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Assessment of Weather Parameters and Population Trends in Nnewi and Onitsha Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author OCC designed the study, performed the statistical analysis, wrote the protocol, wrote the first draft of the manuscript, and managed the analyses of the study. Authors MNJ and DE managed the literature searches. All authors read and approved the final manuscript

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ABSTRACT

The increasing population affects weather and meteorological parameters through various mechanisms such as human activities, urbanization, and the production of excessive greenhouse gases (GHGs) through commercial products and industrialization. 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. We carried out statistical analyses on the weather parameters and human population representing GHGs. In our study, we obtained results that show that increasing GHGs as defined by the increase in population adversely affects weather/metrological parameters. The yearly average temperature (T) increased from ~ 26.0 ℃ in 2010 to ~ 28.5 ℃ in for both Onitsha and Nnewi in 2024. Similarly, the yearly average dewpoint (DP) fell from ~ 23.5 ℃ to ~ 21.5 ℃, the yearly average

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humidity (H) decreased from 86% to 70%, and the yearly average windspeed (WS) increased from $\sim 11\ km/h$ to ~ 20 km/h from 2010 to 2024. The yearly average solar radiation (SR) increased from ~170 W/m^2 in 2010 to ~ 220 W/m^2, and the yearly average UV index (UVI) from ~6.0 in 2010 to ~8.5 in 2024. The results of the correlation study indicate that the population positively correlates with T, WS, SR, and UVI, but negatively correlates with DP, H, and the amount of precipitation (PP). The magnitude of the slopes and intercepts of the linear fits to the scatter plots of the population and weather parameters were consistently higher in Nnewi than in Onitsha, indicating greater adverse effects in Nnewi than in Onitsha. In conclusion, this study revealed that increasing population (increasing GHG) affects 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 increasing levels of GHGs.

Keywords: 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 (National Oceanic and Atmospheric Administration [NOAA], 2021).

Certain gases in Earth's atmosphere, known as GHGs, can absorb this longwave radiation emitted by the Earth's surface. These GHGs, including water vapor, carbon IV oxide (CO_2), and methane (CH_4), 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 assumed to be vital for life as we know it (Intergovernmental Panel on Climate Change [IPCC], 2021).

According to Shivanna (Shirley & Cindy, 2020), climate change refers to long-term changes in temperature and weather caused by human activities. Manifestations of climate change include an increase in average global temperature and extreme, unpredictable weather. Climate change is no longer a looming threat; it has become a tangible reality with far-reaching consequences. While the natural greenhouse effect is essential for maintaining Earth's habitable temperature, human activities have significantly disrupted this balance by releasing excessive GHGs into the atmosphere.

Decades of scientific data reveal an undeniable rise in global temperatures, primarily driven by human-caused GHG emissions (Ravishankara et al., 2009). The years 2011–2020 are estimated to be the warmest on record, with each decade since the 1980s consistently surpassing the previous one (Isaksen et al., 2022). A global temperature increase of 1.5 °C above pre-industrial levels, coupled with ongoing biodiversity loss, poses catastrophic and irreversible risks to health (Atwoli et al., 2021; Burton et al., 1978). Earth's average surface temperature has significantly increased, with notable warming trends since the late 19th century, leading to disruptions in climatic patterns, biodiversity, and human activities.

The Intergovernmental Panel on Climate Change (Intergovernmental Panel on Climate Change

[IPCC], 2021)) projects that global temperatures will rise by 1.5–2.0 °C above pre-industrial levels by the end of the 21st century if current emissions persist. Other significant climatic changes include melting ice caps and rising sea levels (Mimura, 2013; Shivanna, 2022), extreme weather events (Bell et al., 2018; Knutson et al., 2020; Sun et al., 2021), changes in biodiversity and ecosystems (Shirley & Cindy, 2020; Weiskopf et al., 2020), challenges in agriculture and food security (Lobell et al., 2011), human health impacts (Ebi et al., 2018; Ebi et al., 2021), and economic and social consequences (World Bank, 2021). Furthermore, food security is threatened (Atanga & Tankpa, 2021; Farooq et al., 2022), mass migration is increasing (Cattaneo & Foreman, 2023; Shepherd, 2005), and ocean acidification and freshwater resource loss are becoming more prominent (Gattuso et al., 2015).

Studies analyzing Earth's energy balance and GHG dynamics have significantly advanced our understanding of climate change. Trenberth et al. (2011) linked Earth's energy imbalance, caused by differences between incoming solar and outgoing terrestrial radiation, to rising GHG concentrations due to population growth. Similarly, the IPCC (2021) provided a comprehensive assessment of GHG emissions, climate feedback, and future climate scenarios, urging immediate emission reductions to mitigate climate impacts.

Qiuhong & Guoyong, [25] examined the global CH_4 budget, identifying agriculture, fossil fuels, and wetlands as major sources. Saunois et al., (2020) identified nitrous oxide (N_2O) as the leading ozone-depleting substance and a contributor to climate change. Monks et al., (2015) explored the chemistry and impacts of tropospheric ozone, a short-lived climate forcer and pollutant linked to fossil fuel combustion and industrial processes, emphasizing its effects on air quality and human health. Le Quéré et al. (2018) highlighted increasing CO_2 emissions from fossil fuels and land-use changes, stressing the importance of carbon management to meet climate targets. Petit et al., (1999) provided evidence of the historical correlation between GHG concentrations and global temperatures from the Vostok ice core, underscoring the importance of long-term climate records for contextualizing current changes. Gulev et al., (2021) presented large-scale indicators of human influence on the climate, such as GHG concentrations, rising global temperatures, and sea-level changes, offering policymakers critical evidence for informed climate action. Together, these studies emphasize the urgent need for targeted mitigation strategies and policy interventions to address the multifaceted challenges of climate change.

Urban centers in Nigeria face mounting challenges due to 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.

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. 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 (T), rainfall (PP), humidity (H), wind speed, (WS) cloud cover (CC), solar radiation (SR), and ultraviolet radiation index (UVI) with population growth patterns in Nnewi and Onitsha and investigate the correlation between weather changes and GHG using human population dynamics.

This study hopes to provide empirical evidence on the relationship between weather and population dynamics which represents increased GHGs in two Nigerian urban centers. Onitsha, as the commercial hub, and Nnewi, an emerging commercial center of Anambra State, have both experienced significant growth accompanied by challenges such as increased traffic congestion, indiscriminate waste dumping, and the frequent presence of heavy-duty vehicles. These factors are clear indicators of rising GHG emissions in the region (Barth & Boriboonsomsin, 2008; Zhang et al., 2015; Frey & Kuo, 2007). So this study will contribute to policy development by offering insights to guide urban planning and climate adaptation efforts (World Meteorological Organization [WMO], 2024). Additionally, it enriches academic discourse on climate-population interactions in sub-Saharan Africa.

1.1 Study Areas

The study areas are Nnewi and Onitsha. Nnewi is a prominent city located in Anambra State, southeastern Nigeria. Geographically, it is positioned at approximately 6.0137° N latitude and 6.9102° E longitude, about 24 km south of Onitsha (Macrotrends, 2024; Britannica, 2024). 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). The map of Nnewi is shown in Appendix 1 (Ezeomedo & Igbokwe, 2019).

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 6.1329° N latitude and 6.7924° E longitude. As of early 2024, Onitsha has an estimated population of 1,695,000, (Macrotrends, 2024; Britannica, 2024) reflecting a 4.44% increase from the previous year. The city is noted for its commercial activity. The map of Onitsha is shown in Appendix 2 (Ezeomedo & Igbokwe, 2013). The decreasing tree cover in Onitsha North resulted in the annual release of 557 tons into the atmosphere on average between 2001 and 2022 (Blocken et al., 2012).

2. DATA DESCRIPTION AND METHODS 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). The Onitsha and Nnewi population data were obtained from (Macrotrends, 2024). 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 meteorological data for the cities were obtained from (Visual Crossing, n.d.). The online data was used because NiMET charges were beyond our reach. The 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/m^2), 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.

Online weather and population data spanning from 2010 to 2024 present a unique opportunity to analyze how weather parameters and GHGs as represented by human population trends interact. This is vital for policy-making in urban planning, public health, and climate adaptation strategies. The yearly average meteorological parameters were calculated from the daily average meteorological parameters. The yearly mean values are shown in Table 2 (for Nnewi and Onitsha). We employed common methods of analysis including time series analysis, correlation analysis, and simple linear regression models and plots (Slangen et al., 2023).

2.1 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.

2.2 Correlation And Regression Analysis

Correlation quantifies the extent of a linear relationship between two or more variables,

Table 1. 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. www.macrotrends.net

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

$$r = \frac{\sum_{i=1}^{n}(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum_{i=1}^{n}(X_i - \bar{X})^2 (Y_i - \bar{Y})^2}} \quad (1)$$

where n is the number of each variable which must be equal, $\bar{X}$ and $\bar{Y}$ are the mean value of the variable X and Y respectively. Interpretation of $r: r = \pm 1$, implies that there is a perfect (+ direct and – indirect) relationship; $\pm 1.0 < r \leq \pm 0.5$, implies there is a strong linear relationship; $\pm 0.5 \leq r < \pm 0.3$, implies there is a weak relationship; $r < \pm 0.3$ 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 Y on X is defined as

$$Y = (m \pm \Delta m)X + C \quad (2)$$

where Y is the assumed dependent variable, X is the assumed independent variable, $m \pm \Delta m$ is the slope with its associated error, and C is the intercept.

3. RESULTS AND DISCUSSION

3.1 Time Series Plots

Fig. 1a illustrates that Onitsha consistently has a higher yearly average population than Nnewi, with both cities experiencing population growth from 2010 to 2024. Fig. 1b shows that while Nnewi's annual population growth rate is higher than Onitsha's, the percentage growth rates were similar (~6.5% for Nnewi and ~5.0% for Onitsha) between 2010 and 2019. However, both cities experienced a downward trend in their annual percentage growth rates after 2019.

Fig. 2a depicts the annual mean T trends for Onitsha and Nnewi, both showing an overall increase over time, with a notable dip in 2022 followed by a return to the upward trend in 2023. These findings align with studies by (Nigeria Erosion and Watershed Management Project, 2024; Nigerian Meteorological Agency, 2023; Oke, 1982; Oke, 1987; World Meteorological Organization [WMO], 2024). Fig 2b presents the annual mean DP trends for the two cities from 2010 to 2024. The data reveals a downward trend from 2010 to 2021, a sharp drop of ~2 ℃ in 2022, and a 1℃ increase in 2023. The decreasing dew point indicates reduced absolute humidity and moisture in the air, potentially driven by several factors. These include – the regional shifts towards drier conditions and increased dry air masses; deforestation, and urbanization which reduces vegetation and lowers local humidity through reduced transpiration; changes in circulation patterns leading to more frequent dry air masses; industrialization, pollution, and aerosol emissions affecting local humidity and cloud formation. These interpretations highlight the complex interplay of natural and anthropogenic factors impacting local climate and humidity levels (Slangen et al., 2023; Environmental Research Center, 2020; Williams, 2018).

Fig 2c, which depicts the annual average H in Onitsha and Nnewi, reveals a declining trend over the years, with a slightly more pronounced reduction in Onitsha. This consistent decrease in humidity carries significant environmental, agricultural, and health implications. Lower H means reduced atmospheric moisture, contributing to more frequent and intense droughts. With less water vapor available for cloud formation and precipitation, dry conditions are exacerbated. In agriculture, reduced humidity negatively impacts crop yields, particularly for moisture-dependent crops, as increased evapotranspiration leads to water stress. The decrease in humidity also affects human health, causing dry air-related issues such as respiratory problems, dry skin, and eye irritation, while promoting the longevity of airborne viruses like influenza. Ecosystems are similarly impacted, with drought-intolerant plant species declining, disrupting food and habitat availability for dependent animals. Additionally, dry conditions increase vegetation dryness, heightening wildfire risks. These humidity trends also influence weather patterns, leading to less cloud cover and altered precipitation, as documented in studies by Brown, (2019), Intergovernmental Panel on Climate Change [IPCC], (2022), Jones & Smith, (2020), United Nations Environment Programme, (2017).

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

Date	T ºC	DP ºC	H %	PP mm	WS km/h	CC %	SR W/m²	UVI
Nnewi								
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

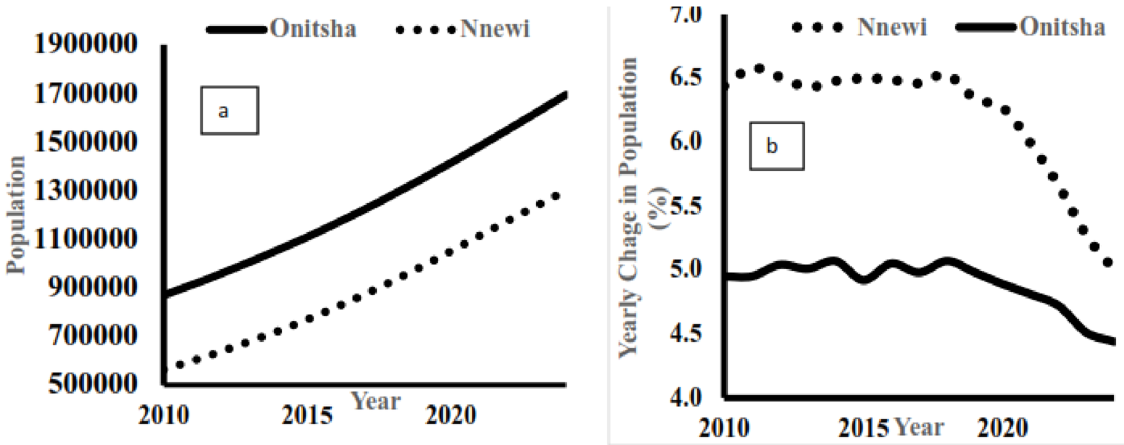

Fig. 1. Plot of the Yearly Average Values (a) and Percentage Change (b) in the Yearly Average Values of the Population of Onitsha and Nnewi

Fig. 2d illustrates the yearly average PP in Onitsha and Nnewi. From 2010 to 2014, both cities experienced similar precipitation levels, but from 2015 onward, Nnewi recorded more rainfall than Onitsha, despite following a similar trend. The lowest PP occurred in 2014, potentially linked to the solar maximum of Solar Cycle 24 in April 2014 (NASA Solar Cycle 25 Prediction Panel, n.d.; NOAA Solar Cycle Progression, n.d.). The observed variability in precipitation patterns in Southeast Nigeria during 2010–2023 reflects broader climatic changes. Between 2010 and 2013, rainfall was stable but punctuated by significant increases, including above-average rainfall in 2012, which caused widespread flooding as observed by Ekwueme & Agunwamba, (2021), Nwafor & Eze, (2019). From 2014 to 2016, precipitation levels remained variable, with a mix of average to above-average rainfall. The period from 2017 to 2019 saw continued variability, consistent with climate change-induced extreme weather patterns. The 2020–2023 period showed a mix of trends, indicating a pattern of variability with potential shifts toward more extreme rainfall events. This increasing unpredictability in rainfall poses challenges for agriculture, water resource management, and disaster preparedness in the region, as noted by Ekwueme & Agunwamba, (2021), Nwafor & Eze, (2019).

Fig 2e shows the yearly average WS in Onitsha and Nnewi from 2010 to 2014. During this period, WSs were relatively low, ranging from ~10–15 km/h. A sharp rise to about 30 km/h occurred in 2018, followed by a reduction to 15–20 km/h between 2020 and 2024. Fig 2f depicts the annual average CC in Onitsha and Nnewi. While the trends were similar throughout the study period, Nnewi consistently had higher cloud cover than Onitsha between 2016 and 2022. Akinsanola and Ogunjobi (2017) investigated changes in these climatic variables over time and their implications for agriculture and water resources in Nigeria. Their findings highlighted the role of CC in influencing rainfall and temperature patterns. They observed a decreasing trend in CC, which affects solar radiation, temperature, and evaporation rates, concluding that Nigeria is undergoing significant changes in climatic variables that are expected to persist as global climate patterns continue to evolve.

Figs 3(a) and 3(b) present the yearly average values of SR and the UVI for Onitsha and Nnewi. Both parameters exhibit notable increases over the years, driven by atmospheric changes and climatic factors. These trends carry significant implications for energy production, climate science, and public health. Between 2010 and 2024, the SR potential in Onitsha and Nnewi has gradually risen, largely due to reductions in atmospheric aerosols and shifts in CC patterns. This increase aligns with the phenomena of global dimming and brightening, where reduced particulate pollution results in clearer skies and greater SR reaching the Earth's surface (International Energy Agency [IEA], 2021; McKenzie et al., 2011).

The UVI, which measures the intensity of UV radiation at the Earth's surface, has also shown an upward trend in both cities. This rise can be attributed to factors such as ozone layer depletion, climate change, and variations in atmospheric composition and CC (Wild, 2012). The increasing levels of SR and UV exposure contribute to global temperature changes, influencing climate patterns and ecosystems. Higher UVI values heighten the risks of health issues such as skin cancer, and other UV-related conditions, emphasizing the importance of sun protection and public awareness (World Health Organization [WHO], 2022).

3.2 Regression Analysis

3.2.1 Population Vs change in population

Fig 4 illustrates the percentage change in population per year relative to the population size for Onitsha and Nnewi. The dotted line represents the linear fit for Nnewi, while the straight line represents the linear fit for Onitsha (with y denoting the percentage change in population per year and x representing the population). The plot reveals a declining trend in the percentage change of population per year for both cities, with Nnewi showing a more decreasing trend in the rate of change compared to Onitsha. The linear fit suggests that the slope for Nnewi is steeper than that of Onitsha, indicating a faster decline in the population growth rate at Nnewi. Despite this, both cities share a correlation coefficient of r = -0.8 between population and percentage change in population, demonstrating a strong relationship between population size and the percentage change in population per year. The higher and faster change in population growth at Nnewi could be attributed to urban migration, with more people moving to the city over time.

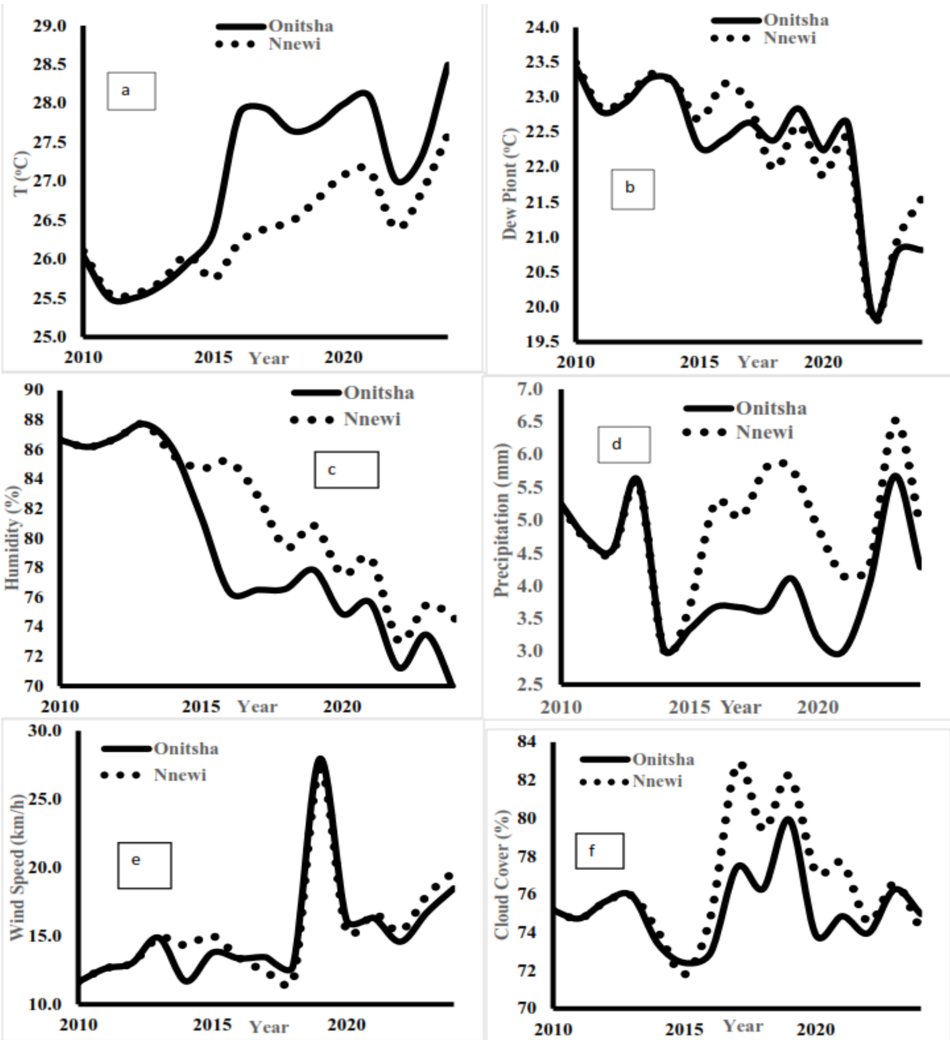

Fig. 2. Plot of the Yearly Average Values of the T (Temperature 2a), Dew Point (2b), Humidity (2c), Precipitation (2d), Wind Speed (2e), and Cloud Cover (2f) For Onitsha and Nnewi

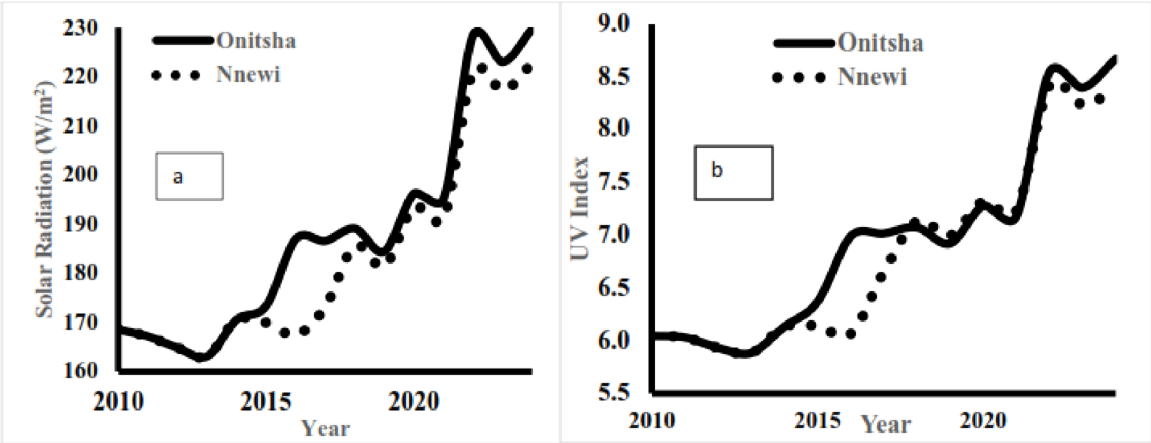

Fig. 3. Plot of the Yearly Average Values of the Solar Radiation (3a) and UV Index (3b), For Onitsha and Nnewi

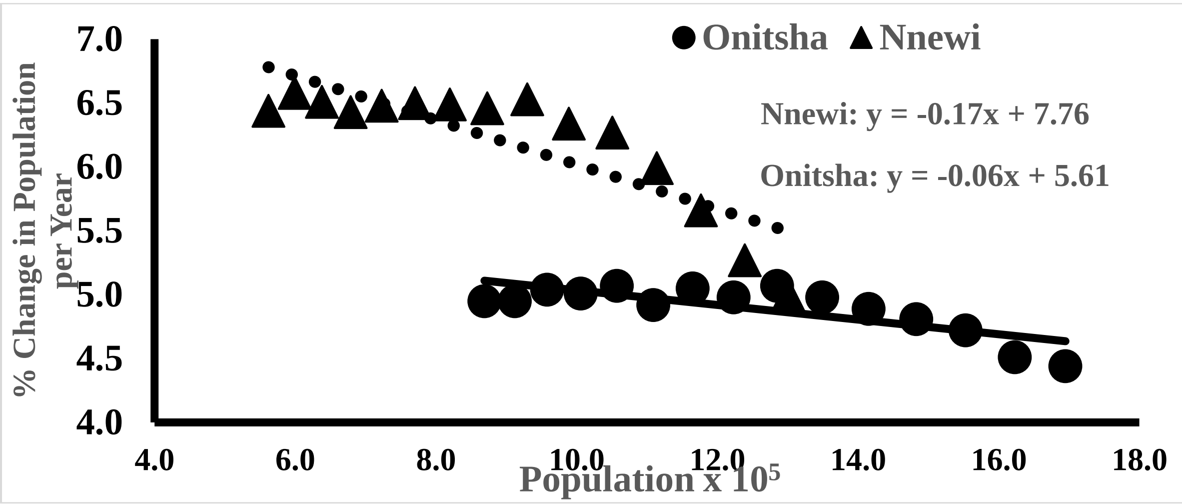

Fig. 4. Plot of the Annual Percentage Change in Population per Year against the Population at Onitsha and Nnewi

A negative slope in this context indicates that as the population increases, the percentage change in the population per year decreases. This suggests that while the absolute number of people continues to grow, the rate of population growth is slowing down. Several factors contribute to this trend. First, population dynamics, such as a shift from rapid to slower growth, can occur as the population base becomes larger, with limited resources, economic constraints, and demographic shifts (like aging populations) playing a role. Additionally, factors like economic development, which typically leads to decreased birth rates and higher living standards, can slow down population growth. Social factors, such as improved access to education and family planning, also contribute to lower growth rates. This pattern of slowing population growth has implications for urban planning, resource allocation, and economic development strategies, influencing policy decisions (United Nations Department of Economic and Social Affairs, 2022; Intergovernmental Panel on Climate Change [IPCC], 2021).

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 T, WS, SR, and UVI, but a negative relation between the population and DP and H. 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 meteorological parameters to that indicated between population and meteorological parameters.

3.2.2 Temperature and population

Using the increasing average T as a proxy for rising GHG concentrations is a valid approach (Intergovernmental Panel on Climate Change [IPCC], 2021), as GHGs are well-established contributors to global warming and local T changes. In this section, we examine the effects of population growth, T, and other weather parameters. GHGs trap heat in the atmosphere, leading to increased global and regional Ts. As their concentration grows, Ts rise correspondingly. According to (Intergovernmental Panel on Climate Change [IPCC], 2021), analyzing the trend of increasing average Ts in a specific town can reveal potential correlations with rising GHG levels, particularly if the data demonstrates a consistent upward trajectory over time.

Fig 5 shows the relationship between T and population in Onitsha and Nnewi, revealing a steady rise in T with population growth. The slope of the T increase is steeper in Onitsha, likely due to heightened GHG emissions from human activities associated with larger populations. Key contributors include transportation (vehicles burning gasoline and diesel (International Energy Agency [IEA], 2021)), industrial processes (fossil fuel combustion and chemical production (International Energy Agency [IEA], 2021)), and agricultural practices (livestock emitting CH_4 and synthetic fertilizers releasing NO_x (Food and Agriculture Organization, 2023)). Additional factors include deforestation, urbanization, and soil degradation, which reduce carbon sequestration and release CO_2 (United Nations Environment Programme, 2017; United Nations Department of Economic and Social Affairs, 2022). Organic waste decomposition in landfills and wastewater treatment also emit methane, while hydrofluorocarbons (HFCs) from refrigerants and industrial aerosols contribute significantly to GHG emissions (United Nations Environment Programme, 2017; United Nations Department of Economic and Social Affairs, 2022). These activities increase with population – the demand for goods, services, energy needs, waste disposals/management, and control of flood water and erosions (which is endemic in Anambra state (Okeke & Nwankwo, 2022; Okoro & Okoro, 2012) and their effect are more prevalent in Onitsha than Nnewi as indicated by the steeper slope in Fig 5.

3.2.3 Dewpoint, humidity, precipitation, and population

Figs 6, 7, and 8 illustrate the relationships between DP, H, precipitation, and population in Onitsha and Nnewi. Correlation coefficients in Table 3 indicate that population growth, representing increased GHG emissions from human activities, strongly impacts dewpoint ($r \approx -8.8$) and humidity ($r \approx -0.9$) negatively in both locations. In contrast, its effect on precipitation is minimal ($r \approx -0.2$ for Onitsha and $r \approx 0.2$ for Nnewi). The slopes of the linear fit in Figs 7 and 8 suggest that population growth similarly influences DP and H in both towns. These effects are primarily driven by urbanization, deforestation, and broader anthropogenic climate changes, which disrupt local atmospheric conditions and moisture dynamics. Human

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

Parameters	r Onitsha	r Nnewi	Parameters	r Onitsha	r 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

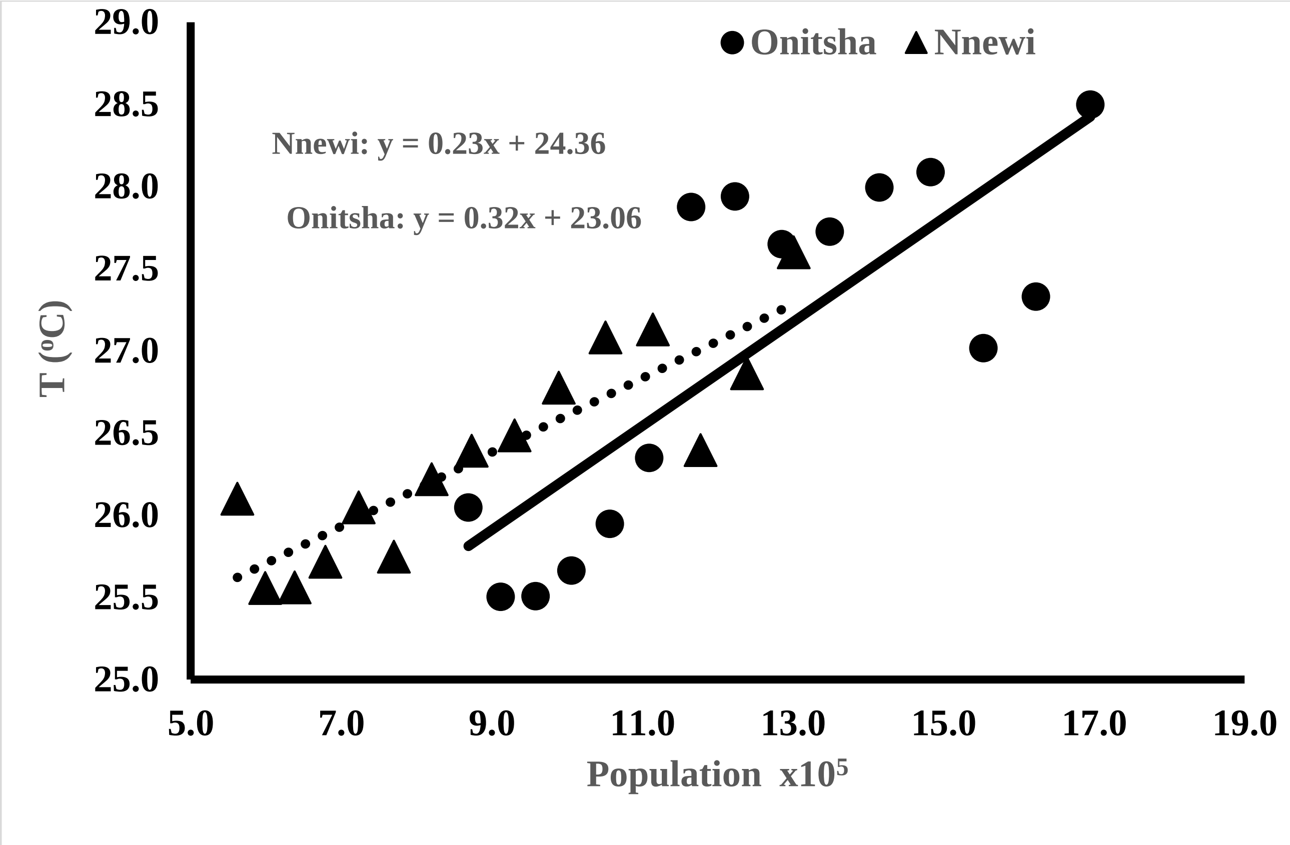

Fig. 5. Plot of the Annual Average Values of Temperature against the Population at Onitsha and Nnewi

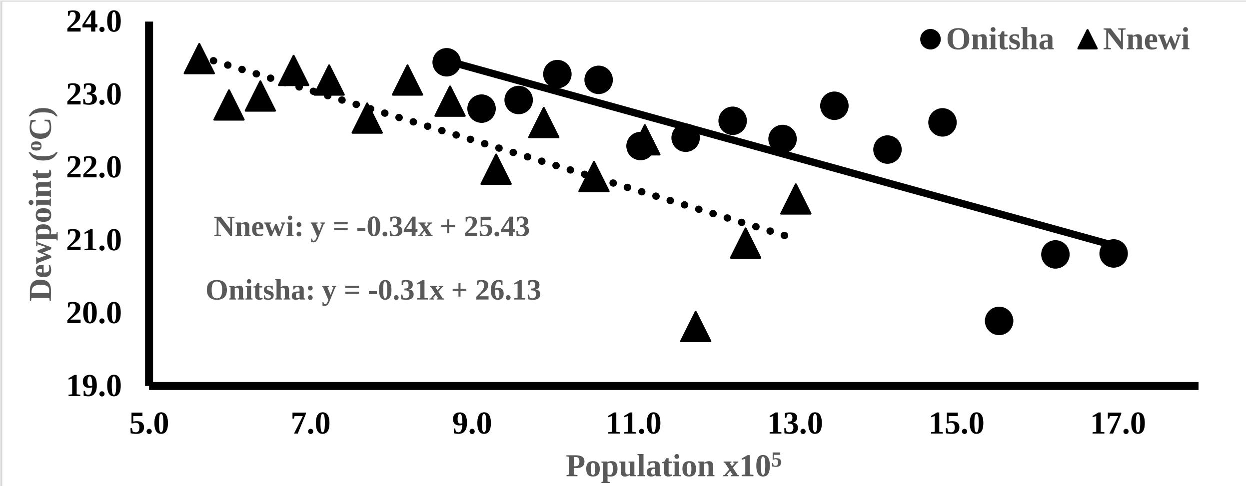

Fig. 6. Plot of the Annual Average Values of Dewpoint against the Population at Onitsha and Nnewi

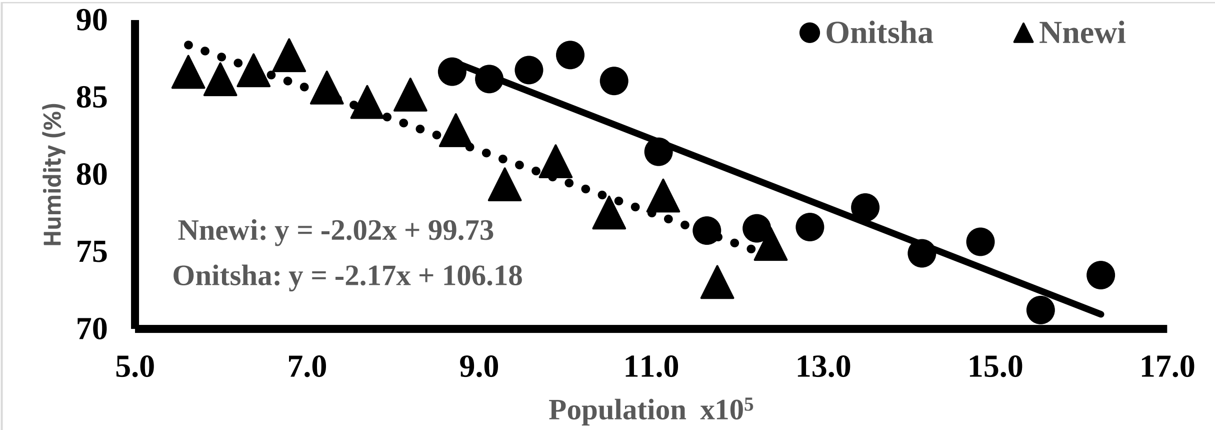

Fig. 7. Plot of the Annual Average Values of Humidity against the Population at Onitsha and Nnewi

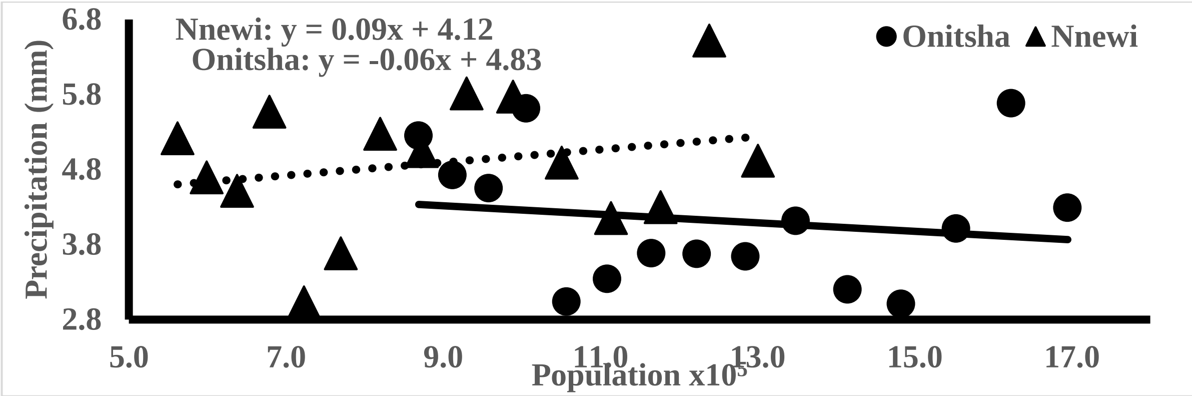

Fig. 8. Plot of the Annual Average Values of Amount of Precipitation against the Population at Onitsha and Nnewi

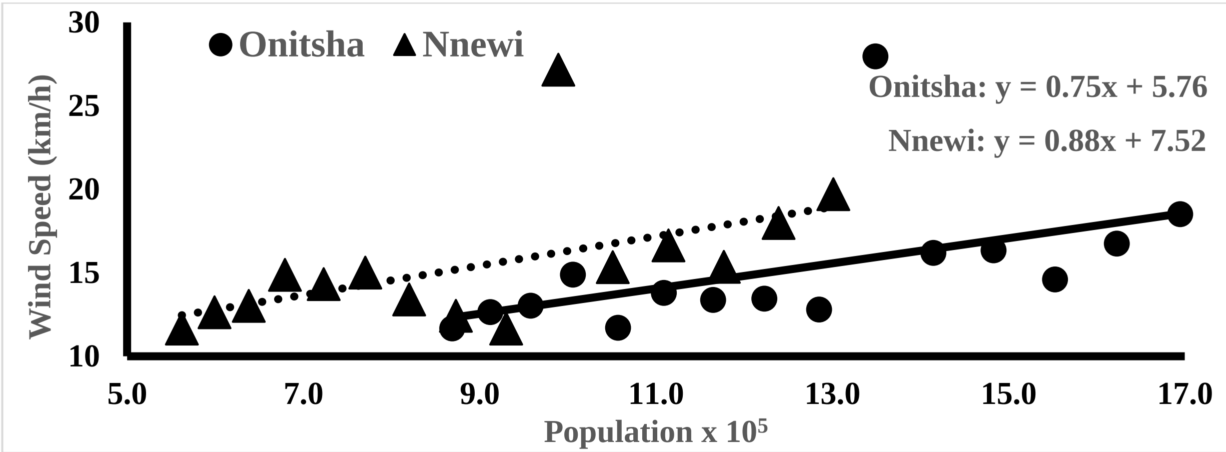

Fig. 9. Plot of the Annual Average Values of Amount of Wind Speed against the Population at Onitsha and Nnewi

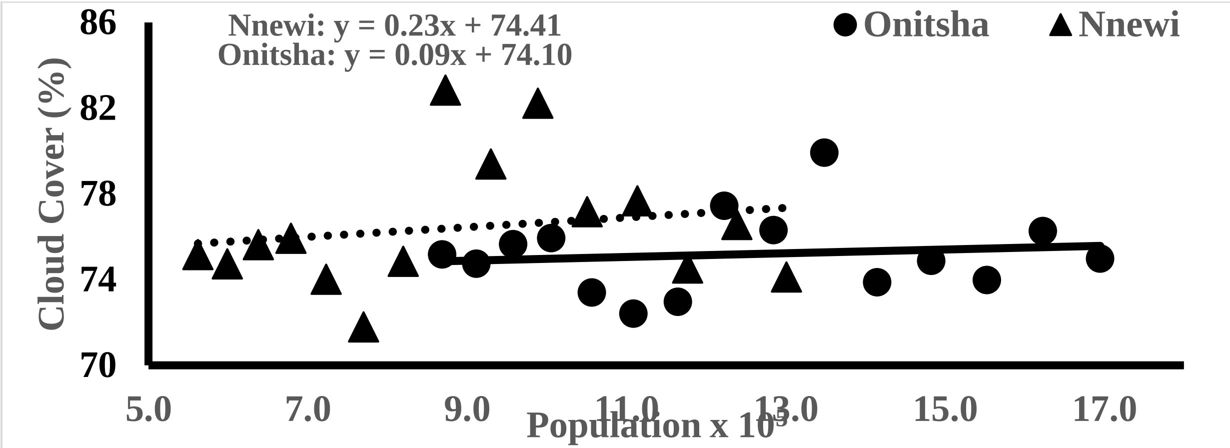

Fig. 10. Plot of the Annual Average Values of Cloud Cover against the Population at Onitsha and Nnewi

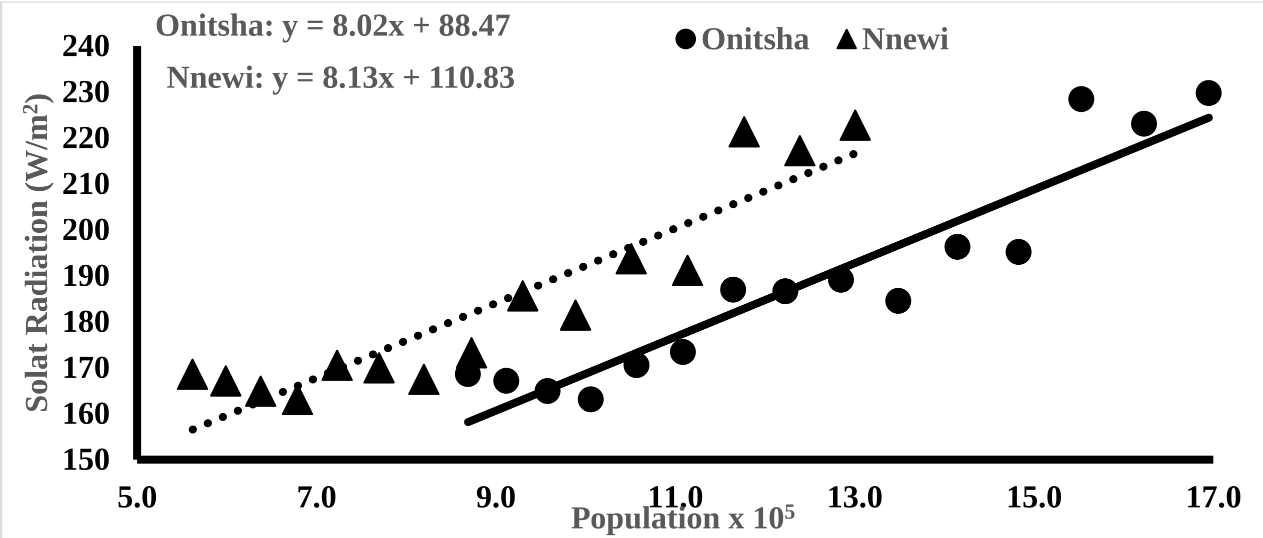

Fig. 11. Plot of the Annual Average Values of the Solar Radiation against the Population at Onitsha and Nnewi

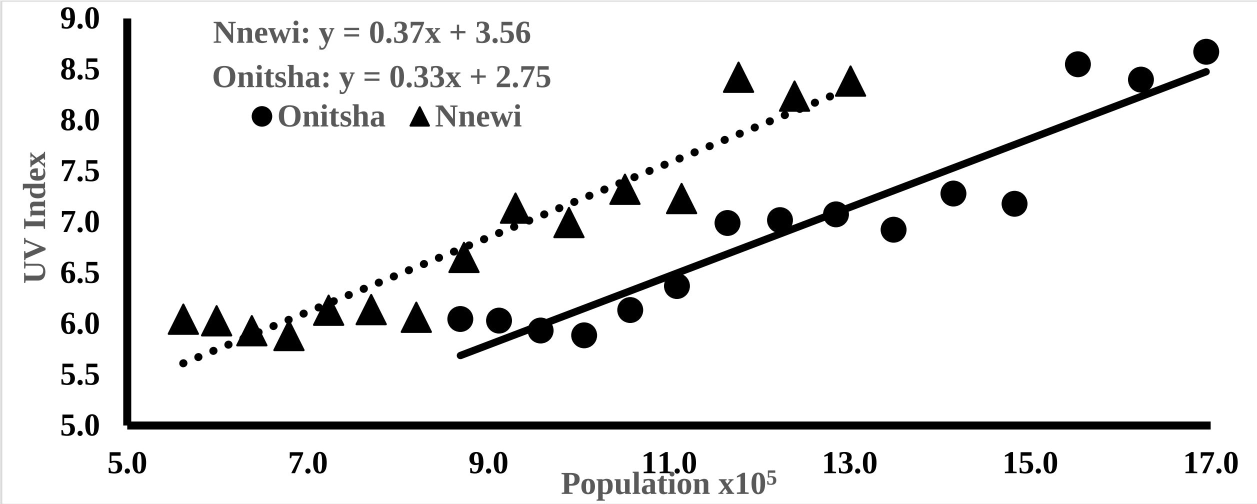

Fig. 12. Plot of the Annual Average Values of the UV Index against the Population at Onitsha and Nnewi

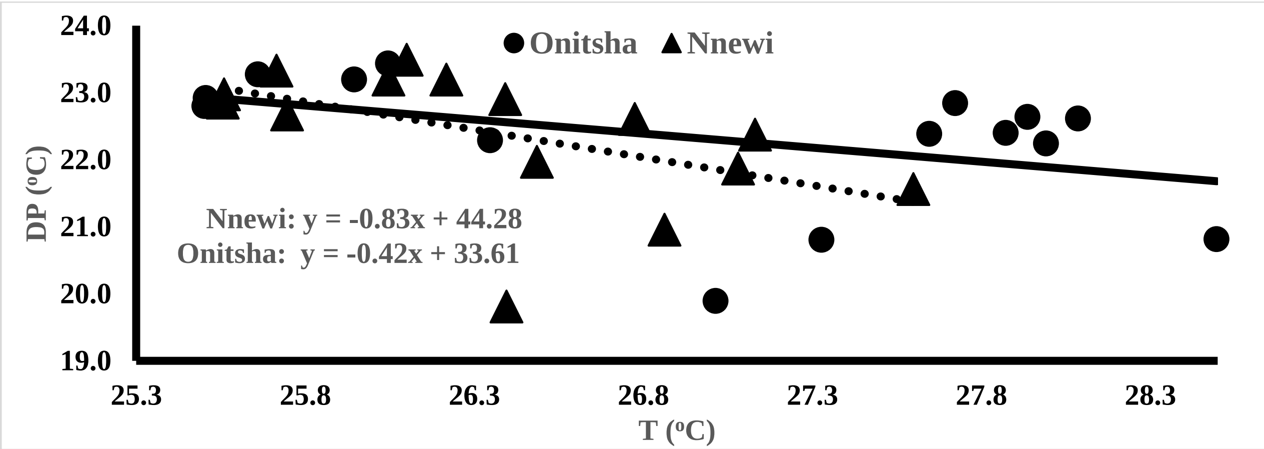

Fig. 13. Plot of the Annual Average Values of the Dewpoint against the Temperature at Onitsha and Nnewi

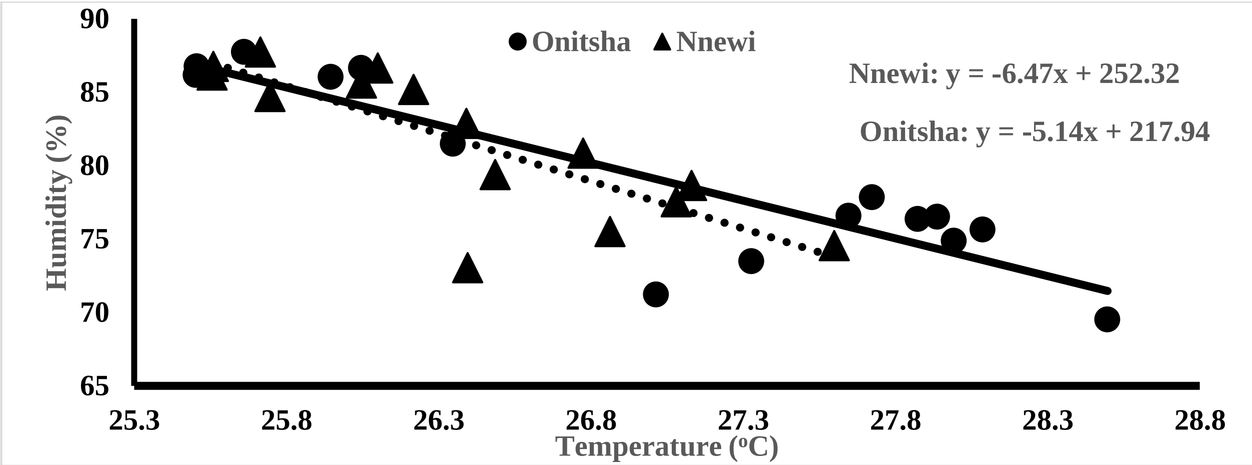

Fig. 14. Plot of the Annual Average Values of the Humidity against the Temperature at Onitsha and Nnewi

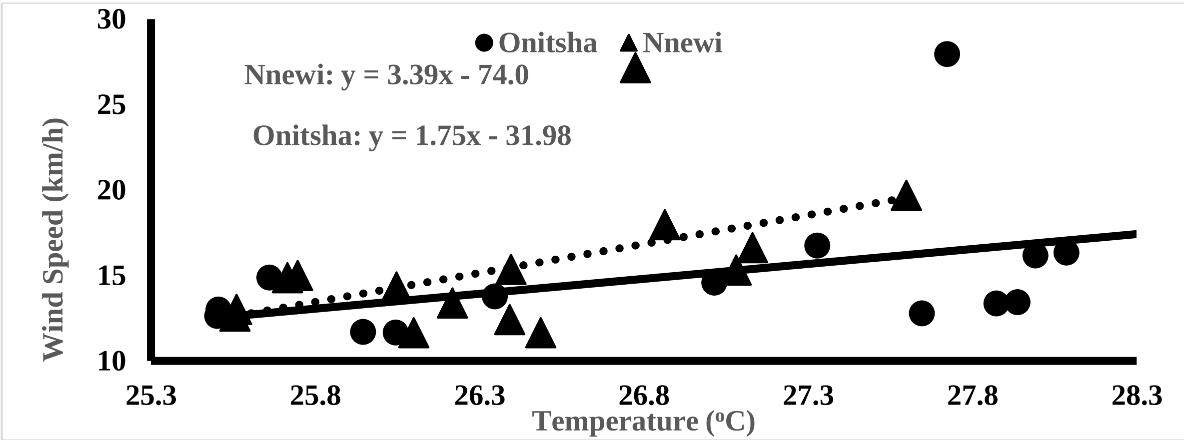

Fig. 15. Plot of the Annual Average Values of the Wind Speed against the Temperature at Onitsha and Nnewi

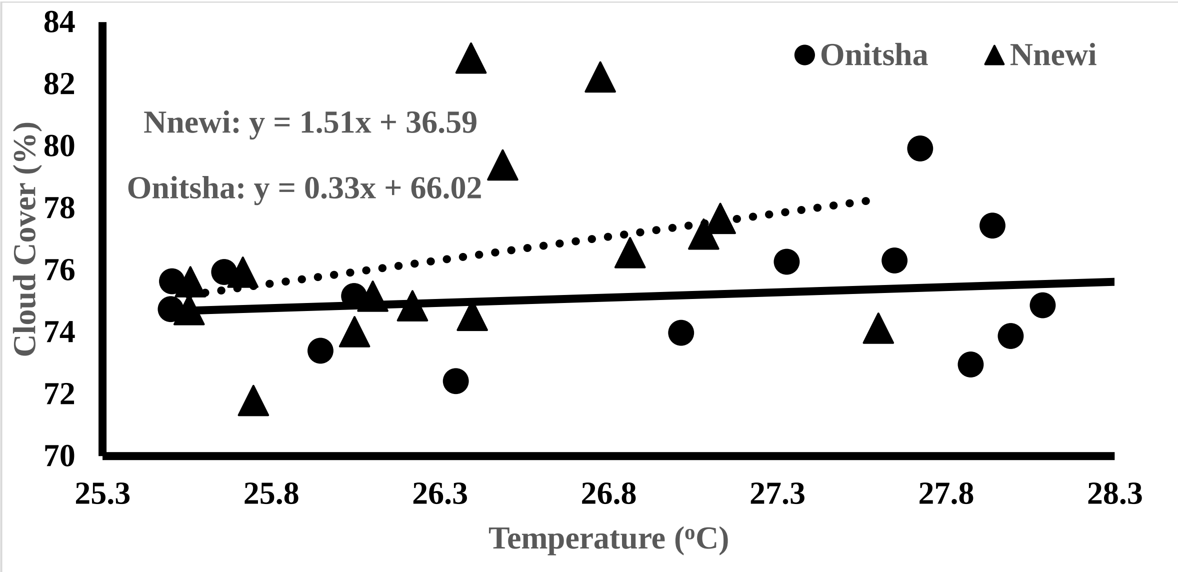

Fig. 16. Plot of the Annual Average Values of the Cloud Cover Level against the Temperature at Onitsha and Nnewi

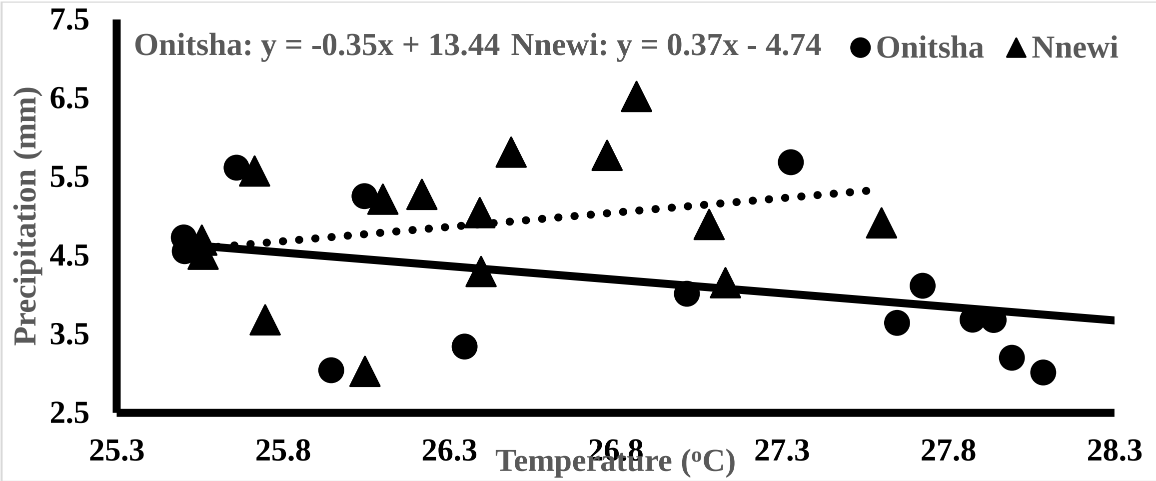

Fig. 17. Plot of the Annual Average Values of the Amount of Precipitation against the Temperature at Onitsha and Nnewi

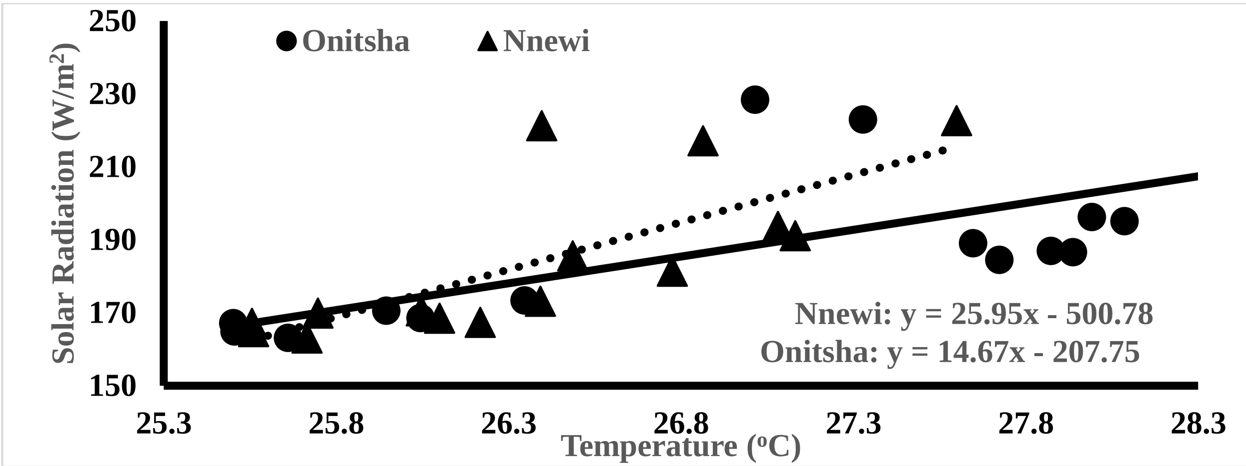

Fig. 18. Plot of the Annual Average Values of the Solar Radiation against the Temperature at Onitsha and Nnewi

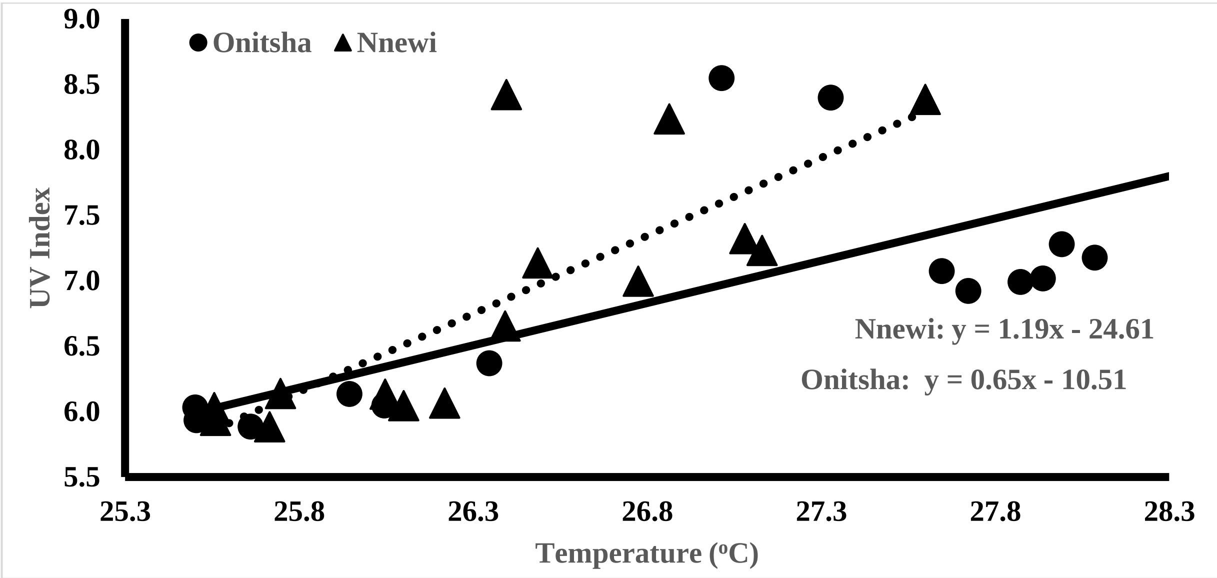

Fig. 19. Plot of the Annual Average Values of the UV index against the Temperature at Onitsha and Nnewi

activities in densely populated areas significantly alter the regional climate through land-use changes, reduced vegetation, and increased GHG emissions, impacting atmospheric moisture behavior (Oke, 1982; United Nations Environment Programme, 2017; Ogungbenro & Morakinyo, 2014; Kharin et al., 2007; Foley et al., 2005).

Our results indicated that human activities and the production of GHGs impact DP 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

Figs. 9-10 are the scatter plots of the WS, CC, and population. The correlation coefficients in Table 3 indicate that population affects WS ($r \sim 0.5$), and CC ($r \leq 0.2$). Fig. 9 plots WS against the population at Onitsha and Nnewi. The simple linear regression shows that human activities influence on WS is similar in both towns and is a direct relation, as indicated by the slope. Human activities, as reflected in population growth, urbanization, and industrialization, contribute to increased GHG emissions and significantly impact WS through mechanisms such as the urban heat island effect, land-use changes, and pollution. In large cities, tall buildings, and dense infrastructure create rough surfaces that increase surface friction, disrupting natural wind patterns and often reducing WSs at ground level. This phenomenon is particularly evident in dense urban centers, where elevated Ts generate thermal gradients that may induce localized wind systems, such as urban breezes, but simultaneously disrupt broader wind flows (Ogungbenro & Morakinyo, 2014). Additionally, tall structures modify natural wind flow by channeling winds in specific directions, resulting in microclimates where winds are funneled between buildings, creating strong localized gusts while weakening wind strength in other areas. Urban heat islands further alter wind direction, as T differences between urban and rural areas drive localized wind circulations that affect broader atmospheric patterns around cities (Frey & Kuo, 2007).

Fig. 10 illustrates the relationship between CC and the population in Onitsha and Nnewi. Human activities such as transportation, industrial emissions, and agriculture release aerosols that act as cloud condensation nuclei, increasing cloud formation, particularly in urban areas. This is more evident in densely populated cities, where low-level clouds trap heat, influencing local weather patterns. Urban heat enhances convection, lifting moist air and promoting cloud development (Shirley & Cindy, 2020).

Urbanization affects wind dynamics by altering surface friction and thermal gradients, leading to changes in WS and direction. Buildings and localized T variations further modify wind circulations. Additionally, the urban heat island effect and climate change influence localized and global pressure patterns. These findings align with our observations, especially regarding the impact of human activities on WS, direction, and cloud formation.

3.2.5 Solar radiation, UV index, and population

Figs. 11–12 present the annual average values of SR, and the UVI to the population of Onitsha and Nnewi. The high correlation coefficient (r ~ 0.9) from Table 3 indicates that human activities and GHG emissions, as represented by population size, significantly influence these parameters in both towns. The similar slopes of the linear fits suggest that the impact of human activities on SR and UVI is comparable in both locations.

Literature, including reports by Environmental Research Center, (2020), World Health Organization [WHO], (2022), United States Environmental Protection Agency [USEPA], (2024), supports these findings. Population growth, urbanization, and industrialization increase air pollution through aerosols, particulate matter, and GHGs. These pollutants scatter, absorb, and reflect solar radiation, reducing the amount of direct solar radiation and UV exposure in urban areas. Urban haze, caused by high vehicular and industrial emissions, significantly reduces solar irradiance, sometimes by 20-30%. Additionally, air pollution and land-use changes linked to population growth diminish solar radiation energy, impacting the potential for solar energy collection in densely populated areas.

Population growth drives increased land demand, leading to significant land-use changes. Agricultural land and forests are often converted into urban or industrial areas, reducing the natural albedo of the land, which affects the balance between solar radiation absorption and reflection. Urban sprawl also constrains the availability of land for large-scale solar energy systems, hindering the deployment of solar farms that require extensive space (World Health Organization [WHO], 2022; United States Environmental Protection Agency [USEPA], 2024; Smithsonian Environmental Research Center, 2020). In conclusion, the rising population in cities like Onitsha and Nnewi amplifies human activities and GHG emissions, adversely affecting meteorological parameters. These changes have detrimental impacts on the climate and the well-being of local populations. These findings align with conclusions from existing literature.

3.2.6 Temperature effect on dewpoint, humidity, precipitation, wind speed, cloud cover, solar radiation, and UV index

Rising Ts are closely linked to increasing levels of GHGs in the atmosphere, a relationship well-documented in climate science. GHGs like CO_2, CH_4, and N_2O trap heat through the greenhouse effect by absorbing and re-radiating infrared radiation emitted by the Earth's surface, reducing heat loss to space. This process contributes to global warming. Human activities such as fossil fuel combustion, deforestation, and industrial processes have significantly increased the concentration of these gases, driving temperature rises (Intergovernmental Panel on Climate Change [IPCC], 2014).

Data shows CO_2 levels have increased from approximately 280 ppm in the pre-industrial era to over 410 ppm recently, correlating with a global T rise of about 1.1°C above pre-industrial levels (United States Environmental Protection Agency [USEPA], 2024; Intergovernmental Panel on Climate Change [IPCC], 2014). CH_4, with over 25 times the global warming potential of CO_2 over 100 years, has also seen sharp concentration increases due to agriculture, livestock, and fossil fuel extraction (United States Environmental Protection Agency [USEPA], 2024). These findings emphasize the utility of T measurements in studying the impact of GHGs on a city's weather and meteorological parameters.

Table 4. Correlation coefficient between temperature and other weather/metrological parameters

	Onitsha	Nnewi
T/DP	-0.44	-0.51
T/H	-0.89	-0.81
T/PP	-0.41	0.25
T/WS	0.46	0.53
T/CC	0.19	0.31
T/SR	0.69	0.76
T/UVI	0.72	0.80

Table 4 presents the correlation between local T and various meteorological parameters in Nnewi and Onitsha. A notable finding is the negative correlation between T and DP, which is moderate for Onitsha (r ~ -0.4) and stronger for Nnewi (r ~ -0.5). The DP, representing the T at which water vapor condenses, decreases as the air's moisture content reduces. Factors such as dry air masses, cold fronts, or strong winds from desert regions contribute to this reduction (National Oceanic and Atmospheric Administration [NOAA], 2021; World Health Organization [WHO], 2022; Global Forest Watch, 2023; National Weather Service [NWS], 2014). Fig. 13 shows the relationship between DP and T, with a steeper rate of decline in Nnewi (slope: -0.83) compared to Onitsha (slope: -0.42). Onitsha's proximity to the River Niger likely moderates the decline, as the river contributes to local humidity levels. While lower dewpoints may bring clearer skies, the adverse effects on human health, agriculture, and wildfire risks outweigh the benefits, especially in areas with persistently low moisture levels Climate change, driven by increased GHG emissions, influences DP by raising Ts and evaporation rates, potentially increasing absolute humidity. However, in areas with dry air masses or reduced moisture, DP declines, leading to environmental and health impacts. Lower DPs are associated with dry air, which can increase wildfire risks, respiratory issues, dry skin, and dehydration. Dry conditions also negatively affect agriculture by reducing soil moisture, limiting crop growth, and increasing irrigation needs.

Fig. 14 illustrates the annual average values of H plotted against T for Onitsha and Nnewi, showing a strong negative correlation (r ~ -0.8), as confirmed in Table 4, with increasing Ts resulting in declining T levels. The rate of this decline is steeper in Nnewi (slope: -6.47) compared to Onitsha (slope: -5.14), likely reflecting regional variations in environmental factors. The combination of rising Ts and falling H levels triggers a cascade of adverse environmental and health effects, as documented by the (National Oceanic and Atmospheric Administration [NOAA], 2021; World Health Organization [WHO], 2022).

Low H and high Ts significantly impact the heat index, which combines air temperature and humidity to gauge how hot it feels. While low H can initially enhance the body's ability to cool itself through sweating and evaporation, sustained high Ts with insufficient H can overwhelm these cooling mechanisms, leading to heat stress and heat exhaustion, particularly in areas experiencing extreme heat. Furthermore, the drop in humidity, coupled with rising temperatures, accelerates evaporation from soil and water bodies, intensifying water stress on crops and plants. This results in poor agricultural yields exacerbates drought conditions, and increases reliance on irrigation systems, particularly in rain-dependent regions (World Health Organization [WHO], 2022).

The interplay of low H and high Ts also drives desertification, as ecosystems struggle to sustain vegetation under these harsh conditions. Vegetation becomes increasingly dry and flammable, reducing its moisture content and heightening the risk of wildfires. These conditions create a dangerous feedback loop, where declining H and rising Ts perpetuate environmental degradation, threaten human health, and compromise agricultural sustainability.

Fig. 15 presents the plot of annual average values of WS against T for Onitsha and Nnewi, showing that rising Ts increase WS in both towns. The slope of the linear fit is steeper in Nnewi (3.39, r ~ 0.5) compared to Onitsha (1.75, r ~ 0.5), indicating that T has a more significant impact on wind speed in Nnewi. Increasing Ts affect WS and direction through changes in atmospheric pressure patterns, heat distribution, and large-scale climate processes, as noted by Rogelj et al., (2018), Vautard et al., (2010), Vecchi & Soden, (2007). These processes influence wind speed and direction by altering the pressure gradients and thermal differences between regions, which drive wind circulation patterns.

Wind is driven by atmospheric pressure differences, typically caused by T contrasts between regions. The rising temperatures can lead to localized increases in WS. For instance, urban heat islands, where cities are warmer than surrounding rural areas, create low-pressure zones that pull in cooler air, generating stronger winds. Similarly, the T contrast between land and sea in coastal regions can intensify sea breezes (Vecchi & Soden, 2007; Jennifer & Stephen, 2012). Temperature changes can also impact local wind patterns, such as mountain-valley and downhill winds, particularly in mountainous regions where temperature differences between valleys and higher elevations are crucial (Rogelj et al., 2018; Vautard et al., 2010).

In conclusion, rising global Ts have complex effects on WS and direction. While some areas may experience weakened winds due to reduced thermal gradients, others may witness increased localized WSs or shifts in wind direction due to changing pressure patterns, jet stream behavior, and storm intensities. Based on these findings, the results suggest that the increasing temperatures in Nnewi and Onitsha are causing adverse effects on WS and direction, creating gusts that could impact the local environment, human health, and economies of the cities.

Fig. 16 presents the plot of annual average values of CC against T for Onitsha and Nnewi. Rising Ts significantly impact CC, typically leading to a decrease in CC, especially during the day. This reduction in CC allows more SR to reach the Earth's surface, intensifying warming, and creating a positive feedback loop where less CC results in more warming, which further suppresses cloud formation (Qiuhong & Guoyong, 2013; Mendoza et al., 2021). Clouds have a dual effect on climate: they reflect sunlight during the day, cooling the surface, but at night, they trap heat, contributing to the greenhouse effect. As Ts rise, studies show a decrease in daytime CC, exacerbating warming, while nighttime cloud cover persists, enhancing heat retention. This leads to more erratic and variable cloud patterns, which affect both local weather and global climate trends.

However, the results observed in Nnewi and Onitsha differ from those found by Qiuhong & Guoyong (2013) and Mendoza et al. (2021), who studied CC variation with T on a global scale, focusing on daytime and nighttime changes. In contrast, our analysis uses daily average values, leading to different patterns and conclusions regarding CC and T interactions in the two cities. Fig. 17 shows the relationship between precipitation and T in Onitsha and Nnewi. The plot indicates that rising Ts negatively affect precipitation in Onitsha (r ~ 0.4, slope ~ -0.4), while in Nnewi, it has a positive effect (r ~ 0.5, slope ~ 0.4).

Rising global Ts significantly impact precipitation patterns by increasing the atmosphere's capacity to hold moisture, as described by the Clausius-Clapeyron equation, which states that atmospheric water vapor increases by approximately 7% for every 1°C rise in T. Higher Ts accelerate the hydrological cycle, leading to more evaporation and consequently more precipitation, often resulting in heavier rainfall events. This has been observed in many regions, with increased frequency and intensity of heavy precipitation events (Trenberth, 2011). Models suggest that extreme precipitation events are expected to become more frequent in the 21st century (Kharin et al., 2007), posing risks for flooding, soil erosion, and disruptions to agriculture and infrastructure (Kharin et al., 2007).

Our findings in Nnewi align with this global trend, where increasing T correlates with higher precipitation. However, the results for Onitsha diverge, showing that as T rises, the amount of precipitation seems to decrease. This contrasts with studies such as (Alexander et al., 2006), who observed global changes in precipitation with rising Ts, but acknowledged regional variations, which could explain the differing trends between the two cities.

Figs. 18 and 19 show the annual average values of SR and the UVI against T in Onitsha and Nnewi. The plots reveal that rising Ts lead to an increase in both SR and the UVI, with a higher rate of increase observed in Nnewi compared to Onitsha, as indicated by the steeper slopes of the linear fits. The correlation between T and SR, as well as the UVI, is strong and positive, with r ~ 0.7 for Onitsha and r ~ 0.8 for Nnewi.

Rising Ts significantly affect SR and UV exposure, which are critical for understanding climate change and public health risks. According to reports by Mendoza et al., (2021), Chodakowska et al., (2024), Umar & Tasduq, (2022), Yuan et al., (2021), increased Ts alter CC and aerosol concentrations, leading to fluctuations in SR. This has been observed in periods of global dimming (1960s to 1980s) followed by brightening, as reduced pollution and clearer skies allowed more solar energy to reach the Earth's surface, influencing global warming feedback mechanisms.

The rise in global temperatures also interacts with ozone layer depletion, which affects the UV index. Warmer Ts and GHG emissions slow down the ozone layer's recovery, resulting in higher levels of UV radiation reaching the Earth's surface. This increases the risk of UV-related health issues, such as skin cancer, particularly in high-risk regions. Moreover, higher UV-B exposure disrupts ecosystems, impacting plant growth and marine life. Thus, the rising UVI due to climate and temperature changes presents significant public health and environmental concerns.

In conclusion, rising Ts are influencing solar radiation and UV exposure in both Nnewi and Onitsha, with Nnewi experiencing a greater rate of increase. This trend poses a growing public health risk, particularly concerning UV-related health issues, as noted by (Umar & Tasduq, 2022).

4. CONCLUSION

The increasing population of Onitsha and Nnewi impacts weather and meteorological parameters through multiple mechanisms, primarily driven by urbanization and industrialization. Population growth implies increased generation of GHGs in both cities, which leads to the development of urban heat islands, where cities become significantly warmer than their surrounding areas due to increased construction materials and reduced vegetation. This urbanization raises local Ts, influencing precipitation patterns, CC, and atmospheric moisture levels. Additionally, industrial activities and vehicle emissions contribute to the production of aerosols that affect Ts, precipitation, and SR by either reflecting or absorbing sunlight. These aerosols alter local climate patterns, further intensifying the effects of climate change. Moreover, higher population densities result in increased water demand and pollution, which in turn affects local humidity and alters rainfall and storm intensity. These interconnected changes have profound effects on both local and global climates, affecting ecosystems and posing significant risks to human health (Garsa et al., 2023).

In the context of this study, the results indicate that rising GHGs, associated with population growth, adversely affect weather and meteorological parameters. The study shows that the impact of these changes is more pronounced in Nnewi than in Onitsha. Specifically, population growth, symbolizing increased GHGs, has a higher influence on T, H, CC, precipitation, SR, and the UVI in Nnewi compared to Onitsha. This highlights the more significant climatic and meteorological shifts occurring in Nnewi due to its increasing population and associated rise in GHG emissions.

In conclusion, this study underscores the effects of increasing population, which correlates with a rise in GHGs, on weather and meteorological parameters. Urbanization and industrial activities raise local Ts, creating urban heat islands, while emissions and water usage influence humidity levels and dewpoint. Aerosols from human activities alter cloud formation and precipitation, leading to changes in local weather patterns. Pollution scatters and absorbs solar radiation, affecting solar energy potential, while urbanization and air pollution also modify the UVI by altering atmospheric composition. The study further connects the rise in T to changes in various meteorological parameters: warmer air increases moisture retention, raising DPs and H, intensifies the water cycle leading to more extreme weather, and reduces CC, increasing SR and UV exposure.

The adverse effects of population growth on meteorological parameters are significant. Urban heat islands elevate temperatures, worsening heatwaves, and driving higher energy demands. Increased emissions raise moisture levels, contributing to discomfort and health issues, while higher temperatures exacerbate humidity, leading to heat stress. Pollutants alter cloud properties, reducing rainfall and worsening droughts, while warmer air intensifies rainfall, leading to flooding and erosion. Air pollution decreases solar radiation by blocking sunlight, and ozone depletion further raises the UV index, increasing skin cancer risks.

Nnewi, as an emerging populous city, is showing more significant changes in weather and meteorological parameters compared to Onitsha, with these changes likely to result in serious adverse climatic and health conditions. The increased population growth, representing a rise in GHG emissions, poses greater risks to public health, agriculture, and ecosystems in Nnewi. This rapid transformation due to population growth will likely exacerbate the challenges posed by climate change, underscoring the urgent need for mitigation and adaptation strategies in urban and rural areas.

This study emphasizes the critical need for relevant government agencies and regulatory bodies to formulate and implement policies that effectively address population growth and the associated rise in GHG emissions due to increased industrial and commercial activities, indiscriminating waste dumping, and unregulated land use. It is crucial that these policies are not only designed to mitigate the impacts of population explosions but also include clear strategies for reducing GHG emissions. Additionally, strong enforcement mechanisms must be established to ensure that these guidelines are adhered to, thus minimizing the adverse effects of climate change. Governments must prioritize the development of sustainable urban planning, industrial practices, and transportation systems that align with environmental goals. Through proactive measures, such as promoting renewable energy sources, enhancing waste management systems, and encouraging sustainable agricultural practices, the detrimental effects of population growth and GHG emissions on weather patterns and public health can be effectively reduced. This holistic approach will help safeguard ecosystems, reduce health risks, and ensure a more resilient future in the face of climate challenges.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

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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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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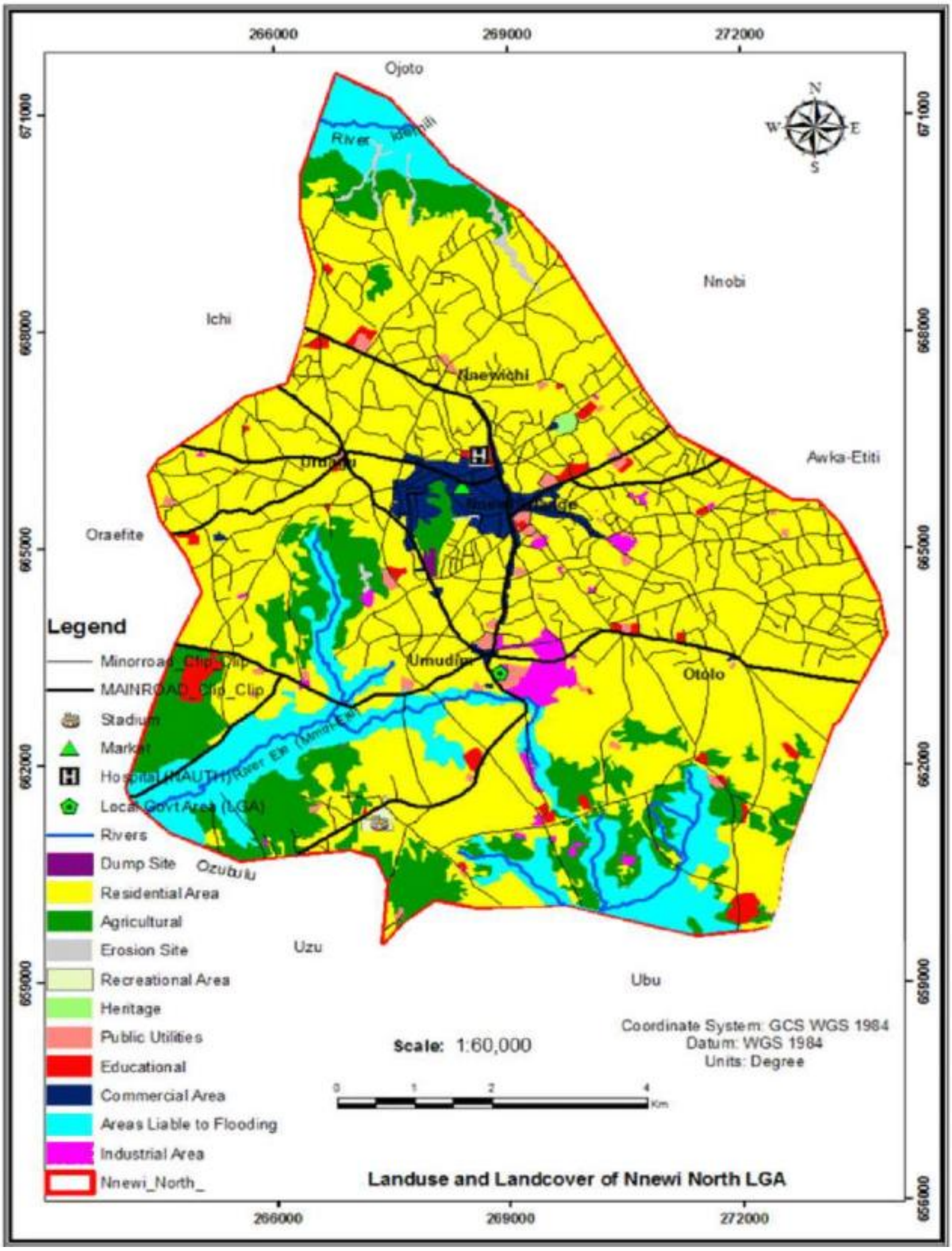
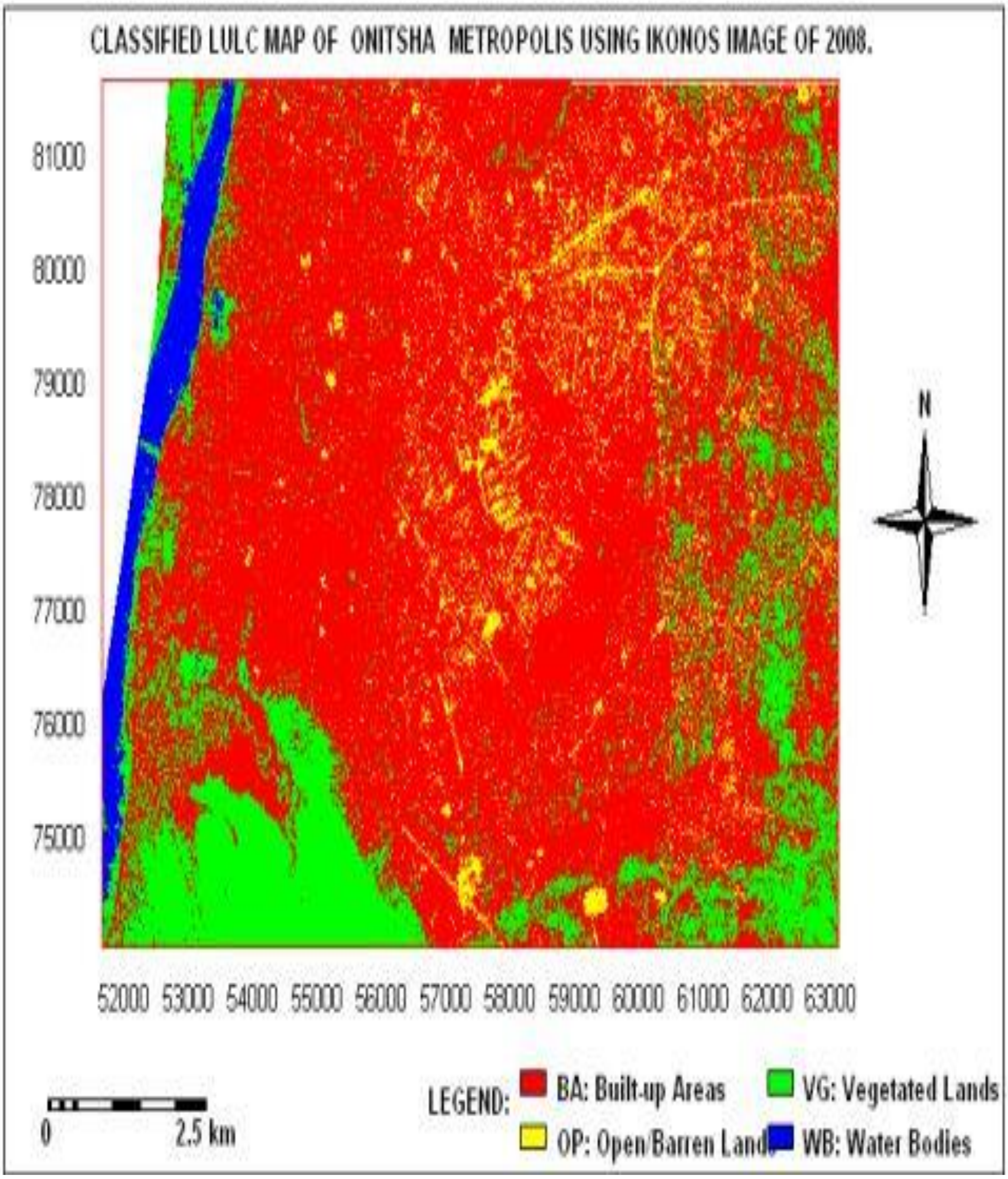
Appendix 1: Map of Nnewi from Ezeomedo, and Igbokwe 2019



Appendix 2 Map of Onitsha culled from Ezeomedo, and Igbokwe (2013)



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