | 1695.4 | 75.1 | 18.8 | 3.9 | 250 | 11.88 |
| 4 | Ochufu | 6.4413º N, 7.4988º E | 33.0 | 23.3 | 1695.4 | 75.1 | 18.8 | 3.9 | 250 | 11.48 |
| 5 | Onuba | 6.5244º N, 7.5106º E | 33.0 | 23.3 | 1695.4 | 75.1 | 18.8 | 3.9 | 250 | 11.78 |
| 6 | Awka | 6.2106º N, 7.0747º E | 32.8 | 23.2 | 3257.9 | 78.0 | 17.9 | 4.6 | 260 | 11.63 |
| 7 | Ezinato | 6.1667º N, 7.0667º E | 32.8 | 23.2 | 3257.9 | 78.0 | 17.9 | 4.6 | 260 | 11.38 |
| 8 | Isiagu | 6.1667º N, 7.0667º E | 32.8 | 23.2 | 3257.9 | 78.0 | 17.9 | 4.6 | 260 | 11.98 |
| 9 | Mbaukwu | 6.1667º N, 7.0667º E | 32.8 | 23.2 | 3257.9 | 78.0 | 17.9 | 4.6 | 260 | 11.70 |
| 10 | Nibo | 6.1667º N, 7.0667º E | 32.8 | 23.2 | 3257.9 | 78.0 | 17.9 | 4.6 | 260 | 12.00 |
| 11 | Amagu | 6.3249º N, 8.1137º E | 32.4 | 23.0 | 1478.9 | 61.0 | 17.2 | 4.0 | 240 | 12.08 |
| 12 | Amachi | 6.2565º N, 8.1137º E | 32.4 | 23.0 | 1478.9 | 61.0 | 17.2 | 4.0 | 240 | 11.78 |
| 13 | Amagu Unuhu | 6.3240º N, 8.1137º E | 32.4 | 23.0 | 1478.9 | 61.0 | 17.2 | 4.0 | 240 | 12.38 |
| 14 | Nkaliki | 6.3249º N, 8.1137º E | 32.4 | 23.0 | 1478.9 | 61.0 | 17.2 | 4.0 | 240 | 13.15 |
| 15 | Agbaja | 6.3249º N, 8.1137º E | 32.4 | 23.0 | 1478.9 | 61.0 | 17.2 | 4.0 | 240 | 11.28 |

Source: Researcher's Compilation 2024

**KEYS :**
1 to 5 are all in Enugu
6 to 10 are all in Awka
11 to 15 are all in Abakaliki