__Original Research Article__

THE EFFECT OF EXTREME TEMPERATURE AND AIR POLLUTANT ON CARDIOVASCULAR DISEASE IN ONDO-STATE NIGERIA

ABSTRACT

This study investigates the relationship between extreme temperatures, air pollutants, and cardiovascular disease in Ondo State, Nigeria. Geographic Information System (GIS) satellite mapping techniques were utilized to analyze the spatial distribution of environmental parameters including methane, carbon monoxide, nitrogen dioxide, sulfur dioxide, and temperature across Ondo State. Data was obtained for the years 2020, 2021, and 2022 to allow for temporal analysis. The parameters exhibited some variations across different local government areas, indicating potential differences in exposure. 2020 data on cardiovascular disease and death cases revealed distinct spatial patterns, with northern regions showing higher disease burden compared to southern areas. The findings highlight the need for targeted public health interventions based on region-specific environmental and health profiles. Enhanced monitoring, continued research on emerging factors, and translation of evidence into policies and community initiatives is recommended to mitigate environmental risks and promote cardiovascular health across Ondo State. Overall, the study demonstrates the utility of GIS mapping for investigating complex connections between environmental factors and health outcomes to guide informed prevention strategies.

Keywords: Cardiovascular disease, Spatial analysis, GIS, Environmental risks, Air pollution

INTRODUCTION

1.1 Background of the Study

Human survival is intricately linked with the environment, and the interaction between human activities and the environment has given rise to global challenges, with climate change emerging as a significant threat. The impact of climate change is broad, affecting various aspects of life, including public health. This study focuses on Ondo State, Nigeria, aiming to investigate the relationship between extreme temperatures, air pollutants, and cardiovascular diseases.

Climate change stands out as a formidable threat to humanity's survival and sustainable development, supported by robust scientific evidence (Odey, 2012). This ecological challenge is particularly pronounced in Ondo State, Nigeria, where the impacts of climate change manifest through extreme temperatures, exerting substantial effects on air quality and, consequently, human health. Indoor Air Quality (IAQ) emerges as a critical facet of environmental health, impacting both enclosed and open spaces. Poor IAQ poses significant health risks, especially for vulnerable populations such as children and the elderly. Immediate health effects, such as fatigue, headaches, and respiratory discomfort, can arise from exposure to indoor pollutants, with prolonged exposure potentially leading to severe conditions like cardiovascular diseases (USEPA, Updated, 2022).

Further compounding environmental challenges is the global issue of air pollution, contributing to seven million premature deaths annually, with cardiovascular diseases at the forefront (WHO, 2021). The outdoor air pollution in Ondo State, attributed to pollutants like methane (CH_4), carbon monoxide (CO), carbon dioxide (CO_2), sulfur dioxide (SO_2), and nitrogen dioxide (NO_2), poses profound implications for respiratory and cardiovascular health, contributing to the broader global health challenges. Recognizing the severity of the issue, the World Health Organization (WHO) has established guidelines for six key pollutants, labeled as "classical pollutants," to regulate and mitigate adverse health outcomes (WHO, 2021).

Governments worldwide acknowledge the critical importance of air quality monitoring to safeguard human health and the environment. However, challenges, including the high cost of monitoring stations, hinder effective monitoring in developing nations like Ondo State (Forbes and Rohwer, 2008). The study seeks to address these challenges by exploring the use of low-cost sensors, providing a cost-effective alternative to enhance monitoring networks and gather more precise and affordable measurements.

Despite the significance of IAQ and pollutant emissions, a notable research gap exists specific to Akure and Ondo State. The study aims to fill this gap by investigating the prevalence of indoor pollutants, identifying local sources, assessing health impacts, and exploring mitigation strategies. Additionally, understanding the level of awareness and knowledge among the local population is crucial for designing effective interventions. The study acknowledges potential limitations, including a limited sample size and a focus on a specific geographic location (Ondo State), emphasizing the need for caution in extending conclusions beyond the study area.

1.2 Understanding the Threats to Ondo State

The complex interaction between human activity, climate change, and environmental concerns presents a substantial danger to Ondo State, Nigeria. The area faces significant consequences, mostly caused by severe temperatures that have a negative influence on air quality and human well-being. Indoor Air Quality (IAQ) is becoming a significant problem, especially because it poses possible health hazards for certain groups. Simultaneously, the presence of outdoor air pollution, caused by pollutants such as methane and nitrogen dioxide, exacerbates the impact of cardiovascular disorders in Ondo State. However serious these difficulties may be, there is a significant lack of research that is preventing a thorough understanding of the extent of indoor pollutants, their origins, health effects, and efficient methods to reduce them in Akure and Ondo State. The lack of sufficient monitoring of air quality, worsened by financial limitations, further hinders prompt measures. The study seeks to address these urgent issues by investigating the complexities of the environmental challenges and suggesting solutions, such as the utilisation of inexpensive sensors to improve monitoring networks. Furthermore, its objective is to evaluate the level of awareness and understanding among the local community regarding the correlation between environmental factors and cardiovascular diseases.

1.3 Investigating the Effects and Developing Solutions

The primary objective of the study is to thoroughly investigate the impact of excessive temperature and air pollution on cardiovascular illnesses in Ondo State, Nigeria. In order to accomplish this goal, the study has established precise objectives. Firstly, it aims to examine the correlations between environmental factors and cardiovascular illnesses by utilising health information. Furthermore, satellite data will be utilised to analyse extreme temperatures and air pollution in Ondo State, offering a more comprehensive understanding of the environmental dynamics. The study also seeks to identify populations that are at higher risk by taking into account age and socio-economic status, recognising the diverse vulnerabilities within the community. The project aims to offer evidence-based suggestions to politicians and healthcare practitioners in order to improve heart health in Ondo State. The project seeks to provide significant insights and practical solutions by connecting these objectives, thereby bridging the gap between environmental concerns and public health outcomes.

1.4 Addressing Challenges and Promoting Well-being

The study is highly significant in tackling crucial environmental and public health issues that are peculiar to Ondo State, Nigeria. The study aims to provide significant insights to the scientific community and local authorities by examining the intricate relationship between severe temperatures, air pollution, and cardiovascular disorders. The study holds multiple dimensions of importance. Firstly, its objective is to provide information for public health plans and interventions, which could potentially result in enhanced health outcomes for the population of Ondo State. Furthermore, the study aims to enhance environmental consciousness and promote a sense of responsibility among the local community, so making a valuable contribution to environmental awareness in the region. Finally, through the examination of inexpensive sensors for monitoring air quality, this work gives a chance for technical advancement, providing a cost-efficient resolution that can be duplicated in other growing areas encountering comparable difficulties. The study's multi-dimensional relevance establishes it as a crucial milestone in tackling environmental and public health issues in Ondo State.

The study's particular emphasis on Ondo State, Nigeria, guarantees a thorough examination of the correlation between severe temperatures, air pollution, and cardiovascular illnesses. The analysis of environmental conditions will rely on satellite data, while the study will investigate the feasibility of using inexpensive sensors for monitoring air quality. Although the findings are anticipated to offer interesting insights that can be applied to Ondo State, it is important to exercise caution when extrapolating the results to areas outside the specific geographic scope.

Recognising the importance of the study, it is essential to acknowledge its inherent constraints. The limitations in sample size can affect the capacity to apply the findings to a larger population, resulting in some level of uncertainty. The utilisation of health records may bring inherent biases, and the levels of awareness may differ among various demographic groups, potentially impacting the results of the study. In addition, limitations in resources, namely budgetary restrictions, can provide difficulties that may impact the extent and comprehensiveness of data gathering. The recognized constraints underscore the importance of meticulous analysis and implementation of the study's results beyond its defined parameters. In general, the study's extent and constraints highlight its dedication to a thorough examination, emphasising openness and the conscientious application of its results.

2.0 LITERATURE REVIEW

2.1 Review of Related Works

Recently, there has been an increasing amount of study exploring the complex connection between air pollution and cardiovascular health. This research has provided insights into the many effects of environmental influences on the human cardiovascular system. Multiple research provide useful insights, each examining distinct aspects of this intricate interaction.

Lawal et al (2022) conduct a comprehensive analysis of air pollution in Nigeria, focusing primarily on Abuja, Kogi, Edo, and Port Harcourt. The study used real-time air quality data obtained from PurpleAir.com, which indicates that the PM2.5 concentrations in certain areas surpassed 20 µg/m3, so breaching the annual air quality regulations. Furthermore, the PM10.0 concentrations in Abuja and Port Harcourt exceeded 40 µg/m_3, suggesting significant levels of pollution. This report underscores the pressing need to tackle air quality issues in Nigeria, specifically focusing on the breach of norms and the associated health consequences.

Taylor et al (2020) adopt a proactive stance by providing a forecasting model that utilises the Bi-directional Long Short-Term Memory (Bi-LSTM) algorithm. The study examines air pollution data from the UCL online database, specifically focusing on industrial emissions, vehicle exhaust, and hazardous gases. The Bi-LSTM model exhibits exceptional precision in forecasting particle matter (Pm2.5 and Pm10) levels in Port Harcourt, Nigeria. Grounded on the disciplines of data science and environmental science, this research presents a highly promising instrument for the management of air quality. Additionally, it furnishes practical and implementable insights for academics and professionals working in these domains.

Nakhratova et al. (2022) provide an extensive review that consolidates current understanding of the correlation between air pollution and cardiovascular diseases (CVD). The authors primarily examine particulate matter and rely on evidence sourced from PubMed, Scopus, Cochrane, and Google Scholar. The review provides an overview of both immediate and prolonged exposures to particulate matter and their connections to different cardiovascular outcomes. This review highlights the crucial role of air pollution in causing cardiovascular disease (CVD) morbidity and mortality by explaining the underlying mechanisms such as oxidative stress, inflammation, and endothelial dysfunction. It emphasises the importance of raising awareness about this issue.

Roukema et al (2022) investigate the complex correlation of air pollution, asthma, obesity, and tidal volume in children. This research, carried out in the Netherlands, investigates the vulnerability of children with asthma and high body mass index (BMI) to air pollution. The research examines the breathing patterns and uses dosimetry models to understand why obese asthmatic children are more susceptible to the harmful impacts of air pollution. Although recognising its constraints, such as reliance on indirect evidence and the necessity for additional research, this study provides significant perspectives on reducing the health impacts of air pollution in this susceptible demographic.

Lu et al (2022) examine the relationship between air quality and cardiovascular illnesses in Shanghai. The study examines the impact of six pollution elements on human health, with a particular focus on the significant role of air pollution in endangering the cardiovascular system. The research provides new insights into the intricate correlation between air quality and cardiovascular health by examining seasonal variations in significant air contaminants and their association with cardiovascular illnesses. This study emphasises the significance of monitoring and tackling air pollution for the well-being of the general public, with practical consequences for policymakers and healthcare practitioners.

Lim et al. (2021) investigate the complex correlation between air pollution and intracranial haemorrhage (ICH) in Singapore. The paper presents a thorough analysis of the current body of literature, recognising the important impact of air pollution on cardiovascular and cerebrovascular illnesses. The research acknowledges the intricate connections between air pollution, different contaminants, and ICH. However, it emphasises the need for additional studies to address the existing knowledge gaps. Dr. Vijay K. Sharma's study enhances our comprehension of the complex relationship between environmental influences and neurological well-being.

Aduroja et al. (2022) examine the occurrence of physical inactivity and unhealthy food trends in Ibadan, Nigeria. The study, encompassing a sample size of 500 individuals, uncovers alarming patterns, such as inadequate levels of physical activity and subpar nutritional practices. The results underscore the necessity of community-led public health promotion programmes and fill a significant knowledge vacuum regarding cardiovascular risk factors in community-based environments in Nigeria.

In Bhatnagar's (2006) study, the focus is on investigating the influence of environmental factors on cardiovascular disease (CVD), with particular emphasis on the role of pollutants in increasing the likelihood of developing CVD. This study emphasises the importance of doing thorough investigations to determine the exact contributions of pollutants and establish a cause-and-effect relationship. This will enhance our understanding of how exposure to pollutants is associated with an increased risk of heart disease.

Mannucci (2022) offers a historical framework, delineating the progression of knowledge concerning the impact of air pollution on cardiovascular well-being. The narrative review highlights air pollution as a worldwide health issue, resulting in millions of additional deaths each year. Mannucci suggests utilising decorative potted plants as a potential method to alleviate indoor air pollution, emphasising the significance of tackling air pollution through inventive tactics.

Olufayo et al (2022) examine the risk variables for cardiovascular disease (CVD) among first-year students at the University of Ibadan, Nigeria. The investigation uncovers alarming patterns, such as smoking, alcohol drinking, lack of physical activity, and unhealthy eating habits among the individuals. The results highlight the significance of implementing timely interventions in educational institutions to target alterable behaviours that contribute to cardiovascular disease risk factors among Nigerian adolescents.

Nouri et al. (2023) examine the effects of brief exposure to sulphur dioxide (SO_2) and particulate matter (PM10) on the number of daily hospital admissions for hypertensive cardiovascular disorders (HCD) in Isfahan, Iran, a city known for its high pollution levels. By employing sophisticated statistical models, researchers discover a notable rise in the likelihood of hospitalisations associated to HCD (Heart and Cardiovascular Diseases) when there are higher levels of both SO_2 (Sulphur Dioxide) and PM10 (Particulate Matter 10). The study highlights the pressing necessity for environmental initiatives and public health strategies to alleviate the hazards connected with pollution.

Taheri et al. (2023), conducted a study in Isfahan to examine the influence of exposure to ambient carbon monoxide (CO) on the number of daily hospital admissions for cardiovascular disease (CVD). Their research demonstrates a notable correlation between exposure to carbon monoxide (CO) and a higher number of hospitalisations due to cardiovascular disease (CVD). This highlights the significance of taking into account different aspects, such as age groups, seasons, and sex, in comprehending this connection. This study offers significant information that can be utilised to design specific public health initiatives.

Yuan et al. (2022) investigate the influence of air pollution on cardiovascular well-being in individuals diagnosed with type 2 diabetes mellitus (T2DM) specifically in Shandong Province, China. Their thorough methodology, which involves integrating microdata from a prominent tertiary hospital with macro data, reveals a harmful influence of air pollution on the cardiovascular well-being of individuals with type 2 diabetes mellitus (T2DM). This impact varies depending on factors such as gender, age, the level of environmental regulation, and the prevailing public health circumstances. This study highlights the importance of environmental governance and the necessity for higher public health spending.

In this study, Feng et al. (2023) examine the correlation between brief exposure to air pollution and the occurrence of hospitalisations due to coronary heart disease (CHD) in Hefei, China. Their examination of daily CHD admissions, in conjunction with air pollution and meteorological data, reveals noteworthy associations between CHD hospitalisation rates and pollutants such as NO_2, O_3, and CO. The subtle results underscore variations in vulnerability based on age, gender, and seasons, underscoring the significance of customised preventive strategies for susceptible CHD patients.

Offiah et al. (2022) investigate the relationship between air pollution levels and environmental lung disorders in Umuahia Metropolis, Southeastern Nigeria. Their investigation, utilising gas metres and structured questionnaires, uncovers heightened concentrations of carbon monoxide (CO), sulphur dioxide (SO_2), and suspended particulate matter (SPM) in outdoor areas, surpassing the usual values by a wide margin. The documented respiratory grievances among inhabitants emphasise the necessity for public consciousness concerning gaseous contaminants.

Choi et al. (2022) provide valuable insights from their study conducted in Korea, examining the correlation between air pollution and clinical outcomes over a one-year period in patients diagnosed with acute myocardial infarction (AMI). Their extensive investigation, conducted over almost ten years and with a substantial group of participants, demonstrates a notable connection between greater levels of sulphur dioxide (SO_2) and particulate matter (PM10) and an increased likelihood of negative clinical consequences. The findings underscore the need of taking into account ambient air pollution levels when evaluating the outlook of cardiovascular events.

In this study, Cortes et al. (2023) investigate the immediate connection between ambient air pollution and mortality related to cardiovascular and respiratory diseases in Rio de Janeiro, Brazil. Although there are possible health hazards, their research reveals no consistent links between exposure to particulate matter <10 μm (PM10) and ozone (O_3) and death related to cardiovascular or respiratory conditions. The findings enhance our comprehensive understanding of the impact of air pollution on health, highlighting the particular nature of these connections in different contexts.

Liu et al. (2022) present significant epidemiological findings from China, examining the lasting effects of exposure to ambient fine particulate matter (PM2.5) on the occurrence of cardiovascular diseases (CVD). Their comprehensive research, conducted across ten locations and encompassing over half a million persons, reveals a clear and direct correlation between prolonged exposure to PM2.5 and the risk of cardiovascular disease (CVD). The study reveals discrepancies among different population subcategories, emphasising the significance of taking into account demographic variables when evaluating the health consequences of air pollution.

Salami and Popoola (2023) provide a thorough examination that specifically addresses the environmental and health consequences of atmospheric air pollutants originating from garbage sites. The authors conduct a thorough analysis of current literature, highlighting the necessity for additional research on the health effects of particulate matters (PMs) in low-income nations, specifically Nigeria. The evaluation suggests strategies to reduce air pollutant levels and emphasises the significance of waste management methods in reducing health concerns linked to landfill operations.

Dodiyi-Manuel and Ajala (2023) provide insights based on a retrospective study conducted in Nigeria. The study focuses on cardiovascular disease (CVD) admissions and mortality patterns in the medical wards of the University of Port-Harcourt Teaching Hospital during a period of 5 years. The study presents data on patterns, characteristics, and results, indicating that cerebrovascular accident, heart failure, and hypertensive crises are the most common reasons for cardiovascular hospitalizations. The results underscore the necessity for proactive measures and interventions to tackle the increasing prevalence of cardiovascular illnesses in the area.

2.2 Understanding and Addressing Challenges in Air Pollution Research

The current body of research on the relationship between air pollution and cardiovascular health is fraught with many limitations and issues. Prior studies mostly concentrate on Nigeria, China, and Iran, so restricting the geographical scope. The focus on a specific area of study hinders the application of research findings to regions that are not well-represented globally. This highlights the necessity for future research to include a more diverse range of geographical locations (Lawal and Muhammed, 2022; Yuan et al., 2022). Typically, individual studies tend to concentrate on examining one or two specific pollutants, disregarding the combined effects of multiple contaminants in real-world scenarios. To conduct a comprehensive risk assessment, it is crucial to investigate the synergistic effects of several pollutants seen in real-world exposure. This necessitates more research, as indicated by studies conducted by Lu and Wang (2022) and Nouri et al. (2023).

Furthermore, there is a need for standardisation in the field of air pollution research modelling. Some research employs intricate models such as Bi-LSTM, but the modelling approaches differ, leading to incorrect outcomes. Enhancing the reliability and replicability of air pollution studies necessitates the establishment and verification of standardised models (Taylor and Ezekiel, 2020; Feng et al., 2023). Another notable disparity exists in the translation of research findings into impactful legislation and community-level initiatives aimed at mitigating the health consequences of air pollution. Additional study and practical implementation are necessary to fully comprehend how research findings can be effectively utilised to tackle community concerns, despite the existing suggestions for preventive measures and interventions (Aduroja et al., 2022; Lim et al., 2021).

Furthermore, it is challenging to determine the specific contributions of individual pollutants to cardiovascular diseases. Several studies recognise the necessity for more extensive research to ascertain the specific effects of different pollutants, but targeted solutions and regulatory measures necessitate more thorough investigation. The underlying physiological and molecular mechanisms via which air pollutants induce cardiovascular illnesses remain inadequately comprehended, with research frequently limited to merely identifying correlations between air pollution and health consequences. Addressing this disparity will facilitate the development of customised therapeutic and preventative measures (Nakhratova et al., 2022; Vonk and Roukema, 2022).

Direct measurements to overcome indirect evidence restrictions and comprehensive data collecting to address knowledge gaps are other crucial gaps. Additionally, suggestions are made for interventions and pragmatic strategies at the community level to enhance health promotion efforts driven by the community, emphasising the necessity for further investigation. To fully comprehend the temporal impact of air pollution on cardiovascular health, it is necessary to conduct longitudinal studies that incorporate both short-term and long-term exposure data. Ultimately, it is crucial to have interdisciplinary cooperation among environmental research, public health, and policy in order to develop effective air pollution health measures. Interdisciplinary collaboration is necessary for the development of effective and long-lasting solutions (Mannucci, 2022; Salami and Popoola, 2023). By addressing these intricate disparities, we can enhance our comprehension of the relationship between air pollution and cardiovascular health.

3.0 METHODOLOGY

3.1 Introduction

This section focuses on the methodology employed in this study to achieve its objective on "The impact of extreme temperatures and air pollutants on cardiovascular disease in Ondo State, Nigeria." The study included an analysis of Ondo State using secondary data obtained from GIS satellite mapping. The study focused on the design, area, population, sample size, and sampling techniques. It also considered the research instrument, its validation and reliability, as well as the administration of the instrument and the method of data analysis.

3.2 Research Design

The study on the correlation between excessive temperature, air pollution, and cardiovascular illness in Ondo State, Nigeria, only relied on secondary data acquired by GIS satellite mapping. The study sought to thoroughly examine and graphically represent the spatial patterns of excessive temperature and air pollution throughout the state. A meticulous methodology was employed to choose satellite imagery, prioritizing high-resolution data that encompasses both temporal and spectral resolutions. This was crucial in order to precisely depict temperature fluctuations and concentrations of air pollutants. In order to fully comprehend the temporal elements, the study focused on obtaining satellite data with extensive temporal coverage. This enabled the study to capture seasonal fluctuations and long-term patterns in extreme temperature and air quality. The data processing entailed the utilisation of sophisticated GIS methodologies, such as picture rectification, atmospheric correction, and geographical analysis. The implementation of these procedures aimed to improve the precision and dependability of the collected data, establishing a strong basis for a thorough investigation of the correlation between environmental factors and cardiovascular health in Ondo State.

3.3 Area of the Study

This study investigates the effects of high temperatures and air pollutants on cardiovascular disease specifically in Ondo State, Nigeria. The study solely investigates the correlation between environmental elements, notably severe temperature and air pollution, and their impact on cardiovascular health in the designated area of Ondo State.

3.4 Sample Size and Sampling Techniques

The study relied heavily on GIS satellite mapping to examine the correlations among many environmental factors, such as CH_4 (Methane), CO (Carbon monoxide), NO_2 (Nitrogen dioxide), SO_2 (Sulphur dioxide), oC (Temperature), Cardio Death, and Cardio Disease. The exclusive reliance on GIS satellite mapping techniques is highlighted by the lack of direct respondent interaction. The selected methodology sought to thoroughly examine and visually represent the distribution and relationships of these variables within the designated study region. The sample size determination and selection were not respondent-centric, but rather aimed at acquiring precise and dependable spatial data via GIS satellite mapping.

3.5 Research Instrument

The research tool utilised for GIS satellite mapping employed a methodical procedure. High-resolution satellite photography was used to capture data on CH_4, CO, NO_2, SO_2, ^{o}C, Cardio Death, and Cardio Disease. We utilised advanced GIS techniques such as picture correction and geographical analysis. Comprehensive data examination was ensured using temporal coverage analysis. Visualization was achieved by the utilisation of spatial analysis tools and mapping software. Stringent quality control methods were enforced, and the technique was meticulously documented to ensure transparency.

3.7 Validation of Research Instrument

The validation of the study instrument underwent meticulous procedures, including cross-referencing GIS-generated data with ground truth verification and existing datasets, expert evaluations, statistical analysis to evaluate correlations, and reproducibility testing. The feedback received from peer reviews and advisers played a crucial role in improving the instrument, guaranteeing its dependability in precisely measuring and displaying the spatial correlations of CH_4, CO, NO_2, SO_2, ^{o}C, Cardio Death, and Cardio Disease within the study region.

3.8 Method of Data Analysis

The GIS satellite mapping data were thoroughly examined to reveal correlations between environmental factors (CH_4, CO, NO_2, SO_2, ^{o}C) and Cardio Disease and Death. This entailed the interpretation of satellite imagery, the comparison of parameters, and the execution of necessary judgements.

4.0 RESULTS AND DISCUSSION

4.1 Result

The GIS-derived data includes important environmental factors such as methane (CH4), carbon monoxide (CO), nitrogen dioxide (NO2), sulphur dioxide (SO2), and temperature (oC). These data are presented in a systematic manner from Figure 1 (a,b,c) to Figure 5 (a,b,c). Simultaneously, Figure 6 and Figure 7 clarify the relevant datasets about Cardio Disease and Death, providing a full depiction of the connection between environmental factors and health consequences.

Figure 1 (a) depicts the characteristics of Methane (CH_4) for different Local Government Areas (LGAs) in Ondo State in the year 2020. The results indicate the spectrum of CH_4 concentrations in each Local Government Area (LGA). Akoko North-East, Akoko North-West, Akoko South-East, Akoko South-West, Akure North, and Akure South all have comparable ranges of 1.825 to 1.829. Meanwhile, the districts of Ese Odo, Idanre, Ifedore, Ilaje, Ile Oluji/Okeigbo, Irele, and Odigbo have population figures ranging from 1.811 to 1.820. Okitipupa, Ondo East, Ondo West, Ose, and Owo have slightly wider ranges, ranging from 1.816 to 1.829. These characteristics offer valuable information about the spatial distribution of Methane levels across the Local Government Areas (LGAs) in Ondo State in the year 2020.

Figure 1 (b) displays the Methane (CH_4) characteristics for the Local Government Areas (LGAs) of Ondo State in the year 2021. The data shows the spectrum of CH4 concentrations within each Local Government Area (LGA). The districts of Akoko North-East, Akoko North-West, Akoko South-East, Akoko South-West, Akure North, and Akure South regularly exhibit a narrow range of values, specifically between 1.835 and 1.838. Similarly, Ese Odo, Idanre, Ifedore, Ilaje, Ile Oluji/Okeigbo, Irele, and Odigbo have ranges that run from 1.822 to 1.830. Okitipupa, Ondo East, Ondo West, Ose, and Owo have slightly wider ranges, ranging from 1.827 to 1.834. By comparing the 2020 data, we can identify probable patterns or shifts in CH4 levels among LGAs in Ondo State. This analysis helps us comprehend the temporal fluctuations in methane concentrations in the region.

Figure 1 (c) presents the Methane (CH_4) data for the Local Government Areas (LGAs) in Ondo State in the year 2022. The given data presents the spectrum of CH4 concentrations observed in each Local Government Area (LGA). The regions of Akoko North-East, Akoko North-West, Akoko South-East, Akoko South-West, Akure North, and Akure South consistently demonstrate a consistent range of values between 1.833 and 1.844. Additionally, Ese Odo, Ifedore, Ile Oluji/Okeigbo, and Ose have values ranging from 1.821 to 1.838. Idanre, Ilaje, and Irele have ranges that are slightly narrower, ranging from 1.821 to 1.832. Ondo West exhibits a wider spectrum of 1.827 to 1.844, which is worth mentioning. These metrics provide significant information about the fluctuations in CH4 levels across the Local Government Areas (LGAs) of Ondo State in 2022. This contributes to our understanding of probable patterns or shifts in methane concentrations over time.

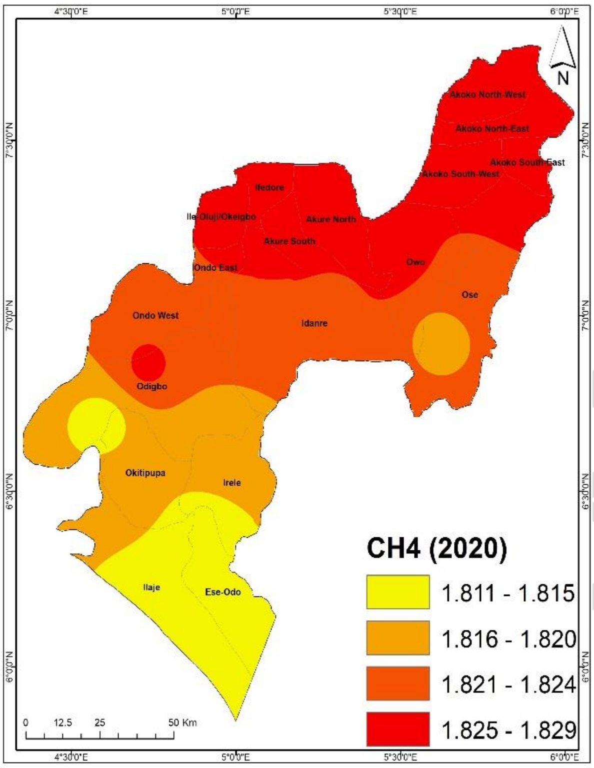

Figure 1 (a) CH_4 2020

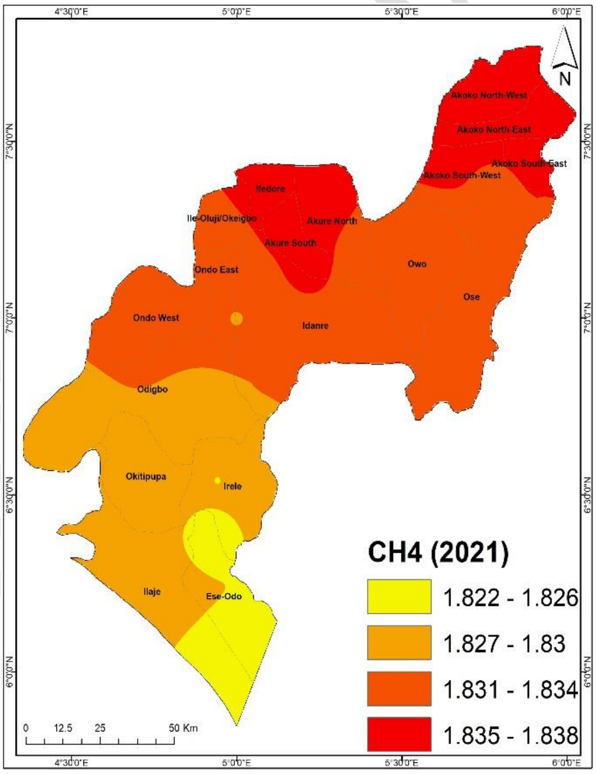

Figure 1 (b) CH_4 2021

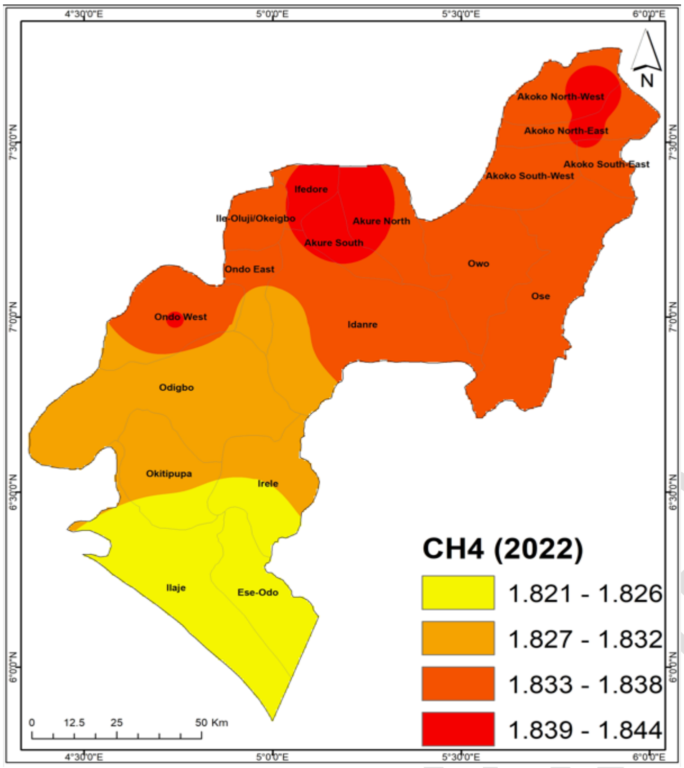

Figure 1 (c) CH_4 2022

Figure 1 displays the Methane (CH4) data pertaining to the local government in Onto state for the years 2020, 2021, and 2022.

Figure 2 (a) depicts the Carbon Monoxide (CO) measurements for Local Government Areas (LGAs) in Ondo State for the year 2020. The data illustrates the spectrum of carbon monoxide concentrations within each Local Government Area (LGA). The districts of Akoko North-East, Akoko North-West, Akoko South-East, Akoko South-West, Akure North, and Akure South constantly exhibit a stable range of values between 126.0 and 128.9. Ese Odo, Idanre, Ifedore, Ile Oluji/Okeigbo, Irele, and Ose have a range of values between 124.4 and 128.9, suggesting a considerably higher level of variability. Ilaje and Okitipupa have narrower ranges, ranging from 122.8 to 127.4 and 122.8 to 125.9, respectively. The ranges observed in Ondo East and Ondo West vary from 126.0 to 128.9. Owo and Odigbo have a common range of values ranging from 124.4 to 127.4. These characteristics offer valuable information about the spatial distribution of carbon monoxide (CO) levels across the Local Government Areas (LGAs) of Ondo State in 2020. This information helps in evaluating potential differences in air quality.

Figure 2 (b) displays the Carbon Monoxide (CO) measurements for the Local Government Areas (LGAs) in Ondo State in the year 2021. The data displays the spectrum of carbon monoxide concentrations within each Local Government Area (LGA). The regions of Akoko

North-East, Akoko North-West, Akoko South-East, Akoko South-West, Akure North, and Akure South regularly have a stable range of values between 125.6 and 133.9. Ese Odo, Idanre, Ifedore, Ile Oluji/Okeigbo, and Ondo West have ranges that run from 122.2 to 127.2. The areas of Ilaje, Irele, Odigbo, Okitipupa, Ondo East, and Owo exhibit wider ranges of CO levels, ranging from 122.2 to 133.9, suggesting the possibility of greater variability in these levels. The range of Ose is from 124.4 to 127.4. These metrics offer significant information on the spatial arrangement of CO concentrations throughout the Local Government Areas (LGAs) of Ondo State in 2021. This helps in comprehending possible differences in air quality and evaluating hazards to environmental health.

Figure 2 (c) presents the Carbon Monoxide (CO) measurements for the Local Government Areas (LGAs) in Ondo State in the year 2022. The data provides information about the spectrum of carbon monoxide concentrations within each Local Government Area (LGA). The regions of Akoko North-East, Akoko North-West, Akoko South-East, Akoko South-West, Akure North, and Akure South regularly have a stable range of values between 144.8 and 160.2. Ese Odo, Idanre, Ifedore, Ile Oluji/Okeigbo, and Ondo East have a range of CO levels ranging from 139.6 to 160.2, indicating the possibility of significant variability. The districts of Ilaje, Irele, Odigbo, Okitipupa, Ondo West, and Owo have more limited variations, ranging from 139.6 to 155.0. The range of Ose is from 139.6 to 155.0. These metrics provide vital information on the spatial distribution of carbon monoxide (CO) concentrations across the Local Government Areas (LGAs) of Ondo State in 2022. They may be used to examine differences in air quality and potential consequences on environmental health.

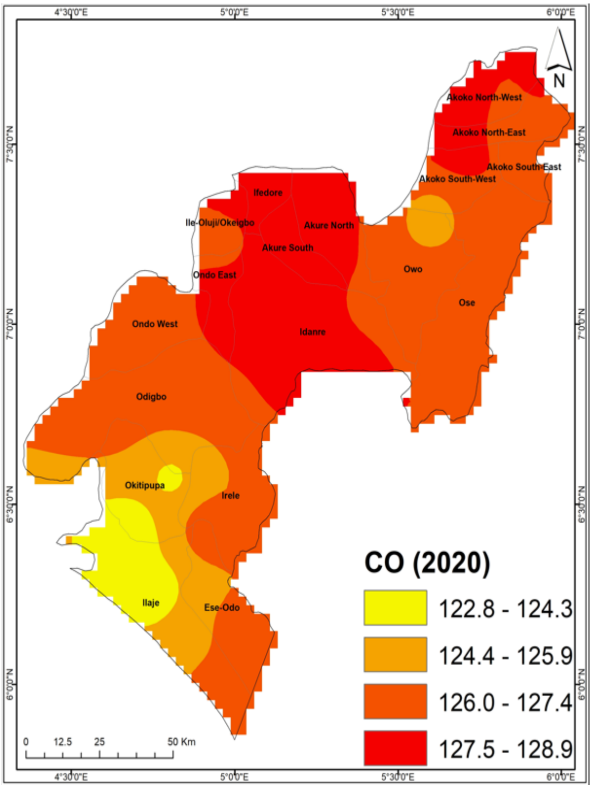

Figure 2 (a) CO 2020

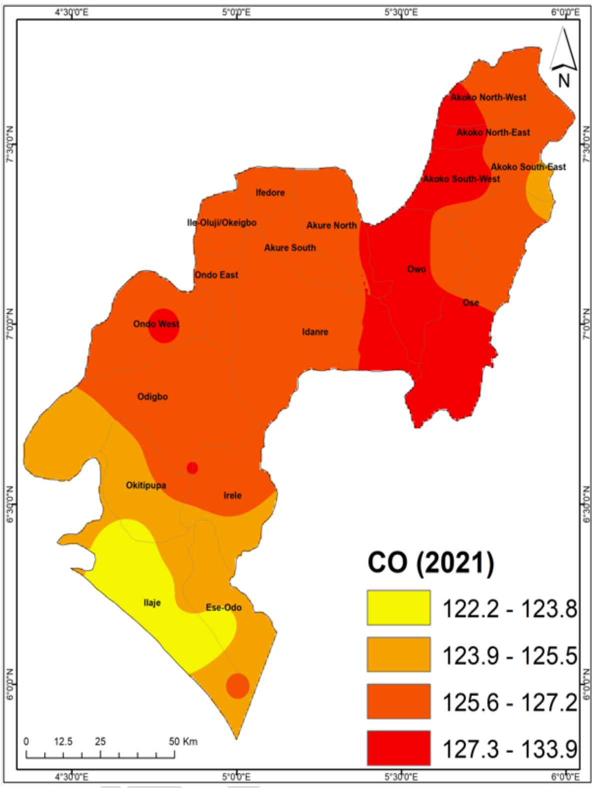

Figure 2 (b) CO 2021

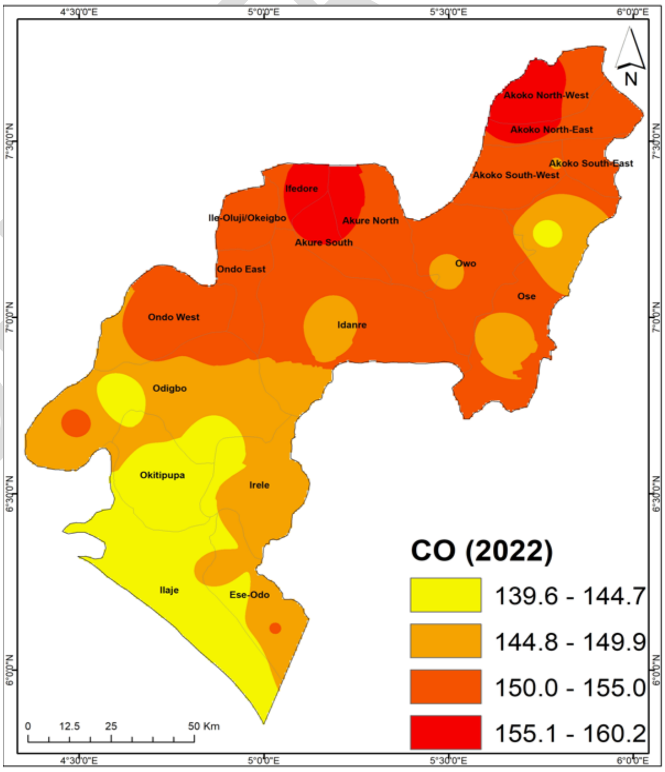

Figure 2 (c) CO 2022

Figure 2 displays the Carbon Monoxide (CO) parameters for the local government in Ondo state for the years 2020, 2021, and 2022.

Figure 3 (a) displays the Nitrogen Dioxide (NO_2) measurements for Local Government Areas (LGAs) in Ondo State throughout the year 2020. The data illustrates the spectrum of NO2 concentrations throughout each Local Government Area (LGA). The regions of Akoko North-East, Akoko North-West, Akoko South-East, and Akoko South-West frequently have comparable values ranging from 1.05 to 1.14. The range of Akure North is between 0.84 and 1.04, whereas the range of Akure South is between 0.84 and 0.93. Ese Odo, Idanre, Ifedore, Ilaje, Ile Oluji/Okeigbo, Irele, Odigbo, Okitipupa, Ondo East, Ondo West, Ose, and Owo exhibit a range of NO2 readings from 0.52 to 1.14, indicating probable fluctuations in air pollution. The data offers valuable information regarding the spatial dispersion of NO2 levels across the Local Government Areas (LGAs) of Ondo State in 2020. This data assists in evaluating air quality and potential environmental consequences.

Figure 3 (b) presents the Nitrogen Dioxide (NO2) data for the Local Government Areas (LGAs) in Ondo State in the year 2021. The data demonstrates the spectrum of NO2 concentrations throughout each Local Government Area (LGA). The regions of Akoko North-East, Akoko North-West, Akoko South-East, and Akoko South-West consistently exhibit NO2 values ranging from 0.99 to 1.19 and 1.1 to 1.19, indicating a roughly similar amount of pollution. The ranges for Akure North and Akure South are 0.89 to 1.09 and 0.79 to 0.98, respectively. The local government areas (LGAs) of Ese Odo, Idanre, Ifedore, Ilaje, Ile Oluji/Okeigbo, Irele, Odigbo, Okitipupa, Ondo East, Ondo West, Ose, and Owo exhibit a range of NO_2 readings from 0.58 to 1.09, suggesting probable variations in air pollution levels in these areas. These metrics aid in comprehending the spatial dispersion of NO_2 concentrations and probable fluctuations in air quality in Ondo State during the year 2021.

Figure 3 (c) displays the Nitrogen Dioxide (NO2) measurements for the Local Government Areas (LGAs) in Ondo State in the year 2022. The data illustrates the spectrum of NO2 concentrations throughout each Local Government Area (LGA). The regions of Akoko North-East, Akoko North-West, Akoko South-East, Akoko South-West, Akure North, and Akure South constantly display fluctuating values ranging from 0.91 to 1.23. The LGAs of Ese Odo, Idanre, Ifedore, Ilaje, Ile Oluji/Okeigbo, Irele, Odigbo, Okitipupa, Ondo East, Ondo West, Ose, and Owo exhibit a wide range of NO_2 values, ranging from 0.58 to 1.23. This suggests that there is a potential for variability in NO_2 levels across these LGAs. Ose stands out for having the most extensive range, which spans from 0.81 to 1.23. These metrics offer valuable information on the spatial arrangement of NO_2 levels and possible fluctuations in air quality in Ondo State in 2022. This information helps in evaluating the environmental effects.

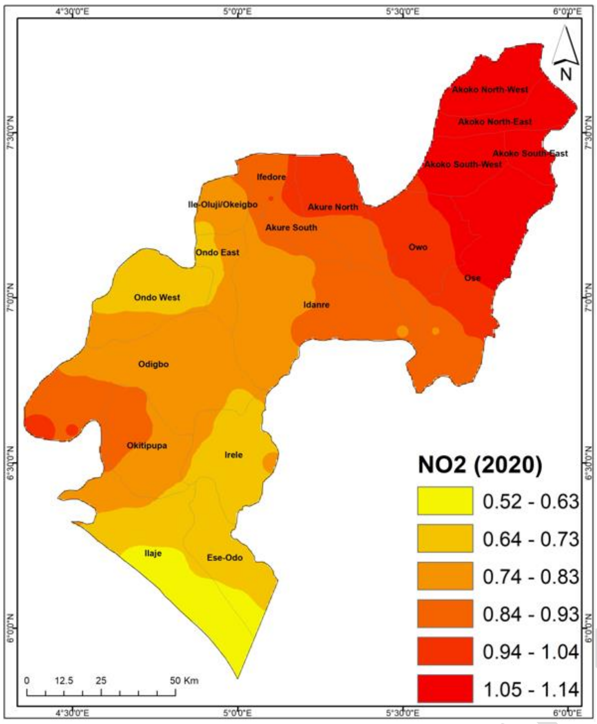

Figure 3 (a) NO_2 2020

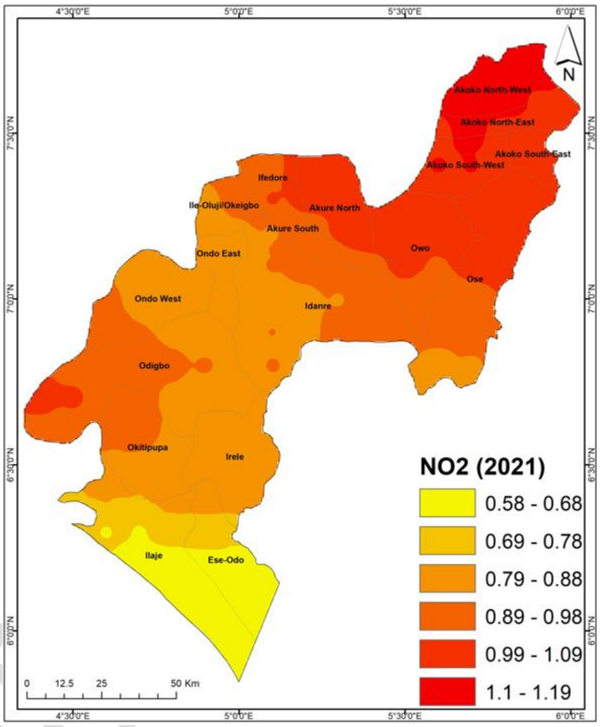

Figure 3 (b) NO_2 2021

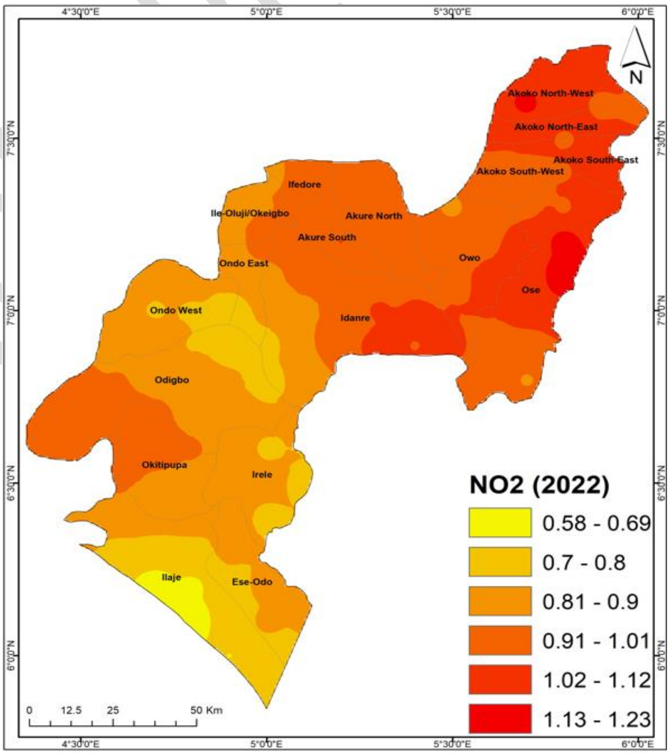

Figure 3 (c) NO_2 2022

Figure 2 presents the Carbon Monoxide (CO) measurements for the local government in Ondo state over the years 2020, 2021, and 2022.

Figure 3 (a) depicts the recorded levels of Nitrogen Dioxide (NO_2) in the Local Government Areas (LGAs) of Ondo State during the course of the year 2020. The data depicts the range of NO_2 concentrations throughout each Local Government Area (LGA). The readings in the regions of Akoko North-East, Akoko North-West, Akoko South-East, and Akoko South-West often fall within a similar range of 1.05 to 1.14. Akure North has a range of 0.84 to 1.04, while Akure South has a range of 0.84 to 0.93. Ese Odo, Idanre, Ifedore, Ilaje, Ile Oluji/Okeigbo, Irele, Odigbo, Okitipupa, Ondo East, Ondo West, Ose, and Owo display varying levels of NO_2 measurements, ranging from 0.52 to 1.14. These readings suggest potential oscillations in air pollution. The data provides useful insights into the spatial distribution of NO2 levels across the Local Government Areas (LGAs) in Ondo State in 2020. This data facilitates the assessment of air quality and potential environmental ramifications.

Figure3 (b) displays the Nitrogen Dioxide (NO_2) measurements for the Local Government Areas (LGAs) in Ondo State throughout the year 2021. The data illustrates the range of NO_2 concentrations throughout each Local Government Area (LGA). The Akoko North-East, Akoko North-West, Akoko South-East, and Akoko South-West regions regularly demonstrate NO2 readings ranging from 0.99 to 1.19 and 1.1 to 1.19, suggesting a somewhat uniform level of pollution. The ranges for Akure North and Akure South are 0.89 to 1.09 and 0.79 to 0.98, respectively. The local government areas (LGAs) of Ese Odo, Idanre, Ifedore, Ilaje, Ile Oluji/Okeigbo, Irele, Odigbo, Okitipupa, Ondo East, Ondo West, Ose, and Owo display a spectrum of NO2 readings ranging from 0.58 to 1.09, indicating likely disparities in air pollution levels within these regions. These measures help to understand the spatial distribution of NO2 concentrations and potential variations in air quality in Ondo State over the year 2021.

Figure 3 (c) presents the recorded levels of Nitrogen Dioxide (NO2) in the Local Government Areas (LGAs) of Ondo State in the year 2022. The data demonstrates the range of NO2 concentrations throughout each Local Government Area (LGA). The regions of Akoko North-East, Akoko North-West, Akoko South-East, Akoko South-West, Akure North, and Akure South consistently exhibit variable values that fluctuate between 0.91 and 1.23. The local government areas (LGAs) of Ese Odo, Idanre, Ifedore, Ilaje, Ile Oluji/Okeigbo, Irele, Odigbo, Okitipupa, Ondo East, Ondo West, Ose, and Owo display a diverse range of nitrogen dioxide (NO_2) readings, varying from 0.58 to 1.23. This implies that there is a possibility of variation in the amounts of NO_2 throughout various Local Government Areas (LGAs). Ose is notable for its exceptionally wide range, which extends from 0.81 to 1.23. These measures provide vital insights into the regional distribution of NO_2 levels and potential variations in air quality in Ondo State in 2022. This data facilitates the assessment of the ecological impacts.

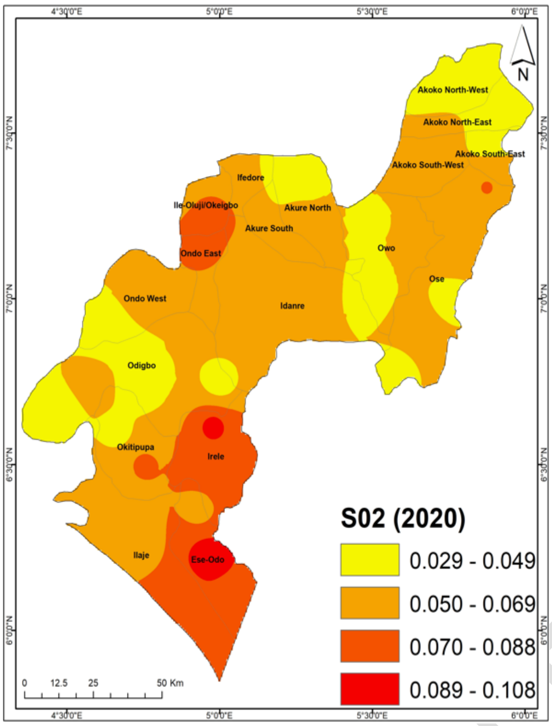

Figure 4 (a) SO_2 2020

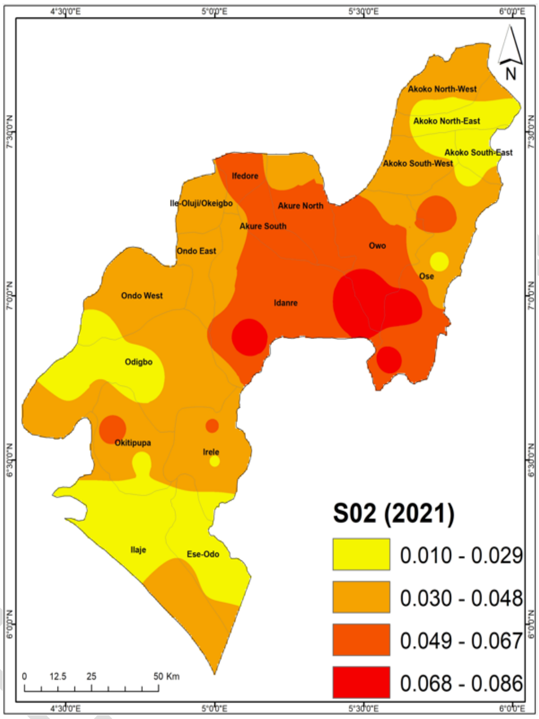

Figure 4 (b) SO_2 2021

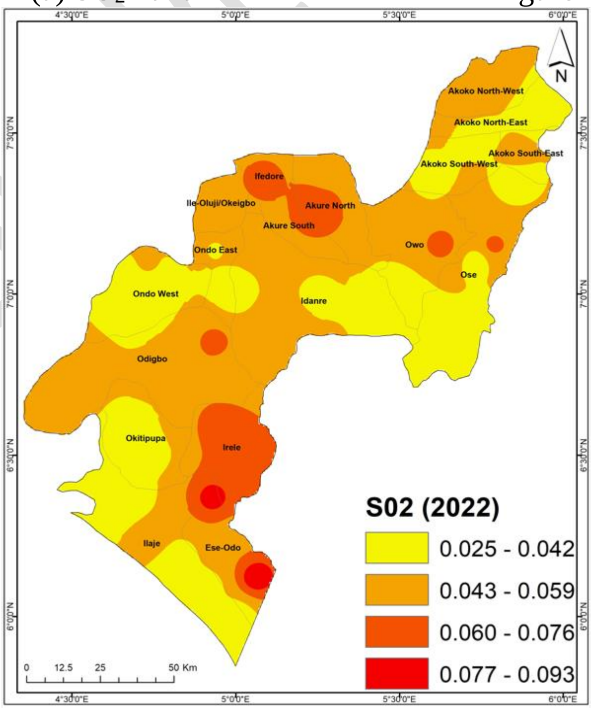

Figure 4 (c) SO_2 2022

Figure 4 shows the Sulfur Dioxide (SO_2) parameters for local government in onto state for year 2020, 2021 and 2022. Figure 5 (a) illustrates the Temperature (oC) parameters for Local Government Areas (LGAs) in Ondo State for the year 2020. The data outlines the range of temperature values within each LGA. Akoko North-East, Akoko North-West, Akoko South-East, and Akoko South-West consistently share ranges from 26.4 to 28.0. Akure North and Akure South exhibit ranges from 26.9 to 27.6. Ese Odo, Idanre, Ifedore, Ile Oluji/Okeigbo, Ondo East, Ondo West, Ose, and Owo have ranges from 26.9 to 28.0, reflecting relatively similar temperature levels. Ilaje, Irele, Odigbo, Okitipupa, showcase a slightly narrower range from 27.7 to 28.0. Notably, Ondo West has a range from 27.3 to 28.0. These parameters provide insights into the spatial distribution of temperature across Ondo State's LGAs in 2020, contributing to the understanding of local climate variations. Figure 5 (b) presents the Temperature (oC) parameters for Local Government Areas (LGAs) in Ondo State for the year 2021. The data outlines the range of temperature values within each LGA. Akoko North-East, Akoko North-West, Akoko South-East, and Akoko South-West consistently share ranges from 27.1 to 28.2. Akure North, Akure South, Ifedore, Idanre, Ile Oluji/Okeigbo, Ondo East, and Owo have ranges from 26.6 to 27.8. Ese Odo, Ilaje, Irele, Odigbo, Okitipupa, Ondo West, Ose showcase a slightly wider range from 26.6 to 28.2. Notably, Ondo West has a range from 27.5 to 28.2. These parameters provide insights into the spatial distribution of temperature across Ondo State's LGAs in 2021, contributing to the understanding of local climate variations and potential impacts on the environment. Figure 5 (c) displays the Temperature (oC) parameters for Local Government Areas (LGAs) in Ondo State for the year 2022. The data outlines the range of temperature values within each LGA. Akoko North-East, Akoko North-West, Akoko South-East, and Akoko South-West consistently share ranges from 26.1 to 27.8. Akure North, Akure South, Ese Odo, Idanre, Ifedore, Ondo East, Ondo West, Ose, and Owo have ranges from 26.1 to 27.4. Ilaje, Irele, and Okitipupa showcase a slightly wider range from 27.1 to 27.8. Ile Oluji/Okeigbo, and Odigbo have ranges from 26.1 to 27.0. Notably, Ondo West has a range from 26.7 to 27.8. These parameters provide insights into the spatial distribution of temperature across Ondo State's LGAs in 2022, contributing to the understanding of local climate variations and potential impacts on the environment.

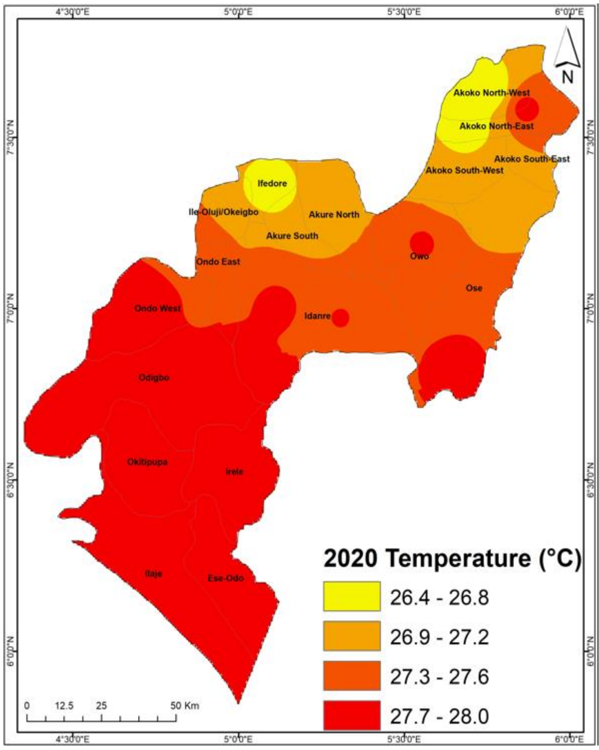

Figure 5 (a) ºC 2020

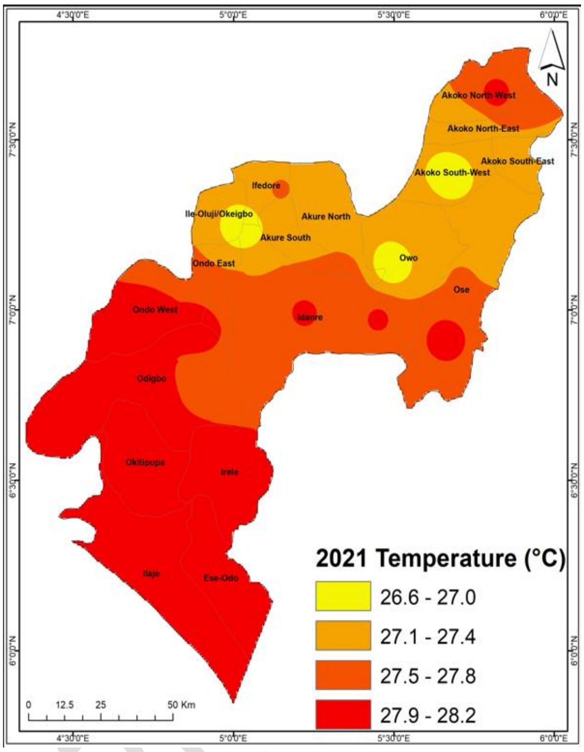

Figure 5 (b) ºC 2021

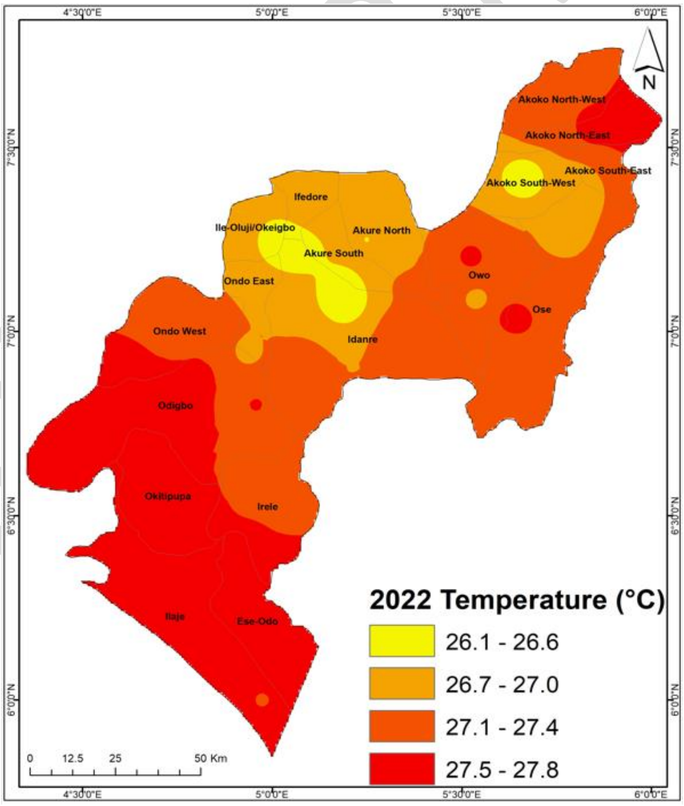

Figure 5 (c) Temperature (ºC) 2022

Figure 4 depicts the temperature (oC) criteria for local governments in each state for the years 2020, 2021, and 2022. Figure 6 depicts a complete picture of Cardio Disease indicators across several local governments in Ondo State for the year 2022. The reported cases are methodically categorised into ranges, providing a clear picture of the prevalence of cardiovascular disease in each location. Notably, Akoko North-East, Akoko North-West, Akoko South-East, and Akoko South-West all have a similar range of documented instances, dating from 1256 to 1959. Correspondingly, Akure North and Akure South both have Cardio Disease cases ranging from 1256 to 1607. Ese Odo, Ile Oluji/Okeigbo, and Ondo East represent a greater period, from 1256 to 1959. Idanre, Ifedore, and Ondo West cover cases from 904 to 1607, ensuring a detailed picture of the reported incidents. Similarly, Irele, Odigbo, and Okitipupa routinely exhibit examples in the 904-1255 range. Finally, Ilaje, Ose, and Owo accurately depict instances within the stated range of 550 to 903, highlighting the differences in Cardio Disease incidence throughout Ondo State's several local governments. Figure 7 appropriately depicts the characteristics connected with Cardio Death across various local governments in Ondo State for 2020. The data, shown in ranges, provides a detailed look at the recorded occurrences in each location. Cardio Death instances in Akoko North-East range from 304 to 405, indicating a particular spectrum for this location. Akoko North-West stands out, with Cardio Death instances ranging from 406 to 610, indicating a different characteristic when compared to other regions. Similarly, Akoko South-East reports incidents ranging from 304 to 508, demonstrating diversity in the documented instances. Akoko South-West provides a range of 305 to 610 for Cardio Death, giving another layer of variety to the provided data. Furthermore, Akure North, Akure South, Idanre, Ifedore, Ilaje, Ile Oluji/Okeigbo, Irele, Odigbo, Ondo East, and Owo often register cases ranging from 304 to 508. Ese Odo reported cases ranging from 200 to 303, whilst Okitipupa, Ondo West, Ose, and Owo show a broader range of 200 to 610. This comprehensive presentation examines the variances in

Cardio Death in Ondo State.

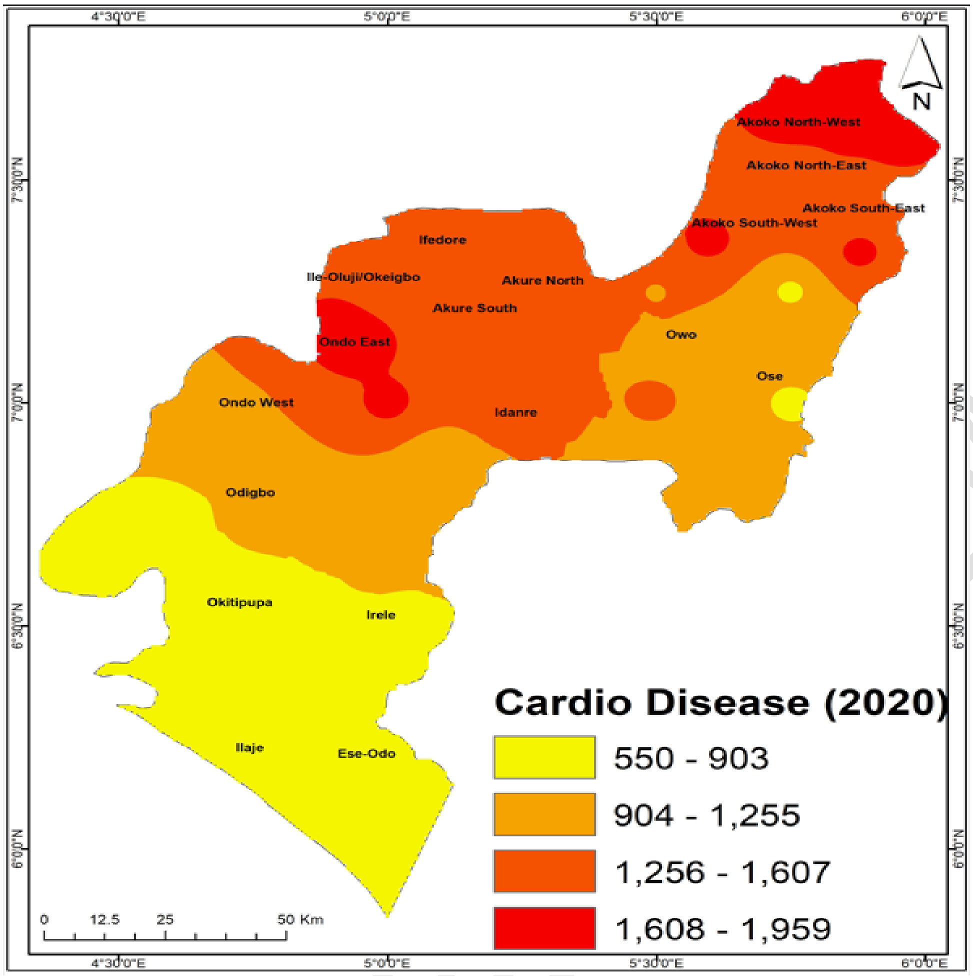

Figure 6: Cardio Disease parameters within various local governments in Ondo State for the year 2022.

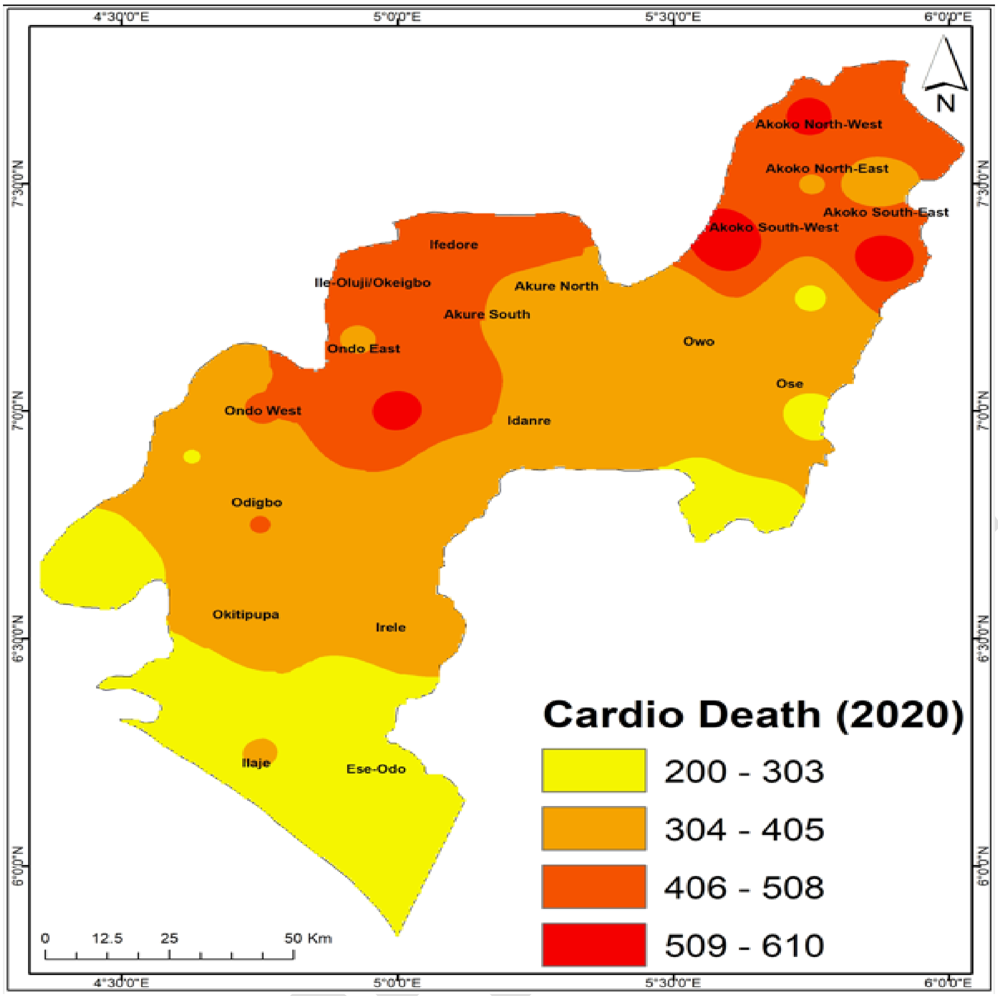

Figure 7: Cardio Death across various local governments in Ondo State for the year 2020.

4.2 Discussion of the Result

The presented GIS-generated data on methane (CH_4), carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), and temperature (oC) across different years and local government areas (LGAs) in Ondo State provides a solid foundation for understanding potential correlations with cardiovascular disease and death. Examining these environmental indicators in conjunction with Cardio Disease and Death data can shed light on the complex relationship between environmental factors and health outcomes.

Methane (CH_4) concentrations within each LGA remain generally stable during the years (2020, 2021, and 2022). The regional distribution of CH_4 levels shows commonalities between locations, implying a degree of regularity in methane exposure. While the data given does not specifically link CH_4 concentrations to Cardio Disease and Death, previous research implies that high methane exposure may have negative respiratory and cardiovascular effects, potentially influencing Cardio Disease outcomes.

Carbon monoxide (CO) levels vary by LGA, particularly in 2020 and 2021, with certain locations showing wider variances. Elevated CO levels have been linked to poor cardiovascular health because they can disrupt oxygen supply to the heart and other organs. The greater ranges seen in some places may imply increased potential health hazards connected with CO exposure, contributing to cardiovascular disease patterns.

Nitrogen dioxide (NO_2) levels vary by local government area, particularly in 2020 and 2021. NO_2 is a known air contaminant that has negative respiratory effects. The wide ranges may indicate variances in air quality and related respiratory health hazards, which could contribute to cardiovascular disease outcomes.

Sulphur dioxide (SO_2) concentrations in 2020, 2021, and 2022 show wide variations across LGAs. SO_2 is a respiratory irritant, and prolonged exposure may lead to cardiovascular difficulties. The changes in SO_2 levels indicate potential variances in air quality, which could affect health outcomes in different places.

Temperature (oC) data for 2020, 2021, and 2022 show very stable variations across each LGA. While temperature may not be the direct cause of cardiovascular disease, it can impact other environmental elements and indirectly contribute to health issues. Extreme temperatures and changes can have an influence on cardiovascular health, particularly in susceptible groups.

As a result, the GIS-generated data gives a regional and temporal overview of environmental characteristics in Ondo State, setting the framework for studying their possible impact on cardiovascular disease and mortality. More research, statistical modelling, and evaluation of other confounding factors would be required to demonstrate more robust links between these environmental characteristics and health outcomes. The observed variations in environmental parameters highlight the significance of comprehensive monitoring and targeted efforts to reduce the possible health hazards associated with air quality and temperature changes.

4.2.1 Analyzing Cardiovascular Health in Ondo State: Insights from 2020 Data

The 2020 statistics on Cardio Disease and Death in Ondo State, as shown in Figures 6 and 7, show a varied spatial distribution of health outcomes across different Local Government Areas.

Figure 6 shows the prevalence of Cardio Disease organised into ranges, providing a thorough snapshot of recorded instances. The northern LGAs, which include Akoko North-East, Akoko North-West, Akoko South-East, and Akoko South-West, consistently have a similar number of cases, indicating a uniform incidence of Cardio Disease in these areas. In the state's central region, Akure North and Akure South have significantly lower but steady case counts. Notably, southern LGAs such as Ilaje, Ose, and Owo have a lower prevalence, indicating a unique health profile in these locations.

Figure 7 focuses on cardio death parameters in 2020, illustrating patterns of mortality associated with cardiovascular disease. The northern LGAs continue to exhibit distinct patterns, with Akoko North-East, Akoko North-West, Akoko South-East, and Akoko South-West displaying particular ranges. Akure North and Akure South frequently show ranges associated with Cardio Death, emphasising the importance of cardiovascular health in the core regions. The centre and southern LGAs, which include Idanre, Ifedore, Ilaje, Ile Oluji/Okeigbo, Irele, Odigbo, Ondo East, and Owo, regularly document instances within specified ranges, contributing to a better understanding of Cardio Death distribution.

The observed variances in cardiovascular disease and death metrics underline the necessity for individualised health treatments that take into account the state's different health landscapes. Lifestyle, healthcare access, and socioeconomic situations may all play a role in the reported discrepancies. Further investigation and analysis of these determinants, as well as ongoing monitoring of health outcomes, are required for informed public health strategies and focused interventions to combat cardiovascular disease and minimise associated mortality in Ondo State.

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This inquiry into cardiovascular health in Ondo State, Nigeria, using GIS-generated data, has provided useful insights into the complex link between environmental factors and health outcomes. The study discovered notable trends. Methane exposure levels were consistent, carbon monoxide showed regional variances, nitrogen dioxide showed diversity, sulphur dioxide showed disparities, and temperature ranged consistently throughout Local Government Areas.

The 2020 Cardio Disease and Death parameters highlighted the regional differences, emphasising the importance of targeted health measures. Northern regions generally reported higher illness prevalence, whereas central areas showed unique patterns and southern LGAs had significantly lower prevalence. These findings highlight the importance of continual monitoring, deliberate interventions, and a holistic approach that takes into account lifestyle, healthcare access, and socioeconomic factors. A comprehensive understanding is required for informed public health policies that contribute to the lowering of cardiovascular disease and associated mortality in Ondo State.

5.2 Recommendation

Several recommendations for targeted interventions are made based on the data and insights from the Ondo State cardiovascular health study. First and foremost, health interventions must be prioritised in the northern Local Government Areas (LGAs), notably Akoko North-East, Akoko North-West, Akoko South-East, and Akoko South-West, where cardiovascular disease prevalence stays continuously high. Interventions tailored to the specific health difficulties encountered by these communities will help to reduce the effect of cardiovascular disease.

It is also advised that centralised cardiovascular health programmes be established in central LGAs such as Akure North and Akure South. These localities consistently show ranges indicative of cardiovascular-related mortality. Implementing awareness campaigns, regular health tests, and educational activities will all help to improve cardiovascular health in these communities. Furthermore, extending comprehensive public health education campaigns across all LGAs is recommended, with a focus on lifestyle changes, early detection, and preventive actions. The emphasis on healthy living, frequent exercise, and balanced eating will help to reduce the region's overall cardiovascular disease burden.

Another important recommendation is to invest in improved air quality monitoring infrastructure, particularly in places with changes in pollutants such as carbon monoxide, nitrogen dioxide, and sulphur dioxide. Timely and reliable data will enable preventive efforts to reduce the potential health concerns connected with air pollution. Community involvement and collaboration with local healthcare providers, leaders, and people are critical. Establishing a collaborative approach will guarantee that health initiatives are effectively implemented and address community-specific requirements. Finally, it is recommended to continue monitoring cardiovascular disease and death rates in order to stay up with changing health landscapes. Supporting ongoing research into new factors affecting cardiovascular health helps keep interventions relevant and adaptable to changing situations in Ondo State.

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