**A STUDY OF WEATHER PARAMETERS AND POPULATION TRENDS IN NNEWI AND ONITSHA , NIGERIA.**

**Abstract**

The increasing population affects weather and meteorological parameters through various mechanisms like population growth drives urbanization, leading to urban heat islands, where cities are significantly warmer than surrounding areas. These changes have far-reaching effects on local and global climates, impacting ecosystems and human health. We studied the relationship between weather parameters and human population trends in Nnewi and Onitsha from 2010 to 2024 by conducting statistical analyses on the weather parameters and human population representing greenhouse gases (GHGs). In our study, we obtained results that show that increasing GHGs as defined by the increase in population adversely affects weather/metrological parameters and that the percentage of adverse effects is higher in Nnewi than in Onitsha. Our study also shows that population growth representing increased GHGs has a higher influence on temperature, humidity, cloud cover, amount of precipitation, solar radiation, solar radiation energy, and UV index in Nnewi than in Onitsha. In conclusion, this study has revealed the effects of increasing population which represents an increasing GHG on weather/metrological parameters and that Nnewi an emerging populous city is showing signs of changes in weather and metrological parameters at a rate higher than that of Onitsha, this may result in serious adverse climatic conditions, and higher risks to public health, agriculture, and ecosystems due to population over-growth which represent increasing GHGs and climate change.

Keyword: Greenhouse gases; weather parameters; population growth; climate change

1. **INTRODUCTION**

Our planet relies on a delicate balance of energy from the sun and the heat it retains. This balance is influenced by the Sun, Earth's characteristics, and the natural greenhouse effect. The Sun is the primary energy source for Earth, emitting radiant energy in the form of visible light and ultraviolet radiation. This energy reaches Earth in about 8 minutes and 20 seconds. Earth, the third planet from the sun, is a rocky planet with a unique atmosphere that allows liquid water to exist on its surface. This atmosphere, composed primarily of nitrogen and oxygen, acts as a protective layer, filtering out harmful solar radiation and shielding the planet from the harsh environment of space (National Oceanic and Atmospheric Administration (NOAA), 2021). The natural greenhouse effect is crucial to keeping Earth warm enough to sustain life. Sunlight reaching Earth consists of shortwave radiation with shorter wavelengths. A portion of this radiation is reflected into space by Earth's surface and atmosphere. However, some of the shortwave radiation is absorbed by the Earth's surface, causing it to warm. In response, the warmed Earth emits longwave radiation with longer wavelengths (NOAA, 2021).

Certain gases in Earth's atmosphere, known as greenhouse gases (GHGs), can absorb this longwave radiation emitted by the Earth's surface. These GHGs, including water vapor, carbon IV oxide (CO₂), and methane (CH4), trap the heat, preventing it from escaping readily back into space (NASA, 2020). This trapping of heat by GHGs is essential for maintaining a comfortable average global temperature, estimated to be around 15 °C without the greenhouse effect, Earth would be a frigid and lifeless planet (Intergovernmental Panel on Climate Change (IPCC), 2021). In essence, the natural greenhouse effect acts like a giant insulating blanket around Earth, allowing sunlight to enter and warm the planet while preventing excessive heat loss. This delicate balance between incoming solar radiation and outgoing heat is vital for life as we know it.

According to Shivanna, (2022), climate change refers to the long-term changes in temperature and weather due to human activities. An increase in average global temperature and extreme and unpredictable weather are the most common manifestations of climate change. Climate change is no longer a looming threat; it's a tangible reality with far-reaching consequences. While the natural greenhouse effect plays a crucial role in maintaining Earth's habitable temperature, human activities are significantly disrupting this delicate balance by releasing excessive amounts of GHGs into the atmosphere. Decades of scientific data show an undeniable rise in global temperatures, primarily driven by human-caused GHG emissions (Rogelj *et al*., 2018). It is estimated that the years 2011-2020 stand as the warmest on record, with each decade since the 1980s consistently exceeding the previous one (Isaksen *et al.,* 2022). A global increase of 1.5 °C above the pre-industrial average and the continued loss of biodiversity risk catastrophic harm to health that will be impossible to reverse (Atwoli *et al.,* 2021). It is also noticed that Earth's average surface temperature has increased, with significant warming trends observed since the late 19th century. This warming leads to disruptions in climatic patterns, affecting biodiversity and human activities. According to the IPCC (2021), the global temperature is projected to rise by 1.5 – 2.0 °C above pre-industrial levels by the end of the 21st century if current emissions continue (IPCC, 2021). Other noticeable climatic changes include melting ice caps and rising sea levels (Mimura, 2013; Slangen *et al*., 2023), extreme weather events (Bell *et al.,* 2018; Knutson *et al*., 2020; Sun *et al.*, 2021)., changes in biodiversity and ecosystems (Weiskopf *et al*., 2020; Shivanna, 2022), Agricultural and Food Security Challenges (Lobell *et al*., 2011), Human Health Impacts (Ebi *et al*., 2018; 2021), Economic and Social Impacts (World Bank, 2021), Food Security Threats (Atanga and Tankpa, 2021; Farooq *et al.,* 2022), Mass Migration (Shirley & Cindy, 2020; Cattaneo & Foreman, 2023), and Ocean Acidification, Loss of Freshwater Resources (Gattuso *et al*., 2015).

Urban centers in Nigeria face increasing challenges stemming from climate variability and population growth (Adeleke *et al*., 2018). In Nigeria, Anambra state, Nnewi, and Onitsha, as key commercial hubs, are no exceptions. Rising temperatures, erratic rainfall patterns, and increasing population densities pose significant risks to infrastructure, public health, and livelihoods.

Nnewi (semi-urban) and Onitsha (urban) centers in Anambra State, serve as prime examples of regions experiencing rapid urbanization and socio-economic transformations. These changes coincide with shifts in weather patterns and population trends. Despite the availability of historical data, limited research has explored the interconnections between weather parameters and population dynamics in these cities. Addressing this gap is critical to understanding how weather influences population trends and vice versa. Insights from such research can inform strategies to mitigate adverse effects and enhance resilience in urban settings.

In this study, we aim to examine the relationship between weather parameters and GHGs as represented by human population trends in Nnewi and Onitsha. Specifically, we want to analyze changes in key weather parameters (temperature, rainfall, humidity, wind speed, wind direction, sea-level pressure, cloud cover, solar radiation, solar energy, and ultraviolet radiation index with population growth patterns in Nnewi and Onitsha and investigate the correlation between weather changes and GHG using human population dynamics.

Online weather and population data spanning from 2010 to 2024 present a unique opportunity to analyze these dynamics. Understanding how weather parameters and GHGs as represented by human population trends interact is vital for policy-making in urban planning, public health, and climate adaptation strategies. This study aims to contribute to the growing body of knowledge on these relationships, with a focus on Nnewi and Onitsha. The study focuses on Nnewi and Onitsha, two cities in Anambra State, Nigeria, covering the period from 2010 to 2024. Online data on weather parameters and population statistics are utilized. While the study examines correlations, causation is not explored due to the complexity of influencing variables.

This study hopes to provide empirical evidence on the relationship between weather and population dynamics which represents increased GHGs in two Nigerian urban centers. It contributes to policy development by offering insights to guide urban planning and climate adaptation efforts (Nwafor & Eze, 2019). Additionally, it enriches academic discourse on climate-population interactions in sub-Saharan Africa.

The study areas are Nnewi and Onitsha. Nnewi is a prominent city located in Anambra State, southeastern Nigeria. Geographically, it is positioned at approximately 6.0150° N latitude and 6.9100° E longitude, about 24 km south of Onitsha. The city serves as a significant commercial and industrial hub in the region. As of 2024, Nnewi's population is estimated at 1,301,000, reflecting consistent growth due to its robust economy and industrial activities (Macrotrends, 2024). Onitsha is a prominent city situated on the eastern bank of the Niger River in Anambra State, southeastern Nigeria. Geographically, it is located at approximately 6.0150° N latitude and 6.9100° E longitude. As of early 2024, Onitsha city proper has an estimated population of 1,695,000, (Macrotrends, 2024; Britannica. 2024) reflecting a 4.44% increase from the previous year

Previous studies like Trenberth *et al.,* (2014) analyzed Earth's energy imbalance, focusing on the difference between incoming solar radiation and outgoing terrestrial radiation. The study linked this imbalance to increasing GHG concentrations and global warming due to population growth. The authors highlighted the significance of accurate energy balance measurements for understanding climate dynamics and predicting future climate change, emphasizing the need for improved climate models and observational systems. The IPCC (2021) report provided a comprehensive assessment of the physical science underlying climate change, detailing GHG emissions, climate feedback, and projections of future climate scenarios. The report emphasized the urgent need to reduce GHG emissions to mitigate climate change impacts, presenting the latest scientific evidence on the role of human activities in driving global warming.

Saunois *et al.* (2020) presented an extensive analysis of the global CH4 budget, covering emissions, atmospheric concentrations, and sinks from 2000 to 2017. The study identified key sources of CH4, including agriculture, fossil fuels, and wetlands, and discussed the implications for climate policy and mitigation strategies. The paper highlighted the significant role of CH₄ in global warming and the need for targeted reduction efforts. Ravishankara, *et al.* (2009) identified nitrous oxide as the leading ozone-depleting substance currently emitted, surpassing chlorofluorocarbons (CFCs). The authors discussed the sources of N2O emissions, primarily from agricultural activities, and their impacts on the ozone layer and climate. The study called for targeted mitigation efforts to reduce N2O emissions and protect both the ozone layer and the climate. Monks *et al.* (2015) reviewed the sources, chemistry, and impacts of tropospheric ozone, a significant GHG and air pollutant produced by human activities. The paper examined how human activities, such as fossil fuel combustion and industrial processes, contribute to ozone formation. It also discussed the role of ozone as a short-lived climate forcer and its effects on air quality and human health.

Le Quéré *et al.* (2018) provided an annual update on the global carbon budget, detailing CO2 emissions from fossil fuels, land use changes, and carbon sinks. The report highlighted the increasing trend in CO2 emissions and the challenges of meeting climate targets. It emphasized the need for comprehensive carbon management strategies to stabilize atmospheric CO2 levels. Petit *et al.* (1999) presented data from the Vostok ice core, revealing the climate and atmospheric history over the past 420,000 years. The study showed a strong correlation between GHG concentrations and global temperatures, providing critical evidence of the natural variability and anthropogenic influences on climate. The findings underscored the importance of long-term climate records for understanding current and future climate change. Gulev *et al*. (2021) compiled large-scale indicators of global climate change, focusing on human influence and the current state of the climate system. The report covered key indicators such as GHG concentrations, global temperatures, and sea level rise. It aimed to support policymakers with the latest scientific evidence to inform climate action and policy decisions.

Despite extensive research, limited studies explore the interaction between weather and population dynamics in sub-Saharan urban centers. Few have utilized long-term online data, particularly in Nnewi and Onitsha. This study addresses these gaps by focusing on 15 years

1. **DATA DESCRIPTION AND METHOD OF ANALYSIS**

Our data were obtained from online platforms, including meteorological databases and population census websites, which provide reliable data for analyses (World Metrological Organization (WMO), 2020; United Nations, 2019). We employed common methods of analysis including time series analysis, correlation analysis, and simple linear regression models and plots (Smith *et al*., 2020).

The Onitsha and Nnewi population data were obtained from https://www.macrotrends.net/global-metrics/cities/22013/onitsha/nnewi/population\_Onitsha\_Nnewi, Nigeria Metro Area Population 1950-2024</a>. [www.macrotrends.net](http://www.macrotrends.net). We used an online population estimate since the National Population Commission website (<https://nationalpopulation.gov.ng/>) contains no information on the population from 2010 – 2024 which is the study period. The estimated yearly population data and the yearly growth rate are shown in Table 1.

The weather/meteorological data for the cities were obtained from [https://www.visualcrossing.com/weather/weather-data-services#](https://www.visualcrossing.com/weather/weather-data-services). The online data was used because NiMET charges were beyond our reach. The weather/meteorological parameters selected from the website include the daily average temperature (T in ), daily average dew point (DP in ), daily average humidity (H in %), daily average precipitation (PP in mm), daily average wind speed (WS in km/h), daily average cloud cover (CC in %), daily average solar radiation (SR in W/m2), and daily average ultraviolet radiation index (UVI). The UVI a value between 0 and 10 indicates the UV exposure level for that day. 10 represents a high level of exposure, and 0 means no exposure. The UVI is calculated based on the amount of short-wave solar radiation, which is a level of cloudiness, type of cloud, time of day, time of year, and location altitude. Daily values represent the maximum value of the hourly values.

The yearly average weather/meteorological parameters were calculated from the daily average weather/meteorological parameters. The yearly mean values are shown in Table 2 (for Nnewi and Onitsha).

**Time Series Analysis**

Time series analysis is a specific way of analyzing a sequence of data points collected over time. In time series analysis, analysts record data points at consistent intervals over a set period rather than just recording the data points intermittently or randomly. Time series analysis typically requires a large number of data points to ensure consistency and reliability. An extensive data set ensures you have a representative sample size and that analysis can cut through noisy data.

**Correlation And Regression Analysis**

Correlation quantifies the extent of a linear relationship between two or more variables, indicating how changes in one variable are related to changes in another, either in the same or opposite direction. The correlation coefficient, denoted as , represents the strength of this linear relationship between two variables, and Y. The degree of this correlation is measured using the product-moment correlation coefficient, as introduced by Fisher (1915), it is given as

.1

where is the number of each variable which must be equal, and are the mean value of the variable and respectively. Interpretation of , implies that there is a perfect (+ direct and indirect) relationship; , implies there is a strong linear relationship; , implies there is a weak relationship; implies there is no relationship between the two variables.

Simple linear regression analysis is the study of the nature and extent of association between two or more variables based on the assumed relationship between them to predict the value of one variable from the other. The simple regression equation of on is defined as

2

where is the assumed dependent variable, is the assumed independent variable, is the slope with its associated error, and is the intercept.

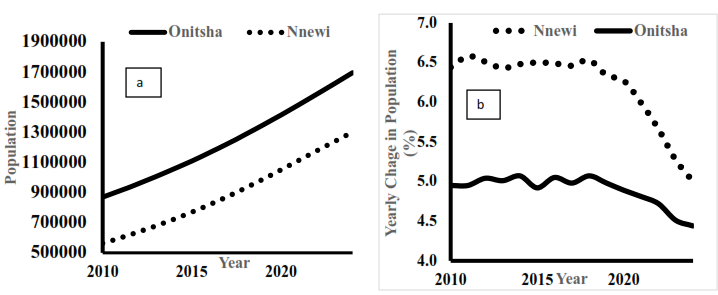
|  |  |  |  |  |
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| **Table 1: Shows The Estimated Population of Onitsha and Nnewi for 2010 - 2014** | | | | |
| **Year** | **Population**  **(Nnewi)** | **Growth Rate**  **(Nnewi)** | **Population**  **(Onitsha)** | **Growth Rate**  **(Onitsha)** |
| 2024 | 1,301,000 | 5.00% | 1,695,000 | 4.44% |
| 2023 | 1,239,000 | 5.27% | 1,623,000 | 4.51% |
| 2022 | 1,177,000 | 5.66% | 1,553,000 | 4.72% |
| 2021 | 1,114,000 | 5.99% | 1,483,000 | 4.81% |
| 2020 | 1,051,000 | 6.27% | 1,415,000 | 4.89% |
| 2019 | 989,000 | 6.34% | 1,349,000 | 4.98% |
| 2018 | 930,000 | 6.53% | 1,285,000 | 5.07% |
| 2017 | 873,000 | 6.46% | 1,223,000 | 4.98% |
| 2016 | 820,000 | 6.49% | 1,165,000 | 5.05% |
| 2015 | 770,000 | 6.50% | 1,109,000 | 4.92% |
| 2014 | 723,000 | 6.48% | 1,057,000 | 5.07% |
| 2013 | 679,000 | 6.43% | 1,006,000 | 5.01% |
| 2012 | 638,000 | 6.51% | 958,000 | 5.04% |
| 2011 | 599,000 | 6.58% | 912,000 | 4.95% |
| 2010 | 562,000 | 6.44% | 869,000 | 4.95% |
| Source: https://www.macrotrends.net/globalmetrics/cities/22013/ Nigeria Metro Area Population 1950-2024</a>. www.macrotrends.net. | | | | |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Nnewi** | | | | | | | |
| **Date** | **T** | **DP** | **H** | **PP** | **WS** | **CC** | **SR** | **UVI** |
|  | **oC** | **oC** | **%** | **mm** | **km/h** | **%** | **W/m2** |  |
| **2010** | **25.9** | **23.8** | **88.7** | **5.1** | **11.6** | **76.4** | **163.4** | **5.9** |
| **2011** | **25.5** | **23.5** | **89.0** | **4.8** | **12.1** | **76.2** | **166.1** | **6.0** |
| **2012** | **25.4** | **23.5** | **88.9** | **4.8** | **12.9** | **75.8** | **163.3** | **5.8** |
| **2013** | **25.5** | **23.6** | **89.0** | **5.7** | **14.8** | **77.2** | **156.6** | **5.7** |
| **2014** | **26.1** | **23.4** | **87.8** | **3.4** | **14.4** | **74.9** | **168.0** | **6.0** |
| **2015** | **25.7** | **23.7** | **86.8** | **3.9** | **15.0** | **76.8** | **163.2** | **5.9** |
| **2016** | **25.9** | **23.6** | **87.7** | **5.2** | **13.4** | **78.8** | **157.4** | **5.7** |
| **2017** | **26.2** | **22.9** | **84.7** | **6.9** | **12.2** | **86.1** | **171.5** | **6.4** |
| **2018** | **26.4** | **22.9** | **84.8** | **7.0** | **11.6** | **86.0** | **182.8** | **7.0** |
| **2019** | **27.0** | **23.3** | **84.8** | **5.4** | **26.4** | **87.4** | **173.0** | **6.6** |
| **2020** | **27.2** | **23.2** | **81.4** | **4.7** | **14.9** | **82.4** | **189.0** | **7.1** |
| **2021** | **26.8** | **23.3** | **84.7** | **3.4** | **16.4** | **81.3** | **177.8** | **6.7** |
| **2022** | **26.5** | **21.6** | **78.4** | **4.1** | **15.3** | **83.9** | **205.9** | **8.3** |
| **2023** | **26.9** | **23.1** | **82.6** | **5.3** | **17.6** | **85.6** | **208.3** | **7.9** |
| **2024** | **27.7** | **23.3** | **76.5** | **4.5** | **19.6** | **85.2** | **217.2** | **8.2** |
|  | **Onitsha** | | | | | | | |
| **2010** | **25.9** | **23.7** | **88.7** | **5.1** | **11.6** | **76.4** | **163.4** | **5.9** |
| **2011** | **25.4** | **23.4** | **89.0** | **4.8** | **12.1** | **76.2** | **166.1** | **6.0** |
| **2012** | **25.3** | **23.5** | **88.9** | **4.9** | **12.9** | **75.9** | **163.3** | **5.8** |
| **2013** | **25.4** | **23.5** | **89.0** | **5.8** | **14.8** | **77.2** | **156.6** | **5.7** |
| **2014** | **26.0** | **23.4** | **88.3** | **3.5** | **11.5** | **73.9** | **168.0** | **6.0** |
| **2015** | **26.7** | **23.6** | **85.9** | **3.3** | **12.7** | **76.4** | **162.9** | **6.1** |
| **2016** | **27.8** | **23.5** | **82.5** | **3.9** | **12.8** | **84.5** | **175.5** | **6.7** |
| **2017** | **27.6** | **23.2** | **80.9** | **3.9** | **13.4** | **83.0** | **182.5** | **6.8** |
| **2018** | **27.7** | **23.4** | **81.2** | **3.3** | **12.5** | **83.8** | **186.0** | **6.8** |
| **2019** | **28.0** | **23.6** | **81.9** | **3.9** | **26.8** | **84.8** | **178.1** | **6.7** |
| **2020** | **28.2** | **23.4** | **78.4** | **2.2** | **15.5** | **79.7** | **192.1** | **7.2** |
| **2021** | **27.9** | **23.5** | **80.7** | **1.5** | **16.2** | **77.3** | **184.2** | **6.8** |
| **2022** | **27.2** | **22.0** | **75.1** | **3.8** | **13.1** | **82.7** | **215.4** | **8.6** |
| **2023** | **27.4** | **23.1** | **79.5** | **4.5** | **17.1** | **85.4** | **213.7** | **8.2** |
| **2024** | **29.1** | **22.9** | **70.1** | **1.7** | **18.8** | **83.3** | **229.4** | **9.0** |

**Table 2: The yearly mean values of the Weather Parameters (for Nnewi and Onitsha).**

1. **RESULTS AND DISCUSSION**

**3.1 Time Series Plots**

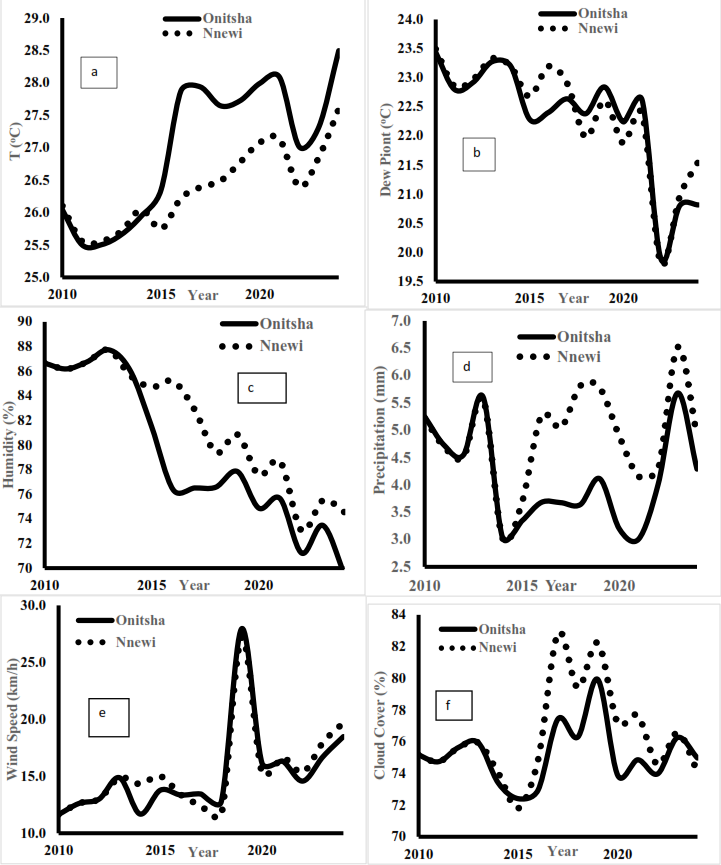


**Figure 1: Plot of the Yearly Average Values (a) and Percentage Change (b) in the Yearly Average Values of the Population of Onitsha and Nnewi**

Fig 1a show the yearly average and change in the annual average population of both Onitsha and Nnewi, which shows that the population of Onitsha is generally higher than that of Nnewi and the population of both cities generally increases from 2010 to 2024. Fig 1b indicates that the annual change in population growth rate is higher for Nnewi than Onitsha and that the percentage growth was similar (at for Nnewi and for Onitsha) from 2010 to 2019, there was a downward trend in the annual percentage growth rate after 2019.

Fig 2a shows the annual mean temperature of Onitsha and Nnewi, both showed similar trends –increasing temperature with the year, with a drop in 2022, and a return to the upward trend in 2023. These trends were similar to the results of Okeke and Nwankwo (2022), the Nigerian Meteorological Agency - NMA, (2023), and the WMO, (2024).

Fig 2b is the plot of the annual mean dew point of Onitsha and Nnewi from 2010 – 2024. The plot indicates a downward trend from the year 2010 to 2021, with a drop of about in 2022, and an increase of in 2023. A decreasing trend in dew point over the years suggests that the amount of moisture in the air is reducing. The dew point is the temperature at which air becomes saturated with moisture and water vapor begins to condense into liquid water. If the dew point is decreasing, it indicates a lower absolute humidity level, meaning the air holds less water vapor. Several potential physical interpretations for a decreasing dew point trend include: (i) climate change effects: Changes in regional climate patterns can lead to a decrease in moisture levels. For instance, a shift towards a drier climate or increased frequency of dry air masses can reduce the dew point. (ii) Land Use and Vegetation Change: Deforestation, urbanization, and changes in land use can impact local humidity levels. Vegetation releases moisture through transpiration, contributing to local humidity. Reduction in vegetation can thus lower the moisture content in the air, decreasing the dew point. (iii) Atmospheric Circulation Changes: Alterations in atmospheric circulation patterns can result in a more frequent occurrence of dry air masses over a region, leading to a consistent decrease in the dew point over time. (iv) Human Activities: Industrial activities, pollution, and aerosol emissions can impact local weather patterns and humidity levels. For instance, aerosols can reduce cloud formation and precipitation, potentially leading to a decrease in dew point if less water vapor is present in the atmosphere (William, 2018; Smith & Brown, 2019).

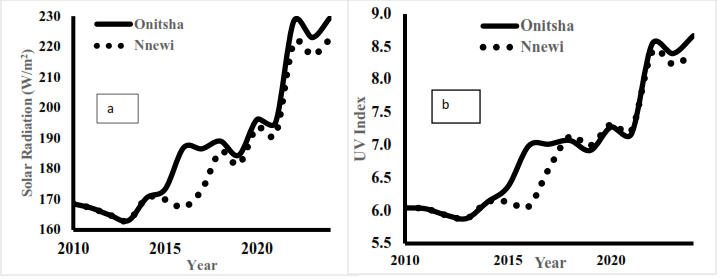


**Figure 2: Plot of the Yearly Average Values of the T (Temperature 2a) , Dew Point (2b), Humidity (2c), Precipitation (2d), Wind Speed (2e), and Cloud Cover (2f) For Onitsha and Nnewi**

Fig. 2c which is the plot annual average humidity indicates a reducing trend in the value of humidity at both cities with year, though the reduction was slightly higher at Onitsha. A trend of reducing humidity over the years can have significant environmental, agricultural, and health impacts. Lower humidity can lead to less moisture in the atmosphere, which often contributes to increased drought frequency and intensity. Reduced humidity means less water vapor is available to condense into clouds and precipitation, exacerbating dry conditions. Reduced humidity can negatively affect crop yields, especially for crops that rely on higher moisture levels for growth. Lower humidity levels can lead to increased evapotranspiration, causing crops to lose more water and potentially suffer from water stress. Decreased humidity can lead to drier air, which can cause respiratory issues, dry skin, and eye irritation. It can also increase the spread of airborne diseases since many viruses, including influenza, survive longer in dry conditions. Lower humidity can affect ecosystems by altering plant and animal life. For example, reduced humidity may lead to a decline in certain plant species that are not drought-resistant, affecting the animals that rely on them for food and habitat. Lower humidity can dry out vegetation, increasing the risk of wildfires. Dry conditions make it easier for fires to start and spread, which can lead to more frequent and severe wildfire events. Humidity plays a critical role in weather formation. Reduced humidity can lead to less cloud cover and precipitation, and contribute to longer dry spells and altered rainfall patterns. These adverse effects of an increasing reduction in humidity levels over the years have been documented extensively (e.g. Brown, 2019; Jones & Smith, 2020; United Nations Environment Programme, 2021; IPCC, 2022).

Fig 2d is the plot of the yearly average of the precipitation of Onitsha and Nnewi. Nnewi and Onitsha showed similar levels of precipitation from 2010 – 2014. From 2015, the trend in the variations was similar, but Nnewi recorded more precipitation than Onitsha. For the years under consideration, 2014, recorded the lowest amount of precipitation, this could be because the solar maximum of Solar Cycle 24 occurred in April 2014 (NASA Solar Cycle 25 Prediction Panel; NOAA Solar Cycle Progression). The trend in the variation of the amount of precipitation in Nnewi and Onitsha followed the reported trend in Southeast Nigeria between 2010 and 2023 showing significant variability, reflecting broader climatic changes affecting the region (Ogungbenro and Morakinyo, 2014; Ekwueme & Agunwamba, 2021). In 2010-2013, during this period, rainfall was generally stable but marked by some increases. Notably, 2012 experienced higher-than-average rainfall, leading to flooding in many areas. This was part of a larger trend of increasing variability in precipitation patterns. In 2014-2016, the amount of precipitation remained variable, with some years experiencing average to above-average rainfall. From 2017-2019, this period was characterized by a continued variability in rainfall. These fluctuations were consistent with the observed impact of climate change, which has been linked to more extreme weather patterns in some regions. In 2020-2023, the most recent years have seen a mix of trends. The overall trend suggests a continuing pattern of variability with a potential shift towards more extreme rainfall events. This period of analysis underscores the increasing unpredictability of rainfall patterns in Southeast Nigeria, likely influenced by global climate change. This trend poses challenges for agriculture, water resources management, and disaster preparedness in the region.

Onitsha and Nnewi experienced similar wind speed patterns for the years 2010 – 2014 shown in Fig 2e. The yearly average wind speed was relatively low of km/h between 2010 – 2018, ten, a sharp rise to about 30 km/h in 2018, followed by a reduction to between 15 – 20 km/h in 2020-2024. Fig 2f, shows the plot of the yearly average values of the cloud cover of Onitsha and Nnewi for 2010 – 2014. The trend of cloud cover in Onitsha and Nnewi though similar throughout the years of the study, cloud cover at Nnewi was relatively higher than that in Onitsha between 2016 – 2022. Akinsanola & Ogunjobi, (2017), investigated how these climatic variables have changed over time, considering the implications for agriculture, and water resources, across Nigeria. They discussed the role of cloud cover in modulating both rainfall and temperature patterns and observed a decreasing trend in cloud cover with year. Changes in cloud cover influence solar radiation, which in turn affects temperature and evaporation rates, and concluded that Nigeria is experiencing significant changes in its climatic variables, which will continue as global climate patterns evolve.



**Figure 3: Plot of the Yearly Average Values of the Solar Radiation (3a) and UV Index (3b), For Onitsha and Nnewi**

Fig3(a&) are the plots of the yearly average values of the solar radiation, and UV index for Onitsha and Nnewi. The trends in solar radiation and UV index have shown notable increases over the years, driven by changes in atmospheric conditions, and climatic factors. These increases have significant implications for energy production, climate science, and public health. Over 2010 -2024, solar radiation solar energy potential in Nnewi and Onitsha has exhibited a gradual increase in many regions, primarily due to reductions in atmospheric aerosols and changes in cloud cover patterns. The increase in solar radiation is linked to global dimming and brightening phenomena, where reduced particulate pollution leads to clearer skies and more solar radiation reaching the Earth's surface (Wild 2012; International Energy Agency (IEA), 2021).

The UV index, which measures the strength of ultraviolet radiation at the Earth's surface, has shown an increasing trend in Onitsha and Nnewi. The increase is traced to ozone depletion and climate change. Factors such as changes in the ozone layer, atmospheric composition, and cloud cover influence the UV index (McKenzie et al., 2011). The Increasing solar radiation and UV levels contribute to changes in global temperatures, affecting climate patterns and ecosystems, and higher UV index values increase the risk of skin cancer, cataracts, and other health issues, highlighting the need for effective sun protection and public awareness, but the rise in solar energy potential has made solar power a cornerstone of the global transition to renewable energy, with significant reductions in GHG emissions. The observed increasing trends underscore the importance of continued research, policy development, and technological innovation to harness solar energy sustainably and mitigate the potential negative effects of increased UV radiation (McKenzie et al., 2011).

* 1. **Regression Analysis**

**3.2.1 Population Vs Change in Population**

**Figure 4. Plot of the Annual Percentage Change in Population per Year against the Population at Onitsha and Nnewi**

Fig 4 is a plot of the percentage change in population per year against the population at Onitsha and Nnewi (here and after the dotted line represents a linear fit for Nnewi and the straight line for Onitsha; y = parameter on the y-axis, x= parameter on the x-axis). The plot indicates that the percentage change per year in population is decreasing at both cities, that of Nnewi was decreasing at a faster rate than Onitsha A linear fit indicates that the slope for Nnewi is steeper than the slope for Onitsha, though the correlation coefficient between the percentage change in population per year and the population is r = 0.8 for both cities (y represents the percentage change in population per year, x represents the population). The percentage change in population per year was higher at Nnewi and is changing faster at Nnewi than at Onitsha with population perhaps due to influx related to urban migration.

A negative slope in this context indicates that as the population increases, the percentage change in the population per year decreases. This often suggests that as the population grows, the rate of growth slows down. In other words, while the absolute number of people may still be increasing, the rate at which the population grows is decreasing. The factors responsible for this include (i) Population Dynamics - Growth Rate: Initially, the population might be growing rapidly. However, as the population base becomes larger, factors such as limited resources, economic constraints, or demographic shifts (like aging populations) might cause the growth rate to decline. In many cases, this pattern can be seen in populations transitioning from high-growth to more stable or even declining growth phases. (ii) Potential Factors like economic development which often leads to decreased birth rates and increased standards of living, which can slow population growth, Social Factors like increased access to education and family planning can also contribute to lower growth rates and policy implications, this trend might influence policies related to urban planning, resource allocation, and economic development strategies (United Nations Department of Economic and Social Affairs, 2022).

Table 3 shows the correlation coefficients between population and the annual percentage change in population with annual average values of weather/meteorological parameters. The Table indicates a strong positive relationship between the population of both cities and temperature measure, wind speed, and solar-related measures (SR and UVI), but a negative relation between the population and dewpoint and humidity. Due to the anti-correlation between the population and annual percentage change in population, the Table indicated the opposite correlations between annual percentage change in population with some of the weather/meteorological parameters to that indicated between population and weather/meteorological parameters.

**Table 3: The Correlation Coefficients Between Population (P) And The Annual Percentage Change In Population (CP) With Annual Average Values Of Weather Parameters**

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| --- | --- | --- | --- | --- | --- |
| Parameters | r | r | Parameters | r | r |
| Onitsha | Nnewi | Onitsha | Nnewi |
| P/Year | 1.00 | 1.00 | CP/Year | -0.74 | -0.80 |
| P/T | 0.79 | 0.88 | CP/T | -0.42 | -0.71 |
| P/DP | -0.80 | -0.81 | CP/DP | 0.79 | 0.73 |
| P/H | -0.93 | -0.96 | CP/H | 0.67 | 0.81 |
| P/PP | -0.17 | 0.23 | CP/PP | -0.26 | -0.22 |
| P/WS | 0.50 | 0.53 | CP/WS | -0.29 | -0.43 |
| P/CC | 0.12 | 0.18 | CP/CC | 0.02 | 0.15 |
| P/SR | 0.94 | 0.93 | CP/SR | -0.84 | -0.92 |
| P/UVI | 0.95 | 0.95 | CP/UVI | -0.82 | -0.87 |
| P: Population; CP: Annual Percentage Change in Population | | | | | |

**3.2.2 Temperature and Population**

Using the increasing average temperature to represent increasing GHGs is a valid approach (IPCC, 2021), as GHGs are known to contribute to global warming and local temperature increases, we investigate the effect of population growth, temperature, and other weather parameters. This is because GHGs trap heat in the atmosphere, increasing global and local temperatures. As the concentration of these gases rises, so does the temperature. According to the IPCC (2021), by analyzing the trend of increasing average temperatures in a specific town, you can infer a possible correlation with rising GHG levels, especially if the data shows a consistent upward trend over time.

Fig 5 is the plot of temperature against the population at Onitsha and Nnewi. The plot indicated a steady rise in temperature as the population increased. The plot indicated a slightly steeper slope in Onitsha than in Nnewi, this may be attributed to the increased effects of GHGs, as a large population is marked by increased human activities that generate GHGs. Human activities that generate GHGs primarily involve the burning of fossil fuels, agricultural practices, and industrial processes. Nnewi and Onitsha transportation involving cars, and trucks, motorcycles that burn gasoline, and diesel, are major sources of producing CO₂, added are industries where factories that produce chemicals, use fossil fuels, releasing CO₂ and other GHGs (IEA, 2021). Livestock farming (poultry, piggeries, etc.) produces CH₄ through digestion (enteric fermentation) and manure management. The application of synthetic fertilizers in farmlands releases N₂O, a potent GHG (Food and Agriculture Organization, 2023). Clearing forests for agriculture, logging, and urban development reduces trees' carbon sequestration capacity and leads to the release of CO₂ when trees are burned or decomposed. Soil degradation, such as deforestation and intensive agriculture, disrupts soil carbon, releasing CO₂ and CH₄ (Global Forest Watch, 2023). Organic waste in landfills decomposes anaerobically, producing CH₄. Wastewater treatment and sewage treatment plants emit CH₄ and NOₓ (U.S. Environmental Protection Agency, 2022, 2023). Hydrofluorocarbons used as refrigerants, are potent GHGs with high global warming potential, and certain industrial aerosols contain GHGs like HFCs (United Nations Environment Programme ,2017; U.S. Environmental Protection Agency, 2022).

**Figure 5: Plot of the Annual Average Values of Temperature against the Population at Onitsha and Nnew**

These human activities increase with population and the demand for goods, services, energy needs, waste disposals/management, and control of flood water and erosions, which is endemic in Anambra state (Okoro, B. C., & Okoro, 2014; Nigeria Erosion and Watershed Management Project 2024) and more prevalent in Onitsha than Nnewi.

**3.2.3 Dewpoint, Humidity, Precipitation and Population**

Figs 6, 7, and 8 are the plots of the dewpoint, humidity, and amount of precipitation against the population respectively. The values of the correlation coefficient in Table 3 indicate that human activities/production of GHGs as represented by the population strongly impact dewpoint ( for Onitsha and Nnewi) and humidity ( Onitsha and Nnewi) negatively at Nnewi and Onitsha, while having a minimal impact on the amount of precipitation ( for Onitsha and forNnewi). The slopes of the linear fit to the scatter plots in Figs 7 and 8 show that the human activities/production of GHGs as represented by the population exhibited similar strength as it impacted dewpoint and humidity at both Onitsha and Nnewi. The impact of the human population representing the production of GHGs on dewpoint, humidity, and precipitation is largely driven by urbanization, deforestation, and the broader effects of anthropogenic climate change. Human activities, particularly in densely populated areas, alter local and regional atmospheric conditions, influencing how moisture behaves in the environment (see Oke, 1982: Kaufmann & Seto, 2001; Foley et al., 2005; United Nations Environment Programme, 2024).

**Figure 6: Plot of the Annual Average Values of Dewpoint against the Population at Onitsha and Nnewi**

**Figure 7: Plot of the Annual Average Values of Humidity against the Population at Onitsha and Nnewi**

**Figure 8: Plot of the Annual Average Values of Amount of Precipitation against the Population at Onitsha and Nnewi**

The dewpoint is the temperature at which air becomes saturated with moisture, leading to condensation (dew, fog, etc.). Human population growth, especially in urban areas, can affect the dewpoint in a few ways (Oke, 1982) (i) Urban areas, with concrete, asphalt, and minimal vegetation, retain heat more effectively than rural areas. This leads to warmer air temperatures, which can increase the capacity of the air to hold moisture and raise the dewpoint. However, because heat can also dry out the air, the exact effect depends on the balance between moisture sources and heat. (ii) Human activities (such as irrigation, air conditioning, and industrial processes) release more water vapor into the atmosphere, increasing the local dewpoint.

Humidity refers to the concentration of water vapor in the air, and human activities can directly and indirectly influence it (United Nations Environment Programme, 2024). Cities often have higher humidity levels due to the heat island effect and the release of water vapor from anthropogenic sources like industry, transportation, and vegetation irrigation. This increases the atmospheric moisture content, especially during warm seasons. When forests are replaced by agriculture or urban areas, the natural process of evapotranspiration (water released by plants) decreases, potentially reducing humidity in those regions. However, in urbanized areas with large populations, the use of water resources (for irrigation, artificial lakes, etc.) can increase local humidity. By implication, human population growth, through activities like urbanization, industrialization, land-use changes, and production of GHGs impact local and regional precipitation patterns (Kaufmann & Seto, 2001; Foley et al., 2005).

Large cities can enhance convection, leading to increased localized precipitation. This is known as the "urban precipitation effect." Cities can produce more rainfall through the combination of the urban heat island effect, increased aerosols from pollution (which serve as cloud condensation nuclei), and enhanced moisture from human activities. Large-scale deforestation disrupts the hydrological cycle, as trees play a crucial role in water vapor release (evapotranspiration). This can lead to reduced rainfall in deforested regions and even drought conditions. GHG emissions and subsequent global warming, largely driven by human activity, are shifting precipitation patterns worldwide.

Urban heat islands can raise the dewpoint due to higher temperatures and moisture from human activities. Human activities (such as irrigation, industrial emissions, and deforestation) influence local humidity levels, often increasing them in urban areas but potentially reducing them in deforested regions. Cities can enhance local precipitation through increased heat and pollution, while deforestation can reduce regional rainfall by disrupting the natural water cycle. Global climate change further exacerbates these effects by shifting rainfall patterns. The results by these authors, Oke, (1982), Kaufmann & Seto, (2001), Foley et al., (2005), and the United Nations Environment Programme, (2024) were similar to the results we obtained at Nnewi and Onitsha. Our results indicated that human activities and the production of GHGs impact dewpoint and humidity negatively. The negligible impact of human activities results we obtained from the regression analysis on human activities/GHGs on precipitation can be attributed to urbanization which may increase precipitation and deforestation which can reduce precipitation.

**3.2.4 Wind Speed, Cloud Cover, and Population.**

Fig 9-10 are the scatter plots of the wind speed, wind direction, pressure at sea level, cloud cover, and population. The correlation coefficients in Table 3 indicate that population affects wind speed (), and cloud cover (). Fig 9 is the plot of wind speed against the population at Onitsha and Nnewi. The simple linear regression shows that the influence on wind speed by human activities is similar in both towns and is a direct relation as indicated by the slope.

**Figure 9: Plot of the Annual Average Values of Amount of Wind Speed against the Population at Onitsha and Nnewi**

Fig. 10 is the plot of cloud cover against the population at Onitsha and Nnewi. We conclude from the plots, that human activities as represented by population have negligible impact on pressure at sea level and cloud cover in Onitsha and Nnewi. Human activities as represented by the human population, particularly through urbanization and industrialization can increase GHGs, and affect wind speed, and cloud cover, through mechanisms like the urban heat island effect, land use changes, and pollution. Large cities with tall buildings and infrastructure create rough surfaces that alter wind patterns by increasing surface friction, which can reduce wind speeds at ground level. This effect is particularly noticeable in dense urban centers which generate thermal gradients due to higher temperatures, which may induce local wind systems (e.g., breezes) within cities but can also reduce wind speeds overall by disrupting natural wind patterns (Oke, 1987). Tall buildings, skyscrapers, and infrastructure in cities can channel winds in specific directions, modifying natural wind flow patterns. These structures create microclimates that redirect winds, often funneling them between buildings (creating strong gusts locally) while weakening winds in other areas. Urban heat islands can also influence wind direction as temperature differences between urban and rural areas create localized wind circulations, altering broader wind patterns in and around cities (Blocken et al., 2012).

Human activities such as transportation, industrial emissions, and agriculture release aerosols into the atmosphere, which can serve as cloud condensation nuclei. This increases cloud formation, particularly in urban areas. More aerosols result in more clouds, especially low-level clouds that trap heat and influence local weather patterns. Warmer urban areas can increase convection, lifting moist air and promoting cloud development. This effect is particularly noticeable in densely populated cities, where increased cloud cover and precipitation are often observed compared to surrounding rural areas (Shepherd, 2005).

Urbanization slows/increases wind speeds at ground level by increasing surface friction and altering thermal gradients. Cities can modify wind direction through building structures and temperature-driven localized wind circulations. Increased aerosols from human activities lead to more cloud formation, particularly in urban areas. The urban heat island effect can cause localized pressure changes, and climate change due to human activity affects global pressure patterns. These reports are in agreement with our results, especially concerning wind speed and wind direction dependent on human activities.

**Figure 10: Plot of the Annual Average Values of Cloud Cover against the Population at Onitsha and Nnewi**.

**3.2.5 Solar Radiation, UV Index, and Population.**

Figs. 11 – 12 are the plots of annual average values of the amount of solar radiation, solar radiation energy, and UV index respectively against the population at Onitsha and Nnewi. The values of the correlation coefficient shown in Table 3 indicate that human activities/GHGs as represented by population strongly affect (with solar radiation and UV index at both towns. The slopes of the linear fit to the scatter plots equally suggest that the strength of the impact of human activities and the generation of GHGs on solar radiation, solar radiation energy, and UV index are similar in Nnewi and Onitsha. Works of literature that have examined the relationship between population and solar radiation, solar radiation energy, and the UV index include the Smithsonian Environmental Research Center (2020), WHO (2022), and - USEPA (2024).

These works of literature reported that population growth leads to urbanization and industrialization, which contributes to increased air pollution. Pollutants such as aerosols, particulate matter, and GHGs can scatter, absorb, and reflect solar radiation. This reduces the amount of direct solar radiation reaching the Earth's surface, especially in urbanized regions with higher populations, Research shows that cities experience a phenomenon called urban haze, which diminishes the amount of solar radiation that reaches the ground. This is particularly significant in large cities with high levels of vehicular and industrial emissions. Population growth also has a significant impact on solar radiation energy through indirect factors such as urbanization, air pollution, and land use changes.

As the population increases, so does industrial activity and vehicular traffic, which contribute to air pollution. Pollutants like particulate matter, aerosols, and GHGs in the atmosphere can reduce the amount of solar radiation reaching the Earth's surface. These pollutants scatter and absorb solar energy, diminishing the potential for energy collection from solar panels in urbanized, heavily populated areas. (Smithsonian Environmental Research Center, 2020; WHO, 2022; USEPA, 2024). Research shows that in cities with high levels of pollution, solar irradiance can be reduced by up to 20-30% due to haze and particulate matter.

**Figure 11: Plot of the Annual Average Values of the Solar Radiation against the Population at Onitsha and Nnewi.**

**Figure 12: Plot of the Annual Average Values of the UV Index against the Population at Onitsha and Nnewi.**

Densely populated areas contribute to the Urban Heat Island effect, where the concentration of buildings, asphalt, and reduced vegetation causes cities to be warmer than surrounding rural areas. This effect can alter local atmospheric conditions and solar energy absorption. The heat generated in these areas may interfere with solar panel performance, as solar panels tend to operate less efficiently at higher temperatures.Moreover, the reflection of solar radiation off urban structures can create variations in how much energy is absorbed or reflected, affecting the overall capture of solar radiation energy.

As populations grow, the demand for land increases, which leads to changes in land use. Agricultural land or forests are often converted to urban or industrial areas, reducing the natural albedo (reflectivity) of the land. This can influence how much solar radiation is absorbed versus reflected into the atmosphere. Urban sprawl, driven by population growth, also limits the space available for deploying solar energy systems, especially large-scale solar farms, which require significant amounts of land (Smithsonian Environmental Research Center, 2020; WHO, 2022; USEPA, 2024).

The conclusion we obtain is that the increasing population of cities leads to an increase in human activities and the generation of Greenhouse affects weather/metrological parameters leading to adverse effects on the human population and climatic conditions of Onitsha and Nnewi. This conclusion is similar to that in existing literature.

**3.2.6 Temperature Effect on Dewpoint, Humidity, Precipitation, Wind Speed, Cloud Cover, Solar Radiation, and UV Index**

Increasing temperatures are often linked to rising levels of GHGs in the atmosphere. This relationship is well-established in climate science. GHGs, such as CO₂, CH₄, and N₂O, trap heat within the Earth's atmosphere, leading to the greenhouse effect (IPCC, 2014). GHGs absorb infrared radiation emitted by the Earth's surface and re-radiate it, reducing the amount of heat that escapes into space. This process results in a rise in global temperatures, known as global warming. As human activities, particularly fossil fuel combustion, deforestation, and industrial processes, increase the concentration of these gases, the temperature rises proportionally.

Specific data and findings indicate a clear correlation between rising CO₂ levels and global temperature increases. For instance, CO₂ concentrations have increased from around 280 ppm (parts per million) in the pre-industrial era to over 410 ppm in recent years, leading to a global temperature increase of about 1.1°C above pre-industrial levels (IPCC, 2014; USEPA, 2024). Additionally, CH₄ is a more potent GHG than CO₂ over short timescales. According to the USEPA, (2024), CH₄ has a global warming potential more than 25 times that of CO₂ over 100 years, and its concentration in the atmosphere has risen sharply due to agricultural practices, livestock, and fossil fuel extraction. Thus, temperature measures can be used to study the effect of GHGs on a city's weather/metrological parameters.

**Table 4. Correlation Coefficient between Temperature and other Weather/Metrological Parameters**

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InTable 4, we display the results of the correlation between local temperature (T) and Dewpoint (DP), Humidity (H), Precipitation, Wind Speed (WS), Cloud Cover (CC), Solar Radiation (SR), and UV Index (UVI) in Nnewi and Onitsha. The result showed that the correlation between temperature and dewpoint is negative and fairly strong for Onitsha () and Nnewi (). The reduction of the dew point is generally linked to the amount of moisture in the air. When the air's moisture content decreases, the dew point, which represents the temperature at which water vapor condenses into liquid, drops as well. Several factors contribute to a reduction in the dew point (National Weather Service (NWS), 2014; WHO, 2022).

As the air cools, its ability to hold water vapor decreases. If the moisture content remains constant, but the temperature drops, the relative humidity increases, potentially reaching saturation (100% humidity). However, in cases where there is less moisture in the air, the dew point also decreases, indicating that condensation will occur at a lower temperature. Climate change, driven by increasing GHG emissions, can indirectly affect the dew point. Warmer temperatures associated with climate change can lead to higher evaporation rates, potentially increasing the absolute humidity and raising the dew point. The dew point can also decrease when a dry air mass moves into an area. For instance, after a cold front pass, the cooler, drier air that follows reduces the dew point. Similarly, strong winds from desert regions or higher elevations can bring in dry air masses, lowering the local dew point.

This interplay between moisture, temperature, and air movement helps explain the variations in the dew point, particularly its reduction in dry or cool conditions. A reduction in dew point temperature can have several adverse effects on both the environment and human health, as it indicates a significant decrease in moisture content in the air (NWS, 2014; WHO, 2022). A lower dew point is often associated with dry air, which can increase the risk of wildfires. Dry conditions reduce the moisture content of vegetation, making it more susceptible to catching fire. Wildfire risk is particularly high in regions experiencing prolonged periods of low dew points and dry air masses. This effect is commonly observed in places where a combination of low humidity, reduced dew points, and hot winds creates dangerous conditions for wildfires (NWS, 2014; WHO, 2022).

Low dew points lead to dry air, which can cause respiratory and skin problems for humans. Dry air can irritate the respiratory system, especially for people with asthma or other lung conditions, leading to increased hospital visits during periods of dry, cold air. Additionally, reduced humidity can cause dry, cracked skin, eye irritation, and dehydration, as moisture evaporates more quickly from the body.Lower dew point temperatures often signal a decrease in atmospheric moisture, which can have negative impacts on agriculture. Crops rely on a certain level of ambient humidity to thrive, and a reduction in dew point can lead to dry soil conditions and poor crop yields. For instance, arid conditions with low dew points can limit plant growth, reduce water retention in the soil, and increase the need for irrigation.Low humidity and a lower dew point lead to an increase in static electricity. This is because dry air allows for the buildup of electrical charges, which can create shocks when people or objects come into contact. While not typically dangerous, static electricity can be annoying and interfere with electronic devices.

In summary, while lower dew point temperatures can sometimes be associated with clearer skies and cooler weather, the adverse effects—especially related to wildfires, human health, and agriculture—are considerable in areas experiencing consistently low dew points. The plot of dewpoint against temperature is shown in Fig. 13, which that a declining dewpoint with increased temperature for Nnewi (with a slope of linear regression as ) and Onitsha (with slope of linear regression as ). the rate of decline is greater in Nnewi than in Onitsha, perhaps Onitsha being close to River Niger might be a contributing factor to the reduced rate of decline.

**Figure 13: Plot of the Annual Average Values of the Dewpoint against the Temperature at Onitsha and Nnewi.**

**Figure 14: Plot of the Annual Average Values of the Humidity against the Temperature at Onitsha and Nnewi.**

Fig 14 is the plot of annual average values of the amount of humidity against the temperature at Onitsha and Nnewi. Table 4.2 shows that a strong negative correlation exists between humidity and temperature (), Fig. 14 also indicates that increasing temperature leads to declining humidity and that the rate of decline is greater in Nnewi (slope is than in Onitsha (slope is . The combination of declining humidity and increasing temperature has significant implications for both the environment and human health. When humidity drops and temperatures rise, several processes are triggered that can lead to adverse outcomes, according to the NWS, (2014), and WHO, (2022). These adverse effects include:

The heat index combines air temperature and humidity to estimate how hot it feels. When humidity is low, the body's ability to sweat and cool down through evaporation is enhanced. However, with rising temperatures and persistently low humidity, the body's cooling mechanisms can become overwhelmed, leading to heat stress and heat exhaustion. This is especially concerning in regions experiencing extreme temperatures with insufficient humidity to balance the heat.Low humidity and high temperatures lead to increased evaporation rates from soil and water sources. As a result, crops and plants suffer from water stress, especially in regions dependent on natural rainfall. Drought conditions are exacerbated, leading to poor agricultural yields and a higher demand for irrigation. Declining humidity alongside temperature rise is a key factor in desertification, as ecosystems are unable to sustain vegetation. Low humidity and high temperatures dry out vegetation, making it more susceptible to ignition. As fuel moisture content decreases, the likelihood of fires increases.

**Figure 15: Plot of the Annual Average Values of the Wind Speed against the Temperature at Onitsha and Nnewi.**

Fig. 15 is the plot of the annual average values of the wind direction against the temperature at Onitsha and Nnewi. The plots showed that increasing temperature affects wind speed by increasing wind speed (slope of the linear fit is Nnewi and Onitsha ) indicating more impact in Nnewi than in Onitsha. Rising temperatures can significantly impact wind speed and wind direction due to changes in atmospheric pressure patterns, heat distribution, and large-scale climate processes primarily created by increasing temperature (Vecchi and Soden, 2007; Vautard et al., 2010; Jennifer and Stephen, 2012; Sara and Todd, 2012). Temperature affects wind speed and wind direction by the following process:

Wind is driven by differences in atmospheric pressure, which are typically created by temperature contrasts between different regions. As temperatures rise, the temperature gradients between the poles and the equator can weaken, reducing the pressure gradient force. This can lead to a decrease in wind speeds, particularly in mid-latitudes. This phenomenon has been observed in the weakening of the jet stream, a fast-flowing air current in the upper atmosphere (Vecchi and Soden, 2007; Jennifer and Stephen, 2012).

In contrast, rising temperatures can also cause localized increases in wind speed. For example, urban heat islands – areas where cities are warmer than their surrounding rural areas—can generate stronger winds as hot air rises, creating a low-pressure area that pulls in cooler air. In coastal regions, the temperature contrast between land and sea can intensify sea breezes (Vecchi and Soden, 2007; Jennifer and Stephen, 2012). As temperatures rise globally, large-scale wind patterns like the Hadley cell - a tropical circulation pattern are expected to shift. Warming of the poles reduces the temperature difference between the equator and the poles, which can shift wind belts like the trade winds and the westerlies poleward. This change in wind direction can affect weather systems, leading to altered storm tracks and precipitation patterns (Vautard et al., 2010). Rising temperatures, particularly in the Arctic, cause the jet stream to weaken and meander more, which can shift wind direction. The jet stream often dictates weather patterns in mid-latitudes, so its shift due to temperature increases can result in more extreme weather events such as prolonged cold spells or heat waves (Sara and Todd, 2012).

Temperature rise can affect local winds such as mountain-valley breezes and downhill winds. Warmer temperatures can modify how these winds develop and behave, especially in mountainous regions where temperature differences between valleys and higher elevations are critical in driving these winds (Sara and Todd, 2012). In conclusion, rising global temperatures have complex effects on wind speed and direction. While some regions may experience weakened winds due to reduced thermal gradients, others may see increased localized wind speeds or shifts in wind direction due to changing pressure patterns, jet stream behavior, and storm intensities. From these literature analyses, our result implies that increasing temperature at Nnewi and Onitsha adversely affects the wind direction and wind speed, creating gusts of wind, which can impact the environment, health, and economies of the cities.

**Figure 16: Plot of the Annual Average Values of the Cloud Cover Level against the Temperature at Onitsha and Nnewi.**

Fig. 16is the plot of the annual average values of the cloud cover against the temperature at Onitsha and Nnewi. Rising temperatures have significant effects on cloud cover, which, in turn, impact climate dynamics. As temperatures increase, cloud cover tends to decrease, particularly during the daytime. This reduction in clouds leads to greater solar radiation reaching the Earth's surface, thereby intensifying warming. This dynamic is known as a positive feedback loop, as less cloud cover allows for more warming, which further reduces cloud formation (Qiuhong & Guoyong, 2013; Mendoza et al., 2021). Clouds have complex effects on the climate. During the day, they can cool the surface by reflecting sunlight, but at night, they trap heat, contributing to the greenhouse effect. As temperatures rise, studies show a decrease in daytime cloudiness, exacerbating warming by reducing the cooling effect of clouds. However, nighttime cloud cover tends to persist, intensifying heat retention. Thus, rising temperatures contribute to more erratic and variable cloud patterns, which have direct consequences for both local weather patterns and global climate trends.

However, our results in Nnewi and Onitsha are at variance with the works of (Qiuhong & Guoyong, 2013; Mendoza et al., 2021), who studied cloud cover variation with temperature during the daytime and nighttime on a global scale, while we used the daily average.

Fig. 17 is the plot of the amount of precipitation against temperature in Onitsha and Nnewi. The figure indicates that rising temperature affects the amount of precipitation in Onitsha negatively with (slope of the linear fit is ), but influences the amount of precipitation in Nnewi positively with and the slope of the linear fit between the cloud cover and temperature is .

**Figure 17: Plot of the Annual Average Values of the Amount of Precipitation against the Temperature at Onitsha and Nnewi.**

Rising global temperatures have a profound impact on precipitation patterns worldwide. As the atmosphere warms, its capacity to hold moisture increases, leading to changes in both the intensity and distribution of precipitation events. This relationship is governed by the Clausius-Clapeyron equation, which states that atmospheric water vapor increases by about 7% for every 1°C rise in temperature. Studies have shown that higher temperatures can lead to more extreme and frequent heavy rainfall events in many regions. For instance, Trenberth (2011) explains that warming accelerates the hydrological cycle, resulting in increased evaporation and, subsequently, more precipitation. This can cause wetter conditions in areas that are already wet and exacerbate dryness in arid regions due to altered atmospheric circulation patterns.

Kharin et al. (2007) project that extreme precipitation events are likely to become more frequent and intense in the 21st century, based on climate model simulations. This intensification of precipitation extremes poses significant risks for flooding and soil erosion, impacting agriculture, infrastructure, and ecosystems. Moreover, Alexander et al. (2006) analyzed global observations and found significant increases in the occurrence of heavy precipitation events over the latter half of the 20th century. Their research supports the idea that warming temperatures contribute to changes in precipitation extremes, although there may be regional variations.

Our results in Nnewi seem to agree with the global trend of increasing temperature causing the increase in the amount of precipitation but seem to vary in Onitsha, where we obtained results that seem to negate the amount of precipitation as temperature increases. Although Alexander et al. (2006) pointed out that global, as temperature rises, amount and frequencies of precipitation change, there are regional variations.

**Figure 18: Plot of the Annual Average Values of the Solar Radiation against the Temperature at Onitsha and Nnewi.**

Figs 18 and 19 are the plots of the annual average values of solar radiation, UV index against the temperature at Onitsha and Nnewi. The plots indicated that increasing temperatures lead to an increase in solar radiation, and UV index with the rate of increase higher in Nnewi than in Onitsha as indicated by the slopes of the linear fits to the plots. Also, the correlation between temperature and solar radiation, and UV index is positive and strong with for Onitsha and for Nnewi.

Rising temperatures have notable impacts on solar radiation, solar radiation energy, and the UV index, which are essential for understanding climate change dynamics and public health risks according to reports by Yuan et al., (2021), Mendoza et al., (2021), Umar and Tasduq (2022), Chodakowska et al., (2024). Increased temperatures alter cloud cover and aerosol concentrations, leading to downward surface solar radiation fluctuations. Research shows periods of global dimming from the 1960s to 1980s followed by brightening due to reduced pollution and clearer skies, enhancing solar energy reaching the surface. This impacts global warming feedback mechanisms (Yuan et al., 2021; Mendoza et al., 2021; Umar and Tasduq, 2022; Chodakowska et al., 2024).

The rise in global temperatures also interacts with ozone layer depletion, influencing the UV index. Warmer temperatures and GHG emissions can slow down the ozone layer's recovery, resulting in higher UV radiation reaching the Earth's surface. This increases the risk of UV-related health issues, such as skin cancer, especially for populations in high-risk regions (Yuan et al., 2021; Mendoza et al., 2021; Umar and Tasduq, 2022; Chodakowska et al., 2024). Furthermore, heightened UV-B exposure disrupts ecosystems, affecting plant growth and marine life. Therefore, the rising UV index due to climate and temperature changes presents a growing public health and environmental concern (Yuan et al., 2021; Mendoza et al., 2021; Umar and Tasduq, 2022; Chodakowska et al., 2024).

In summary, increasing temperatures influence solar radiation and energy systems, creating challenges for energy forecasting and public health due to rising UV exposure. In both Nnewi and Onitsha, our results indicated rising temperatures causing an increase in solar radiation, solar energy radiation, and UV index, the rate of increase is higher in Nnewi than in Onitsha. This increasing solar and UV radiation according to Umar and Tasduq, (2022), poses a greater risk factor especially as it relates to health issues.

**Figure 19: Plot of the Annual Average Values of the UV index against the Temperature at Onitsha and Nnewi**

**4. Conclusion**

The increasing population affects weather and meteorological parameters through various mechanisms e.g. population growth drives urbanization, leading to Urban Heat Islands, where cities are significantly warmer than surrounding areas. Increased construction materials and reduced vegetation raise local temperatures, affecting precipitation patterns and cloud cover. Industrial activities and vehicles produce aerosols, influencing temperature, precipitation, and solar radiation by reflecting or absorbing sunlight, and altering local climate patterns. Higher population density increases water demand and pollution, influencing local humidity and altering rainfall and storm intensity. These changes have far-reaching effects on local and global climates, impacting ecosystems and human health (Garsa et al., 2023).

In our study, we obtained results that show that increasing GHGs as represented by the increase in population adversely affects weather/metrological parameters and that the effects are more in Nnewi than in Onitsha. Population growth representing increased GHGs has a higher influence on temperature, humidity, cloud cover, amount of precipitation, solar radiation, solar radiation energy, and UV index in Nnewi than in Onitsha.

In conclusion, this study has revealed the effects of increasing population which represents an increasing GHG has on weather/metrological parameters including:

**Temperature**: Urbanization and industrial activities contribute to urban heat islands, raising local temperatures.

**Dewpoint & Humidity**: Increased water usage and emissions affect moisture levels and local atmospheric humidity.

**Precipitation & Cloud Cover**: Aerosols from human activity alter cloud formation and precipitation, influencing regional weather.

**Solar Radiation**: Pollution scatters and absorbs solar radiation, affecting solar energy potential.

**UV Index**: Urbanization and air pollution can impact UV radiation exposure by altering atmospheric composition.

Concluding on effects of rising temperature, rising temperatures influence weather/metrological parameters as:

**Dewpoint & Humidity**: Warmer air holds more moisture, raising dewpoints and humidity levels.

**Precipitation & Cloud Cover**: Higher temperatures intensify the water cycle, leading to more extreme weather events and altering cloud cover patterns.

**Solar Radiation**: Clearer skies due to temperature-driven cloud reduction increase solar irradiance, affecting solar energy production.

**UV Index**: Ozone depletion due to global warming allows more UV radiation to reach Earth's surface, raising the UV index.

The adverse effects of increasing population on meteorological parameters include: Urban heat islands elevated temperatures, worsening heatwaves, and energy demands. Increased emissions and industrial activity raise moisture levels, leading to discomfort and health issues, also higher temperatures intensify humidity, aggravating heat stress. Pollutants alter cloud properties and reduce rainfall, exacerbating droughts, warmer air causes more extreme rainfall, leading to flooding and erosion. Air pollution blocks solar radiation, reducing sunlight while ozone depletion raises the UV index, increasing skin cancer risks, also clearer skies may increase solar radiation energy but higher UV radiation threatens health (Yuan et al., 2021; Mendoza et al., 2021; Umar and Tasduq, 2022; Chodakowska et al., 2024).

Nnewi an emerging populous city is showing signs of changes in weather and metrological parameters at a rate higher than that of Onitsha, this may result in serious adverse climatic conditions, and higher risks to public health, agriculture, and ecosystems due to population growth which represent increasing GHGs and climate change.

**References**

Adeleke, A. O., Eze, U. C., & Nnaji, C. C. (2018). Climate variability and urban resilience in Nigeria. *Journal of Environmental Studies*, 45(2), 123-136.

Akinsanola, A. A., & Ogunjobi, K. O. (2017). Analysis of rainfall and temperature variability over Nigeria. *Atmospheric Research*, 183, 237-250. DOI: 10.1016/j.atmosres.2016.10.024.

Alexander, L. V., Zhang, X., Peterson, T. C., et al. (2006). Global observed changes in daily climate extremes of temperature and precipitation. *Journal of Geophysical Research*, 111(D5), D05109. doi:10.1029/2005JD006290, https://doi.org/10.1029/2005JD006290

Atanga, R.A and Tankpa, V. (2021). Climate Change, Flood Disaster Risk and Food Security Nexus in Northern Ghana. Front. Sustain. Food Syst. 5:706721.

Atwoli, L., Baqui, A. H., Benfield, T., Bosurgi, R., Godlee, F., Hancocks, S., Horton, R., Laybourn-Langton, L., Monteiro, C. A., Norman, I., Patrick, K., Praities, N., Olde Rikkert, M. G. M., Rubin, E. J., Sahni, P., Smith, R., Talley, N., Turale, S., & Vázquez, D. (2021). Call for Emergency Action to Limit Global Temperature Increases, Restore Biodiversity, and Protect Health. mBio, 12(5), e0249121.

Bell, J. E., Brown, C. L., Conlon, K., Herring, S., Kunkel, K. E., Lawrimore, J., Luber, G., Schreck, C., Smith, A., & Uejio, C. (2018). Changes in extreme events and the potential impacts on human health. Journal of the Air & Waste Management Association (1995), 68(4), 265–287.

Britannica. (2024). Onitsha. In *Encyclopedia Britannica*. Retrieved from <https://www.britannica.com/place/Onitsha-Nigeria>

Brown, L. T. (2019). *Climate Change and Humidity: Impacts on Global Ecosystems*. Cambridge University Press.

Burton, I., Kates, R. W., & White, G. F. (1978). *The environment as hazard*. Oxford University Press.

Cattaneo, C., & Foreman, T. (2023). Climate change, international migration, and interstate conflicts. Ecological Economics, 211, 107890

Chodakowska, E., Nazarko, J., Nazark, L.,  and Rabayah, S. H., (2024), Solar Radiation Forecasting: A Systematic Meta-Review of Current Methods and Emerging Trends, *Energies*, *17*(13), 3156; <https://doi.org/10.3390/en17133156>

Ebi, K. L., Campbell-Lendrum, D., & Wyns, A. (2018). Human health. In Global warming of 1.5°C: An IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. Intergovernmental Panel on Climate Change.

Ebi, K. L., Vanos, J., Baldwin, J. W., Bell, J. E., Hondula, D. M., Errett, N. A., Hayes, K., Reid, C. E., Saha, S., Spector, J., & Berry, P. (2021). Extreme Weather and Climate Change: Population Health and Health System Implications. *Annual review of public health*, *42*, 293–315.

Ekwueme, B. N., & Agunwamba, J. C. (2021), A trend analysis and observed variability in rainfall and air temperature in river basins in Southeast Nigeria, https://link.springer.com/article/10.1007/s12665-021-09768-9.

Farooq, M. S., Uzair, M., Raza, A., Habib, M., Xu, Y., Yousuf, M., Yang, S. H., & Ramzan Khan, M. (2022). Uncovering the Research Gaps to Alleviate the Negative Impacts of Climate Change on Food Security: A Review. Frontiers in plant science, 13, 927535.

Fisher, R. A. (1915). Frequency distribution of the values of the correlation coefficient in samples from an indefinitely large population. *Biometrika, 10*(4), 507–521. <https://doi.org/10.1093/biomet/10.4.507>

Foley, J. A., DeFries, R., Asner, G. P., Barford, C., Bonan, G., Carpenter, S. R., ... & Snyder, P. K. (2005). Global consequences of land use. *Science, 309*(5734), 570–574. https://doi.org/10.1126/science.1111772.

Food and Agriculture Organization (2023), Greenhouse Gas Emissions from Agriculture, Forestry, and Other Land Use. [www.fao.org/3/i6340e/i6340e.pdf](http://www.fao.org/3/i6340e/i6340e.pdf)

Garsa, K., Khan, A. A., Jindal, P., & Others. (2023). Assessment of meteorological parameters on air pollution variability over Delhi. *Environmental Monitoring and Assessment, 195,* 1315. <https://doi.org/10.1007/s10661-023-11922-2>

Gattuso, J.-P., Magnan, A., Bopp, L., Cheung, W. W. L., Duarte, C. M., Hinkel, J., ... & Turley, C. (2015). Contrasting futures for ocean and society from different anthropogenic CO₂ emissions scenarios. Science, 349(6243), aac4722. doi.org/10.1126/science.aac4722

Global Forest Watch (2023). Forest Monitoring, Land Use, and Deforestation Trends. [www.globalforestwatch.org](https://www.globalforestwatch.org)

Gulev, S. K., Thorne, P. W., Allan, R. J., Dai, A., Domingues, C. M., Dunn, R. J. H., ... & Ziese, M. (2021). Indicators of global climate change 2022: Annual update of large-scale indicators of the state of the climate system and human influence. *Earth System Science Data, 13*(6), 2941–2964. <https://doi.org/10.5194/essd-13-2941-2021>

<https://nationalpopulation.gov.ng/>

[https://www.visualcrossing.com/weather/weather-data-services#](https://www.visualcrossing.com/weather/weather-data-services).

IEA.(2021). Global Energy Review 2021: CO₂ Emissions in 2020. [www.iea.org/reports/global-energy-review-2021](http://www.iea.org/reports/global-energy-review-2021)

IPCC, (2014). Climate Change 2014: Mitigation of Climate Change – Industry. www.ipcc.ch/report/ar5/wg3/industry

IPCC,(2022). Climate Change 2022: Impacts, Adaptation, and Vulnerability. Cambridge University Press. https://www.ipcc.ch/report/ar6/wg2/

IPCC. (2021). Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.K. Allen, M. R. (Eds.)]. Cambridge University Press. Retrieved from https://www.ipcc.ch/report/ar6/wg1/

Isaksen, K., Nordli, Ø., Ivanov, B., Køltzow, M. A. Ø., Aaboe, S., Gjelten, H. M., Mezghani, A., Eastwood, S., Førland, E., Benestad, R. E., Hanssen-Bauer, I., Brækkan, R., Sviashchennikov, P., Demin, V., Revina, A., & Karandasheva, T. (2022). Exceptional warming over the Barents area. Scientific Reports, 12(1), 9371.

Jennifer A. F. and Stephen J. V., (2012), The influence of Arctic amplification on mid-latitude weather and climate, *Nature Climate Change*, DOI:10.1038/nclimate1500, https://doi.org/10.1038/nclimate1500

Jones, K. L., & Smith, M. E. (2020). The Impact of Decreasing Humidity on Agricultural Productivity in Arid Regions. *Journal of Environmental Science*, 34(5), 678-690.

Kaufmann, R. K., & Seto, K. C. (2001). Changes in the Climate System Due to Urbanization. *Global Environmental Change*, 11(2), 77-93

Kharin, V. V., Zwiers, F. W., Zhang, X., & Wehner, M. (2007). Changes in temperature and precipitation extremes in the IPCC ensemble of global coupled model simulations. *Journal of Climate*, 20(8), 1419-1444. doi:10.1175/JCLI4066.1, https://doi.org/10.1175/JCLI406

Knutson, T. R., Camargo, S. J., Chan, J. C. L., Emanuel, K., Ho, C.-H., Kossin, J., ... & Wu, L. (2020). Tropical cyclones and climate change assessment: Part II. Projected response to anthropogenic warming. Nature Climate Change, 10(3), 191–199. <https://doi.org/10.1038/s41558-019-0643-0>

Le Quéré, C., Andrew, R. M., Friedlingstein, P., Sitch, S., Pongratz, J., Peters, G. P., ... & Zheng, B. (2018). Global carbon budget 2018. *Earth System Science Data, 10*(4), 2141–2194. https://doi.org/10.5194/essd-10-2141-2018.

Lobell, D. B., Schlenker, W., & Costa-Roberts, J. (2011). Climate trends and global crop production since 1980. *Science*, 333(6042), 616-620.

Macrotrends. (2024). Onitsha population. Retrieved from <https://www.macrotrends.net/cities/22013/onitsha/population>

McKenzie, R. L., Aucamp, P. J., Bais, A. F., Björn, L. O., & Ilyas, M. (2011). Ozone depletion and climate change: Impacts on UV radiation. *Photochemical & Photobiological Sciences*, 10(2), 182-198. DOI: [10.1039/C0PP90034F, <https://doi.org/10.1039/C0PP90034F>).

Mendoza, V., Marni P.. M., Garduño, R., & Mendoza, B., (2021), Thermodynamics of climate change between cloud cover, atmospheric temperature, and humidity, *Scientific Reports*, 11:21244 <https://doi.org/10.1038/s41598-021-00555-5>

Mimura N. (2013). Sea-level rise caused by climate change and its implications for society. Proceedings of the Japan Academy. Series B, Physical and biological sciences, 89(7), 281–301.

Monks, P. S., Archibald, A. T., Colette, A., Cooper, O., Coyle, M., Derwent, R., ... & Williams, M. L. (2015). Tropospheric ozone and its precursors from the urban to the global scale from air quality to short-lived climate forcer. *Atmospheric Chemistry and Physics, 15*(15), 8889–8973. <https://doi.org/10.5194/acp-15-8889-2015>

NASA. (2020). What is the greenhouse effect? Retrieved from https://climate.nasa.gov/climate\_resources/240/the-greenhouse-effect-simplified/

National Oceanic and Atmospheric Administration (NOAA), 2021).

National Weather Service (NWS), 2014 https://www.epa.gov/sunsafety

Ngwenya, M., Busayo, E. T., Simatele, M. D., & Others. (2024). Evidence of increasing water scarcity due to frequent drought under SSP2-4.5 climate change scenario in the Western Cape Province, South Africa. *Research Square*. Preprint (Version 1). <https://doi.org/10.21203/rs.3.rs-1234567/v1>

Nigeria Erosion and Watershed Management Project (2024). [www.worldbank.org](http://www.worldbank.org)

Nigerian Meteorological Agency. (2023). *Climate Change Impacts on Southeastern Nigeria: Annual Temperature Trends in Onitsha and Nnewi*. Nigerian Meteorological Agency. <http://www.nimet.gov.ng/reports/temperature-trends-2023>

NOAA. (2021). Annual Dew Point Trends in the United States: A Comprehensive Report. NOAA. https://www.noaa.gov/reports/dew-point-trends

NOAA. (2021). Trends in Atmospheric Carbon Dioxide. Retrieved from https://www.esrl.noaa.gov/gmd/ccgg/trends/

Nwafor, A. O., & Eze, C. N. (2019). Urbanization and population dynamics in Anambra State. *African Journal of Social Sciences*, 12(3), 34-56.

Ogungbenro, S. B., & Morakinyo, T. E. (2014): An analysis of rainfall distribution and trends across various climatic zones in Nigeria, including the Southeast*. Journal of Weather and* *Climate Extremes* <https://doi.org/10.1016/j.wace.2014.10.002>

Oke, T. R. (1982). The Energetic Basis of the Urban Heat Island. *Quarterly Journal of the Royal Meteorological Society*, 108(455), 1-24.

Oke, T. R. (1987). *Boundary Layer Climates*. Routledge. London.

Okeke, C. N., & Nwankwo, E. A. (2022). Trends in Temperature Changes in Southeastern Nigeria: A Case Study of Onitsha and Nnewi. *Journal of Climate Research*, *15*(2), 89-105.

Okoro, B. C., & Okoro, I. C. (2012). An Assessment of Gully Erosion in Anambra State: *Journal of Environmental Science and Engineering*, 6(3), 453-460.

Petit, J. R., Jouzel, J., Raynaud, D., Barkov, N. I., Barnola, J. M., Basile, I., ... & Stievenard, M. (1999). Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica. *Nature, 399*(6735), 429–436. <https://doi.org/10.1038/20859>

Qiuhong T., Guoyong, L., (2013) Changes in Cloud Cover, Precipitation, and Summer Temperature in North America from 1982 to 2009, 1733–1744, *Journal of Climate* DOI: <https://doi.org/10.1175/JCLI-D-12-00225.1>

Ravishankara, A. R., Daniel, J. S., & Portmann, R. W. (2009). Nitrous oxide (N2O): The dominant ozone-depleting substance emitted in the 21st century. Science, 326(5949), 123-125.

Rogelj, J., Shindell, D., Jiang, K., Fifita, S., Forster, P., Ginzburg, V., ... & Vilarino, M. V. (2018). Mitigation pathways compatible with 1.5°C in the context of sustainable development. In *Global warming of 1.5°C*. IPCC.

Sara M., and Todd G. V., (2012), Observed changes in surface wind speed over the past 30 years, Nature *Climate Change*, doi:10.1038/nclimate1322, https://doi.org/10.1038/nclimate1322

Saunois, M., Stavert, A. R., Poulter, B., Bousquet, P., Canadell, J. G., Jackson, R. B., ... & Zheng, B. (2020). The global methane budget 2000–2017. *Earth System Science Data, 12*(3), 1561–1623. <https://doi.org/10.5194/essd-12-1561-2020>

Shepherd, J. M. (2005). A Review of Current Investigations of Urban-Induced Rainfall and Recommendations for the Future. *Earth Interactions*, 9(12), 1-27.

Shirley, L. A., & Cindy, H. R. (2020). Climate Change and Forced Migration. International migrations , 11 , e1846.

Shivanna, K. R. (2022). Climate change and its impact on biodiversity and human welfare. Proc.Indian Natl. Sci. Acad., 88(2):160–71.

Slangen, A.B.A, Palmer MD, Camargo CML, Church JA, Edwards TL, Hermans THJ, Hewitt HT, Garner GG, Gregory JM, Kopp RE, Santos VM and van de Wal RSW (2023). The evolution of 21st century sea-level projections from IPCC AR5 to AR6 and beyond. Cambridge Prisms: Coastal Futures, 1, e7, 1–13

Smith, J. A., & Brown, L. M. (2019). Trends in Dew Point Temperatures: Implications for Regional Climate Change. *Journal of Atmospheric Sciences*, 76(4), 245-260.

Smith, J. B., et al. (2020). Climate change and its impacts: A global overview. *Environmental Research Letters*, 15(8), 084001. https://doi.org/10.1088/1748-9326/ab83f3

Smithsonian Environmental Research Center on how pollution affects solar energy (2020), https://serc.si.edu/research/research-topics/global-change/changes-ultraviolet-radiation

Sun, Y., Zhang, X., Ding, Y., Chen, D., Qin, D., & Zhai, P. (2021). Understanding human influence on climate change in China. National science review, 9(3), nwab113.

World Bank (2021)

Trenberth, K. E. (2011). Changes in precipitation with climate warming. *Climate Research*, 47(1-2), 123-138. doi:10.3354/cr00953, https://doi.org/10.3354/cr00953

UDEPA on solar energy and UV effects (2024), <https://www.epa.gov/sunsafety/learn-about-uv-index>

Umar, S. A., and Tasduq, S. A., (2022) Ozone Layer Depletion and Emerging Public Health Concerns - An Update on Epidemiological Perspective of the Ambivalent Effects of Ultraviolet Radiation Exposure, *Frontiers*, V 12 <https://doi.org/10.3389/fonc.2022.866733>.

United Nations Department of Economic and Social Affairs.(2022), World Population Prospects 2022. [www.un.org/development/desa/pd/world-population-prospects-2022](https://www.un.org/development/desa/pd/world-population-prospects-2022)

United Nations Environment Programme (2017). Report of the Technology and Economic Assessment Panel: HFCs. https://ozone.unep.org/system/files/documents/UNEP-TEAP-HFC-Assessment-Report-2017.

Vautard, R., Cattiaux, J., Yiou, P., Thepaut, J. N., & Ciais, P. (2010). Global shifts in wind speed and direction with climate change: Implications for renewable energy potential. *Nature Geoscience.* <https://doi.org/10.1038/ngeo979>

Vecchi G.A. and Soden, B.J. (2007), Impact of global warming on tropical cyclone activity in the North Atlantic, *Journal of Climate*, DOI. 10.1175/JCLI4130.1, https://doi.org/10.1175/JCLI4130.1

Weiskopf, S. R., Rubenstein, M. A., Crozier, L. G., Gaichas, S., Griffis, R., Halofsky, J. E., Hyde, K. J. W., Morelli, T. L., Morisette, J. T., Muñoz, R. C., Pershing, A. J., Peterson, D. L., Poudel, R., Staudinger, M. D., Sutton-Grier, A. E., Thompson, L., Vose, J., Weltzin, J. F., & Whyte, K. P. (2020). Climate change effects on biodiversity, ecosystems, ecosystem services, and natural resource management in the United States. Science of The Total Environment, 733, 137782.

Wild, M. (2012). Enlightening global dimming and brightening. *Bulletin of the American Meteorological Society*, 93(1), 27-37 <https://doi.org/10.1175/BAMS-D-11-00074.1>

Williams, R. T. (2018). *Climate Change and Atmospheric Dynamics*. Oxford University Press.

World Bank. (2021). Poverty *and shared prosperity 2021: Reversals of fortune.* World Bank Publications

WHO (2022), https://www.who.int/news-room

WMO. (2020). State of the climate in Africa. Geneva, Switzerland.

WMO. (2024). Rising Temperatures in Southeastern Nigeria: Evidence from Onitsha and Nnewi. *World Meteorological Organization*. <https://www.wmo.int/nigeria/onitsha-nnewi-temperature-rise>

[www.macrotrends.net](http://www.macrotrends.net)

Yuan, M., Leirvik, T., and Wild, (2021) M., Global Trends in Downward Surface Solar Radiation from Spatial Interpolated Ground Observations during 1961–2019, *Journal of Climate* 34(23)9501–9521, DOI: <https://doi.org/10.1175/JCLI-D-21-0165.1>