Journal of
Modern Chemistry &
Chemical Technology

ISSN: 2229-6999 (Online)
ISSN: 2321-5208 (Print)
January–April
Volume 15, Issue 1, 2024
DOI (Journal): 10.37591/JoMCCT

http://sciencejournals.stmjournals.in/index.php/JoMCCT/index

Research JOMCCT

Monitoring and Modeling of Atmospheric Change Indices in Parts of Imo State Using GIS, MATLAB and ANN

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Abstract

Geographic Information System (GIS) and Matrix Laboratory (MATLAB) Models were used to study air quality in parts of Imo State. Primary data were obtained by conducting relevant analysis using standard instrumental methods on open-air rainwater samples collected in the dry and the rainy seasons for two consecutive years. GIS showed that the pollutants were present throughout the year. Artificial Neural Network (ANN) of MATLAB 2015 was used to represent data with regards to pollutant concentration in all the areas considered. Analysis of Variance (ANOVA) and the Multi-Comparative plots showed that all the Criteria pollutants except CO were affected by seasonal change. All the pollutants exceeded the WHO, NAAQS and FEPA Standards with the Air Quality Index (AQI) indicating poor air quality with grade E for all the areas studied. Hot spot locations appeared more for SO_2, PM_{10}, in the dry seasons while the average concentration of CO showed the same trend with $NO_2$with higher levels during the rainy seasons. Therefore, the findings from this research provides knowledge of patterns and trends of air pollutant dispersion and other reliable information that could be useful to the Government, relevant pollution regulatory agencies and the general public for better proactive decision making and pollution control in Imo State.

Keywords: Air Pollutants, Heavy metals, GIS, MATLAB, ANN.

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Received Date: February 01, 2024
Accepted Date: May 03, 2024
Published Date: May 06, 2024

Citation: J.C. Ike, U.U. Egereonu, C.K. Enenebeaku, C.O. Akalezi, A.A. Bilar, M.C. Igbomezie, J.C. Egereonu, N.J. Okoro, M.O. Ezekoye, I.C. Obiagwu. Monitoring and Modeling of Atmospheric Change Indices in Parts of Imo State Using GIS, MATLAB and ANN. Journal of Modern Chemistry & Chemical Technology. 2024; 15(1): 25–74p.

INTRODUCTION

Atmospheric pollution is one of the major challenging environmental problems facing both the developed and developing countries of the world today. This is associated with sudden weather changes which may result to loss of farm products, damage to properties and sometimes fatalities. These results as flash floods and sudden electric storms overtake areas of farming, industrial and residential activities [1, 2, 3,]. Air pollution is responsible for environmental incidents such as acid rain, precipitation (smog), ozone layer damage, global warming and also play a major role in climate change. It may also cause diseases, allergies and even death to humans, other living organisms such as animals and food crops [4, 5], practically affecting the quality of air and in turn, the quality of life. Volcanic eruptions inject dust, ash, and a variety of chemical compounds into the atmosphere are responsible for climate change and human activities such as the burning of fossil fuel, emission from industries and factories, gas-flaring, vehicular emission, agricultural activities, etc., produce a worldwide increase in the atmospheric concentration of carbon dioxide (CO_2) and other greenhouse gases such as CH_4, N_2O, and H_2O which transmits visible light but traps infrared radiation near the earth's surface resulting to global warming trend [6, 7, 8, 9, 10]. The impacts of climate change threaten our health by affecting the food we eat, the water we drink, the air we breathe, and the weather we experience. Climate change causes high temperature, melting of ice, high rise in sea levels, flooding etc.

Research has shown that the damage cost of air pollution in Nigeria is about 1.2% of the Gross Domestic Product (GDP) which is higher than the Sub-Saharan African region at 0.3% [11]. This is not unconnected to the fact that one of the basic requirements of human existence is clean air. Also, the severity of air pollution problems in the cities reflects the level and speed of development [12, 13, 14]. Like weather, air quality could change daily or even hourly hence, the need for regular monitoring.

The introduction of contaminants such as sulphur dioxide (SO_2), carbon monoxide (CO), nitrogen dioxide (NO_2), particulates and chlorofluorocarbons (CFCs) at toxic level by human activities has resulted to fluctuations in times of the year and also been reported to affect the observed air quality, influencing air pollutants dispersal by either increasing or decreasing their concentration in the atmosphere. The concentration of atmospheric pollutants over the seasons is attributed to weather, atmosphere conditions, emission rates, and topography [15, 16]. Other factors, such as pollutant transportation and transformation, pollutant emissions, meteorological conditions also affect air pollution [17, 18].

Models which integrate new observations into coherent theoretical frameworks were employed to test this understanding by providing results that could be compared with independent data as would be observed in the monitoring locations in both the dry and the rainy seasons for the study duration. Air pollutant mappings produced using these models could be used as an information source to boost the health of the inhabitants of Imo State and would also help relevant agencies make valid decisions necessary and strategic for better pollution policies, control and management.

The contribution of pollution by atmospheric pollutants to poor air quality in Nigeria has continued to be on the increase. Research reveal that over 4.8 million Imolites inhale daily, a deadly mix of particulate matter (PM), asbestos, Sulphur dioxide (SO_2), nitrogen oxide (NO_2), carbon monoxide (CO) and partially un-burnt hydrocarbon [19], which have detrimental effects and contributes to death of thousands annually without being identified as the cause.

However, despite the weight of scientific evidence of the people’s health deterioration, air quality policies in Nigeria has remained the same over the last decade indicating a gap between conventional/traditional measuring monitoring approach and air quality policies [20, 21, 22]. Conventional/traditional measuring methods used in the assessment of air quality can only describe air quality at specific locations and times without giving clear guidance on the identification of the causes of the air quality problem. To make effective urban air quality management programs, comprehensive information about the seasonal and diurnal variation of pollutant concentrations in different areas of a city is needed [23].

Various studies have investigated the effect of seasonality on air pollution using conventional/traditional measuring approaches [24, 25, 26, 27, 28, 29, 30], but not enough work has been carried out in assessing the air quality in different areas of Imo State using more proactive and predictive approaches. Earlier studies have been conducted on atmospheric pollutants to ascertain their dispersion and concentration, validating the result of air quality index using a pool of statistical techniques (spatial variation of pollutants determination using Analysis of Variance (ANOVA), Box

ISSN: 2229-6999 (Online), ISSN: 2321-5208 (Print)

and Whiskers plots as well as Co-efficient of Variation (CV)) to Interpret the observed air quality data [31].

The gap in Nigeria air quality policies exists because relevant authorities are not using proactive predictive approaches in developing effective strategies for air quality planning [32, 33, 21, 34, 22]. However, more predictive and proactive approaches; GIS (IDW method) and MATLAB (Polynomial linear regression) are being used in this research to present the spatial variation of air pollutants concentration in the study area and interpret the experimental/actual data. This approach will provide more complete information on urban air pollution helping scientists and urban planners devise better solution to the problem of urban air pollution and population exposure.

MATERIALS AND METHODS

Gasman Air-Monitor-Crowcon, Hazdust Particulate Monitor –Model EPAM 5000, Pollution Models-GIS (IDW Method), MATLAB 2015 (Polynomial linear regression).

Study Area

Imo State lies within latitudes 4°45'N and 7°15'N, and longitude 6°50'E and 7°25'E with an area of around 5,100 sq. km. The state has a population of approximately 3.9 million according to the 2006 census, a projected population of 5,408,800. The study areas consist of Owerri Municipal, Ehime Mbano and Mbaitoli. Owerri is the State capital of Imo State, Nigeria. Rain falls for most months of the year with a brief dry season. The rainy season begins in April and lasts until October, with annual rainfall varying from 1,500 mm to 2,200 mm (60 to 80 inches). An average annual temperature above 20°C (68°F) creates an annual relative humidity of 75%, with humidity reaching 90% in the rainy season. The dry season is experienced between two months of harmattan from December to late February.

Geological Map of Study Area

Brief description of Imo State Sampling Locations

2.4 Air Quality Sampling Gas pollutants Concentrations were collected from the distributed sampling stations across the study area and Coordinate values of locations captured using GPS (Global Positioning System) device. Stratified random sampling technique was used using the Crowcon Gas Monitor while dust concentration was measured using the HAZ-DUST EPAM 5000 Particulate Monitor in the selected. Sampling frequency for the criteria air pollutants (SO_2, CO, NO_2& PM_{10}) carried out twice weekly for 14 weeks in both the dry and the rainy seasons in the 35 select air monitoring locations for 2 years. The gas pollutants were determined

MATLAB Modeling

MATLAB modeling was used for the analysis of the research. Simple linear regression technique was used to provide a means to model a straight line relationship between an independent and a dependent variable. The five variables used for this research include; Location (longitude and latitude) of study area, Population of the study area, Wind speed of the study area, Distance of study area from the reference, Height of measuring equipment from ground level.

The regression model is given by: $y = mx + c$ (basic polynomial equation) Where, y = Output dependent variable (Pollutant Concentration in the atmosphere) x = Independent input variable (Location, population, distance, height) m = Slope c = y-intercept

$$y = a_o x + a$$

Using the fifth degree polynomial, $y = a_o + x_1a_1 + x_2a_2 + x_3a_3 + x_4a_4 + x_5a_5$ (1)

Obtaining the matrix schematics from the mathematical equation

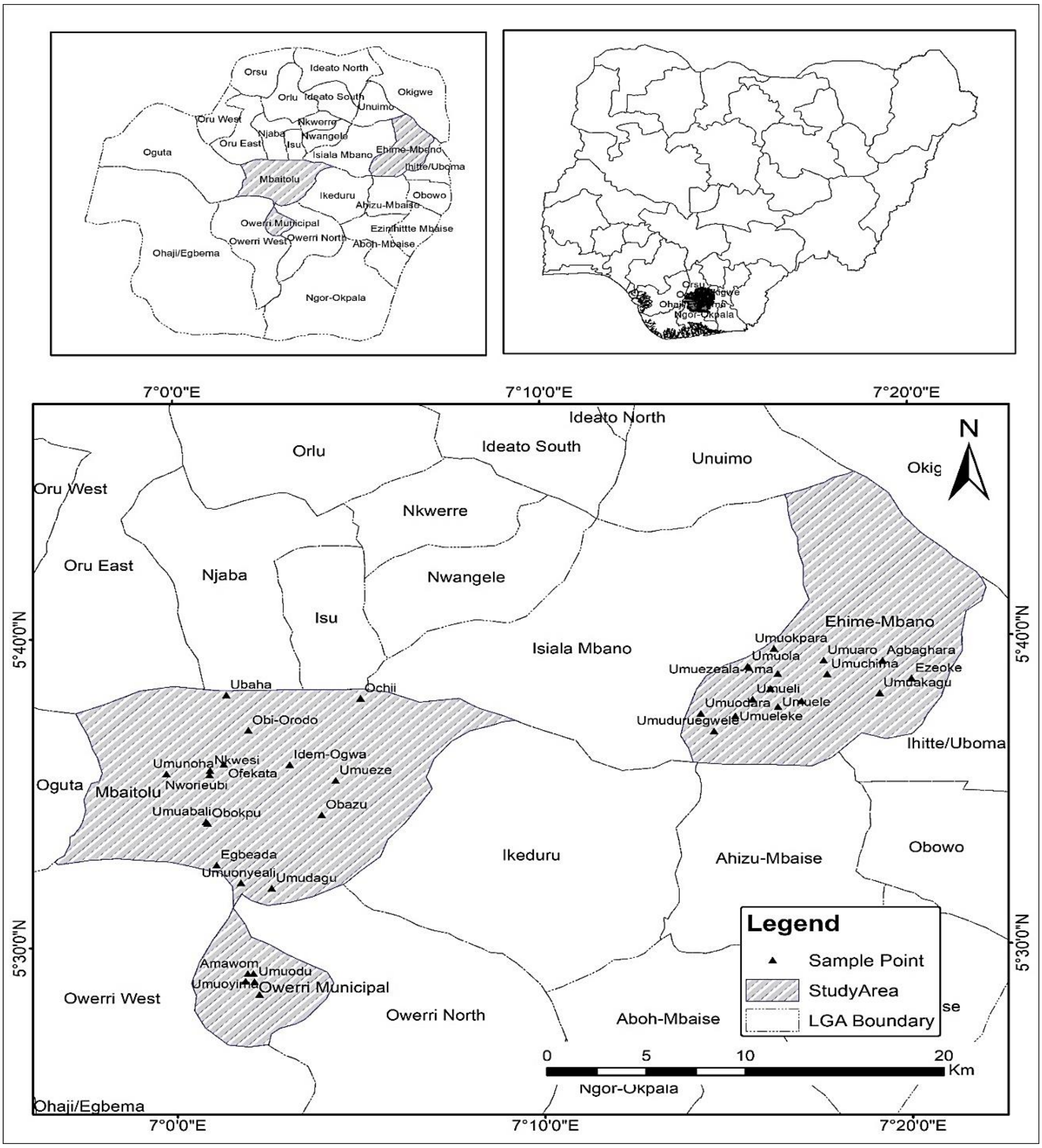


Figure 1. GIS Map of Study Area showing Imo State Sampling locations.

Table 1. The GPS and Description of each Sampling Location.

S/N	Sampling Area	Co-Ordinates (Longitude/Latitude)	Sampling Site	Description
	Owerri Municipal L.G.A.			
1.	Amawom	5.48570, 7.03221	Ekeonunwa Street, Owerri.	Commercial, Residential
2.	Umuodu	5.48141, 7.03523	Ihugba Street, Owerri	Commercial, Residential
3.	Umuonyeche	5.48166, 7.03113	Rotobi Street, Owerri.	Commercial, Residential
4.	Umuoyima	5.47454, 7.03747	Oyima Street, Owerri.	Commercial, Residential
5.	Umuororonjo	5.48585, 7.03473	Oha-Owerre Hall	Commercial, Residential
	Ehime Mbano L.G.A.			

	Umuezeala			
6.	Umuezeala-Ama	5.64607, 7.27366	Umuezeala-Ama Secondary School.	Residential
7.	Umuezeala-Owerre	5.63123, 7.28432	Mercy girls Sec. Sch., Umuezeala, Owerre.	Commercial, Residential
8.	Umuopara	5.63804, 7.27029	Lutheran Church, Umuopara, Ogboama, Umuezeala.	Residential
	Umueze II			
9.	Umueleke	5.62340, 7.25425	St. Michael's Catholic Church, Umueleke.	Residential
10.	Umuodara	5.62479, 7.23861	Emmanuel Anglican Church, Umuodara.	Residential
11.	Umuduruegwele	5.61529, 7.24459	Umuduruegwele Health Center, Umueze II.	Residential
	Umunakanu			
12.	Umuele	5.62821, 7.27366	Oil Mill, Umuele.	Commercial, Residential
13.	Umueli	5.63233, 7.26211	St. Barnabas Ang. Church, Umueli, Umunakanu.	Residential
14.	Umuola	5.65517, 7.25774	St. Mathias Anglian Church, Umuola, Umunakanu.	Residential
	Umunumo			
15.	Umuaro	5.65312, 7.29449	Nkwo-Umunumo.	Commercial, Residential
16.	Umuokpara	5.65957, 7.27201	Ibeafor Sec. Sch., Umunumo.	Residential
17.	Umuchima	5.64561, 7.29604	St. Charles Catholic Parish, Umuchima, Umunumo.	Residential
	Nsu			
18.	Agbaghara	5.65281, 7.32121	St. Columbus Catholic Church, Agbaghara, Nsu.	Residential
19.	Ezeoke	5.64312, 7.33425	St. Paul's Cathedral, Ezeoke, Nsu.	Residential
20.	Umuakagu	5.63528, 7.31985	St. Mark's Anglican Church, Umuakagu.	Commercial, Residential
	Mbaitoli L.G.A			
	Mbieri			
21.	Obazu	5.57121, 7.06627	Obazu Girls Sec. Sch., Obazu, Mbieri.	Commercial, Residential
22.	Umuonyeali	5.53472, 7.02946	Industrial Market, Umuonyeali, Mbieri.	Commercial, Residential
23.	Umudagu	5.53176, 7.04340	Ukwu-Uko, Umudagu, Mbieri.	Commercial, Residential
	Ogwa			
24.	Idem-Ogwa	5.59841, 7.05204	St. Marks Church, Idem-Ogwa.	Residential
25.	Ochii	6.65454, 7.08435	St. James Ang. Church, Ochii, Ogwa.	Residential
26.	Umueze-Ogwa	5.64068, 7.06507	Ang. Church, Umueze, Ogwa.	Residential
	Ubomiri			
27.	Egbeada	5.54443, 7.01844	Holy Family Table Water, Egbeada, Ubommiri.	Commercial, Residential
28.	Obokpu	5.56700, 7.01453	Nkwo-Ubommiri Market.	Commercial, Residential
29	Umuabali	5.56789, 7.01385	St. Mary's Catholic Church, Umuabali, Ubommiri.	Residential

	Orodo			
30.	Obi-Orodo	5.61708, 7.03330	Primary Health Center, Obi-Orodo.	Residential
31.	Ofekata	5.59882, 7.02211	Shammah Int'l Sch., Ofekata, Orodo.	Residential
32.	Ubaha	5.63619, 7.02343	St. Paul's Ang. Church, Ubaha, Orodo.	Residential
	Ifakala			
33.	Umunoha	5.59381, 6.99607	Holy Trinty Anglican Church, Ifakala, Umunoha.	Residential
34.	Nworieubi	5.59312, 7.01563	UBA, Nworieubi.	Commercial, Residential
35.	Nkwesi	5.59548, 7.01586	Nkwesi Town Hall	Residential

$$= \begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ - \\ - \\ - \\ y_{14} \end{bmatrix} \begin{bmatrix} 1 \\ 1 \\ 1 \\ - \\ - \\ - \\ 1 \end{bmatrix} \begin{bmatrix} x_1 & x_2 & x_3 & x_4 & x_5 \\ x_6 & x_7 & x_8 & x_9 & x_{10} \\ x_{11} & x_{12} & x_{13} & x_{14} & x_{15} \\ - & - & - & - & - \\ - & - & - & - & - \\ - & - & - & - & - \\ x_{66} & x_{67} & x_{68} & x_{69} & x_{70} \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \\ a_2 \\ - \\ - \\ - \\ a_{13} \end{bmatrix}$$

$$y \quad = \quad x \quad * \quad a$$

Figure 2. MATLAB Matrix Schematics

Finding the inverse of x; a = y/x

Multiplying the inverse of x and y = yx^{-1}

a = Regression coefficient

a_o = Factor

1….5 = Order of polynomial

GIS Modelling

To achieve the above GIS modelling results for the predicted value of the unsampled location from the weighted values, data was collected from the stations varied in season, both the dry and the wet seasons for two years. This data was cleaned, converted to machine language (Comma Separate Value) and stored in the folder readable by the software. Arcmap 10.6 software was used to perform the interpolation method as stated above. The area extent to be used was Imo State boundary, IDW Power coefficient of 2. Inverse distance weighted (IDW) interpolation explicitly shows that measured values closest to the prediction location have more influence on the predicted value than those farther away.

Determination of Air Quality Index Analysis (AQI)

AQI is used to communicate to the public how polluted the air currently is or how polluted it is forecast to become [33]. It describes ambient air quality. AQI can increase due to an increase of air emissions. As it increases, an increasing percentage of the population is likely to experience increasingly severe adverse health effects. AQI is based on “Criteria” pollutants regulated under the clean air act; SO_2, CO, NO_2& PM_{10}.

Index = Pollutant Concentration x 100 Pollutant Standard Level

RESULTS

Results obtained from the analysis of pollutants concentration of the atmosphere in 35 select locations within Imo State in both the dry seasons (November D_1, January D_2, February D_3) and the rainy seasons (June R_1, July R_2, August R_3) for a 2-year analytical period using standard instrumental methods are as follows;

Table 2. Dry Season (Year 1) Mean Value Data for Gases and PM_{10}

S/N	Sampling Area	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	PM_{10} (mg/m^3)
	Owerri Municipal L.G.A.				
1.	Amawom	40	0.55	0.82	10.35
2.	Umuodu	40	0.54	0.82	10.54
3.	Umuonyeche	40	0.53	0.85	10.54
4.	Umuoyima	41	0.54	0.82	10.44
5.	Umuororonjo	39	0.55	0.85	10.54
	Ehime Mbano L.G.A.				
	Umuezeala				
6.	Umuezeala-Ama	48	0.63	0.51	12.34
7.	Umuezeala-Owerre	48	0.64	0.53	12.39
8.	Umuopara	48	0.65	0.53	12.10
	Umueze II				
9.	Umueleke	47	0.62	0.53	12.17
10	Umuodara	47	0.62	0.52	12.16
11.	Umuduruegwele	47	0.64	0.56	12.24
	Umunakanu				
12.	Umuele	46	0.64	0.52	12.30
13.	Umueli	47	0.64	0.55	12.37
14.	Umuola	48	0.63	0.52	12.20
	Umunumo				
15.	Umuaro	46	0.60	0.50	12.15
16.	Umuokpara	46	0.65	0.54	12.30
17.	Umuchima	47	0.63	0.53	12.30
	Nsu				
18.	Agbaghara	49	0.68	0.56	12.30
19.	Ezeoke	50	0.65	0.55	12.12
20.	Umuakagu	48	0.63	0.55	12.11
	Mbaitoli L.G.A				
	Mbieri				
21.	Obazu	43	0.65	0.60	10.12
22.	Umuonyeali	44	0.63	0.62	10.21
23.	Umudagu	44	0.62	0.62	10.33
	Ogwa				
24.	Idem-Ogwa	43	0.62	0.62	10.23
25.	Ochii	43	0.65	0.65	10.38
26.	Umueze	43	0.63	0.61	10.33

	Ubomiri				
27.	Egbeada	46	0.69	0.65	11.70
28.	Obokpu	46	0.70	0.64	11.45
29	Umuabali	45	0.68	0.62	11.55
	Orodo				
30.	Obi-Orodo	46	0.69	0.64	11.50
31.	Ofekata	47	0.69	0.63	11.56
32.	Ubaha	45	0.70	0.62	11.63
	Ifakala				
33.	Umunoha	45	0.72	0.60	11.47
34.	Nworieubi	47	0.74	0.67	11.69
35.	Nkwesi	46	0.71	0.64	11.46

Table 3. Rainy Season (Year 1) Mean Value Data for Gases and PM_{10}

S/N	Sampling Area	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	PM_{10} (mg/m^3)
	Owerri Municipal L.G.A.				
1.	Amawom	51	0.58	0.67	7.36
2.	Umuodu	52	0.58	0.68	7.52
3.	Umuonyeche	52	0.60	0.67	7.55
4.	Umuoyima	53	0.58	0.67	7.50
5.	Umuororonjo	52	0.59	0.68	7.53
	Ehime Mbano L.G.A.				
	Umuezeala				
6.	Umuezeala-Ama	62	0.66	0.42	8.77
7.	Umuezeala-Owerre	62	0.65	0.45	8.65
8.	Umuopara	62	0.68	0.45	8.70
	Umueze II				
9.	Umueleke	61	0.65	0.43	8.54
10	Umuodara	62	0.65	0.43	8.57
11.	Umuduruegwele	62	0.66	0.45	8.54
	Umunakanu				
12.	Umuele	60	0.68	0.43	8.60
13.	Umueli	60	0.68	0.45	8.61
14.	Umuola	60	0.67	0.47	8.63
	Umunumo				
15.	Umuaro	62	0.64	0.43	8.55
16.	Umuokpara	61	0.67	0.44	8.56
17.	Umuchima	62	0.66	0.45	8.58
	Nsu				
18.	Agbaghara	63	0.70	0.46	8.65
19.	Ezeoke	64	0.68	0.45	8.63
20.	Umuakagu	64	0.65	0.45	8.60
	Mbaitoli L.G.A				
	Mbieri				
21.	Obazu	55	0.65	0.50	7.32
22.	Umuonyeali	56	0.68	0.51	7.34
23.	Umudagu	57	0.67	0.52	7.35
	Ogwa				

24.	Idem-Ogwa	56	0.65	0.54	7.25
25.	Ochii	56	0.68	0.55	7.21
26.	Umueze	57	0.67	0.52	7.24
	Ubomiri				
27.	Egbeada	58	0.71	0.55	8.18
28.	Obokpu	58	0.73	0.54	8.20
29	Umuabali	57	0.71	0.53	8.21
	Orodo				
30.	Obi-Orodo	59	0.73	0.54	8.05
31.	Ofekata	58	0.74	0.54	8.06
32.	Ubaha	59	0.73	0.53	8.04
	Ifakala				
33.	Umunoha	58	0.75	0.50	8.24
34.	Nworieubi	59	0.77	0.54	8.35
35.	Nkwesi	57	0.75	0.54	8.31

Table 4. Dry Season (Year 2) Mean Value Data for Gases and PM_{10}

S/N	Sampling Area	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	PM_{10} (mg/m^3)
	Owerri Municipal L.G.A.				
1.	Amawom	44	0.62	0.90	11.05
2.	Umuodu	43	0.58	0.88	11.08
3.	Umuonyeche	43	0.56	0.88	11.16
4.	Umuoyima	45	0.57	0.87	11.15
5.	Umuororonjo	42	0.56	0.86	11.00
	Ehime Mbano L.G.A.				
	Umuezeala				
6.	Umuezeala-Ama	51	0.65	0.55	12.88
7.	Umuezeala-Owerre	50	0.65	0.58	12.82
8.	Umuopara	50	0.66	0.56	12.80
	Umueze II				
9.	Umueleke	50	0.63	0.55	12.80
10	Umuodara	49	0.65	0.54	12.84
11.	Umuduruegwele	51	0.64	0.58	12.82
	Umunakanu				
12.	Umuele	49	0.68	0.55	12.86
13.	Umueli	50	0.65	0.57	12.87
14.	Umuola	51	0.66	0.56	12.80
	Umunumo				
15.	Umuaro	50	0.63	0.53	12.75
16.	Umuokpara	49	0.68	0.57	12.83
17.	Umuchima	48	0.65	0.56	12.70
	Nsu				
18.	Agbaghara	49	0.70	0.58	12.74
19.	Ezeoke	52	0.68	0.57	12.72
20.	Umuakagu	50	0.65	0.58	12.80
	Mbaitoli L.G.A				
	Mbieri				

21.	Obazu	46	0.67	0.63	10.78
22.	Umuonyeali	47	0.65	0.64	10.21
23.	Umudagu	46	0.63	0.64	10.33
	Ogwa				
24.	Idem-Ogwa	45	0.64	0.65	10.87
25.	Ochii	46	0.68	0.65	10.88
26.	Umueze	46	0.65	0.65	10.93
	Ubomiri				
27.	Egbeada	48	0.70	0.67	12.20
28.	Obokpu	48	0.72	0.68	11.91
29	Umuabali	45	0.70	0.66	12.15
	Orodo				
30.	Obi-Orodo	47	0.70	0.67	11.95
31.	Ofekata	48	0.71	0.65	11.96
32.	Ubaha	45	0.72	0.65	11.95
	Ifakala				
33.	Umunoha	47	0.72	0.63	11.93
34.	Nworieubi	50	0.76	0.65	12.04
35.	Nkwesi	50	0.74	0.64	12.01

Table 5. Rainy Season (Year 2)Mean Value Data for Gases and PM_{10}

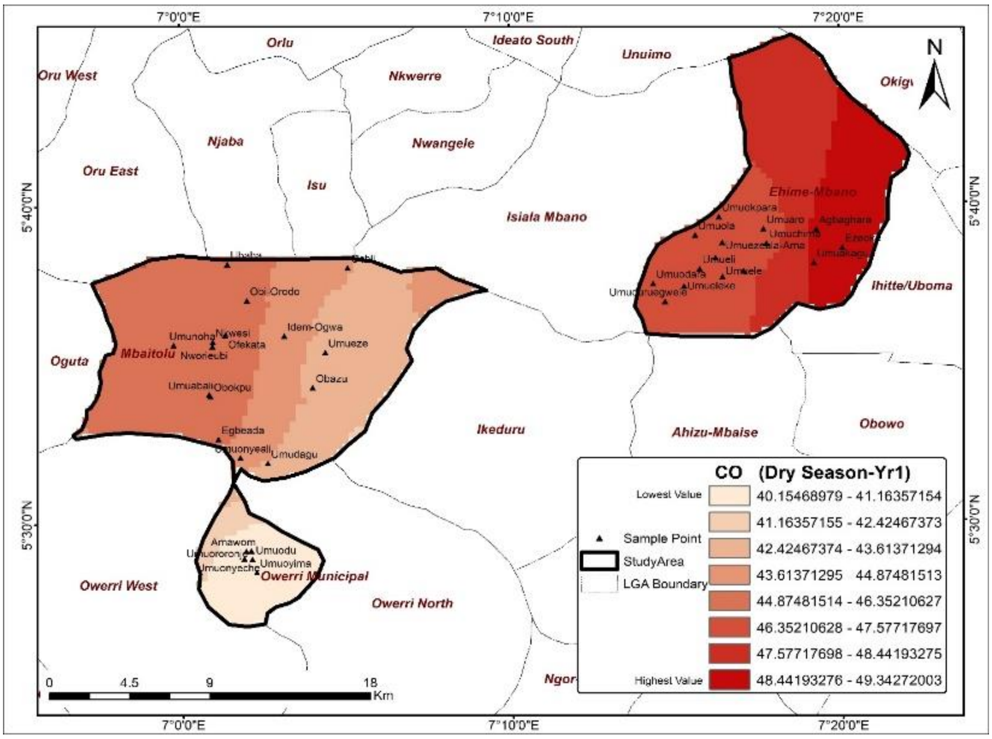
S/N	Sampling Area	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	PM_{10} (mg/m^3)
	Owerri Municipal L.G.A.				
1.	Amawom	56	0.78	0.75	7.70
2.	Umuodu	54	0.78	0.78	7.69
3.	Umuonyeche	56	0.77	0.76	7.72
4.	Umuoyima	56	0.75	0.78	7.71
5.	Umuororonjo	55	0.76	0.77	7.68
	Ehime Mbano L.G.A.				
	Umuezeala				
6.	Umuezeala-Ama	66	0.84	0.51	9.01
7.	Umuezeala-Owerre	65	0.85	0.50	8.86
8.	Umuopara	66	0.84	0.51	8.85
	Umueze II				
9.	Umueleke	65	0.85	0.48	8.85
10	Umuodara	67	0.86	0.51	8.90
11.	Umuduruegwele	65	0.87	0.50	8.92
	Umunakanu				
12.	Umuele	67	0.83	0.52	8.85
13.	Umueli	64	0.85	0.50	8.85
14.	Umuola	65	0.84	0.48	8.78
	Umunumo				
15.	Umuaro	65	0.83	0.49	8.86
16.	Umuokpara	65	0.85	0.50	8.95
17.	Umuchima	68	0.85	0.50	8.84
	Nsu				
18.	Agbaghara	65	0.80	0.50	8.94

19.	Ezeoke	66	0.83	0.52	9.02
20.	Umuakagu	65	0.85	0.50	8.95
	Mbaitoli L.G.A				
	Mbieri				
21.	Obazu	58	0.87	0.51	8.42
22.	Umuonyeali	57	0.86	0.52	8.46
23.	Umudagu	57	0.87	0.51	8.45
	Ogwa				
24.	Idem-Ogwa	56	0.91	0.53	8.52
25.	Ochii	58	0.92	0.51	8.53
26.	Umueze	57	0.93	0.54	8.55
	Ubomiri				
27.	Egbeada	58	0.90	0.56	8.68
28.	Obokpu	56	0.91	0.50	8.65
29	Umuabali	58	0.86	0.53	8.70
	Orodo				
30.	Obi-Orodo	62	0.93	0.53	8.85
31.	Ofekata	61	0.90	0.54	8.76
32.	Ubaha	61	0.86	0.55	8.75
	Ifakala				
33.	Umunoha	58	0.87	0.53	8.81
34.	Nworieubi	62	0.93	0.55	8.85
35.	Nkwesi	61	0.86	0.54	8.80

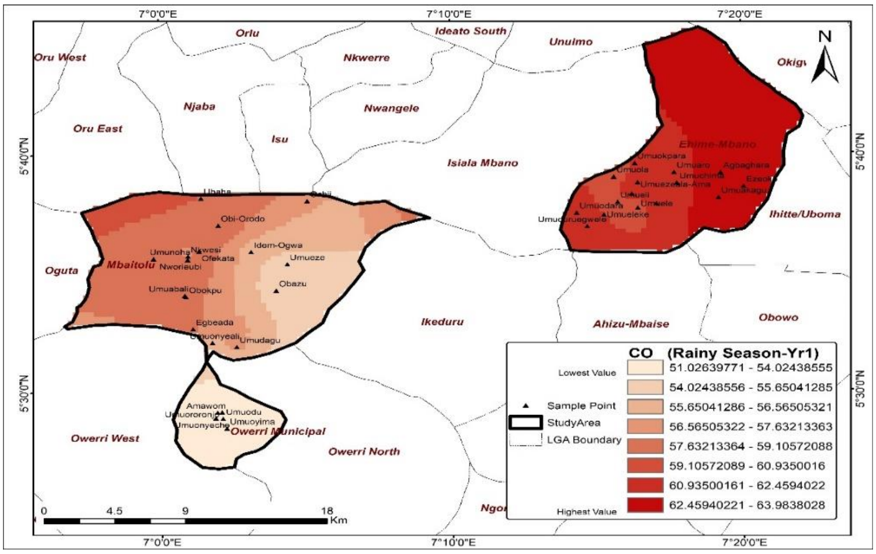
Table 6. Mean Values for CO (ppm) for both years

S/N	Sampling Area	YR1 DRY	YR2 Dry	Dry Mean	YR1 Rainy	YR2 Rainy	Rainy Mean
	Owerri Municipal L.G.A						
1.	Amawom	40	44	42	51	56	54
2.	Umuodu	40	43	42	52	54	53
3.	Umuonyeche	40	43	42	52	56	54
4.	Umuoyima	41	45	43	53	56	55
5.	Umuororonjo	39	42	41	52	55	54
	Ehime Mbano L.G.A.						
	Umuezeala						
6.	Umuezeala-Ama	48	51	50	62	66	64
7.	Umuezeala-Owerre	48	50	49	62	65	64
8.	Umuopara	48	50	49	62	66	64
	Umueze II						
9.	Umueleke	47	50	49	61	65	63
10.	Umuodara	47	49	48	62	67	65
11.	Umuduruegwele	47	51	49	62	65	64
	Umunakanu						
12.	Umuele	46	49	48	60	67	64
13.	Umueli	47	50	49	60	64	62
14.	Umuola	48	51	50	60	65	63
	Umunumo						
15.	Umuaro	46	50	48	62	65	64

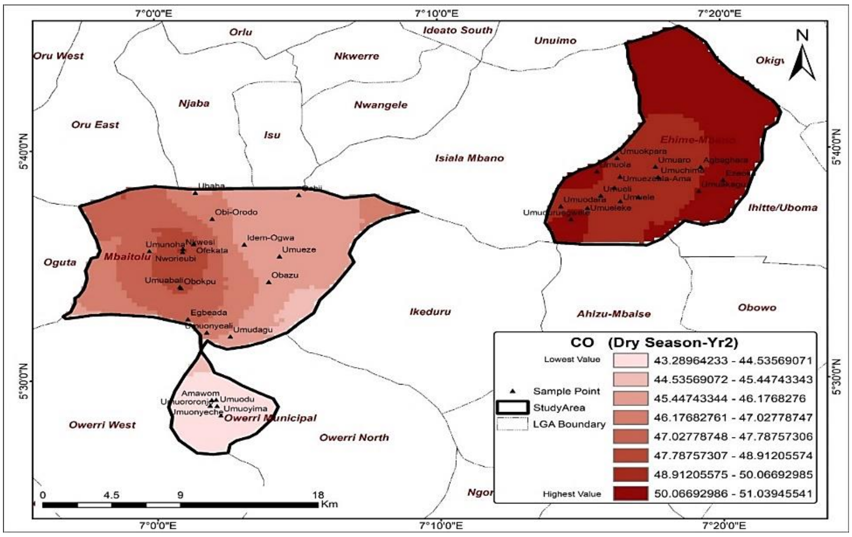
16.	Umuokpara	46	49	48	61	65	63
17.	Umuchima	47	48	48	62	68	65
	Nsu						
18.	Agbaghara	49	49	49	63	65	64
19.	Ezeoke	50	52	51	64	66	65
20.	Umuakagu	48	50	49	64	65	65
	Mbaitoli L.G.A						
	Mbieri						
21.	Obazu	43	46	45	55	58	57
22.	Umuonyeali	44	47	46	56	57	57
23.	Umudagu	44	46	45	57	57	57
	Ogwa						
24.	Idem-Ogwa	43	45	44	56	56	56
25.	Ochii	43	46	45	56	58	57
26.	Umueze	43	46	45	57	57	57
	Ubomiri						
27.	Egbeada	46	48	47	58	58	58
28.	Obokpu	46	48	47	58	56	57
29.	Umuabali	45	45	45	57	58	58
	Orodo						
30.	Obi-Orodo	46	47	47	59	62	61
31.	Ofekata	47	48	48	58	61	60
32.	Ubaha	45	45	45	59	61	60
	Ifakala						
33.	Umunoha	45	47	46	58	58	58
34.	Nworieubi	47	50	49	59	62	61
35.	Nkwesi	46	50	48	57	61	59



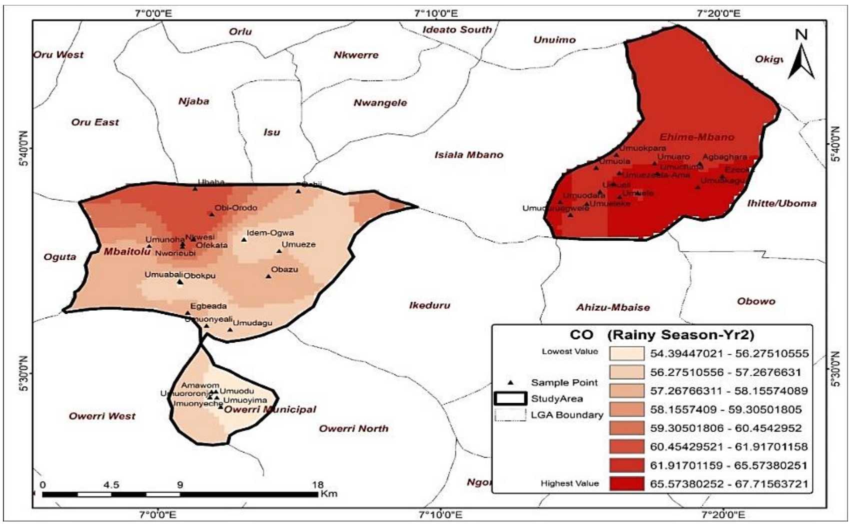
CO at Dry Season Year 1



CO at Rainy Season Year 1

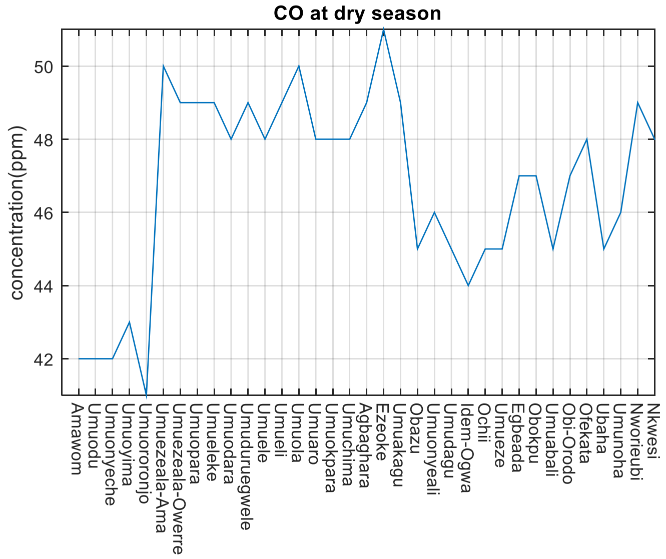


CO at Dry Season Year 2

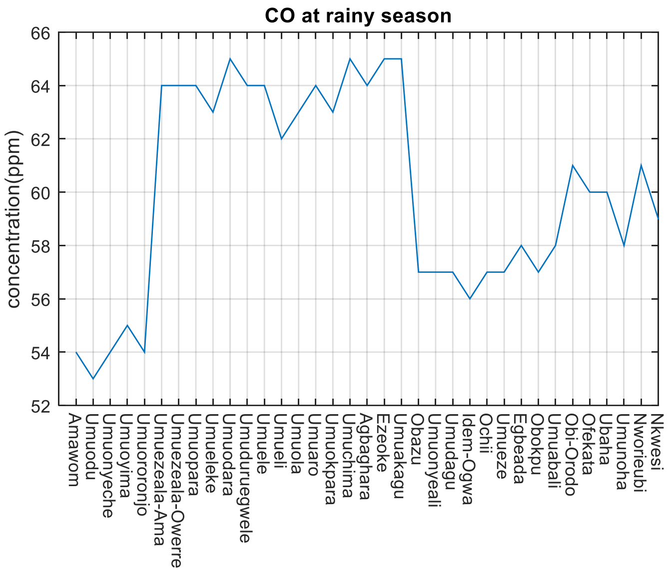


CO at Rainy Season Year 2

Figure 4. Carbon Monoxide GIS Comparison Model.



Carbon Monoxide at Dry Seasons



Carbon Monoxide at Rainy Seasons

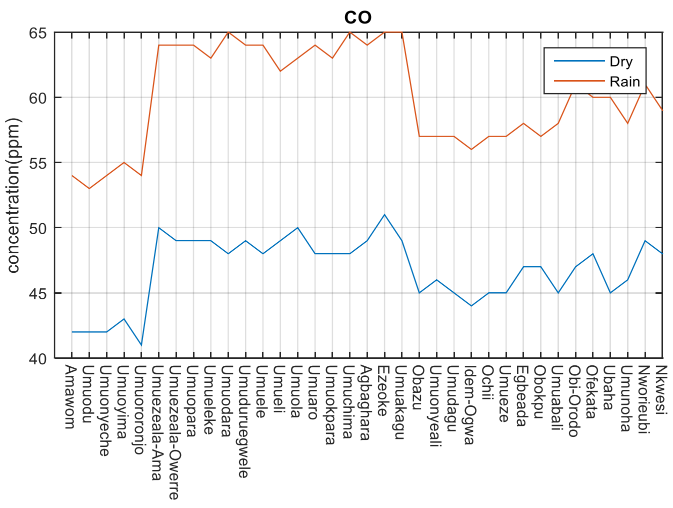
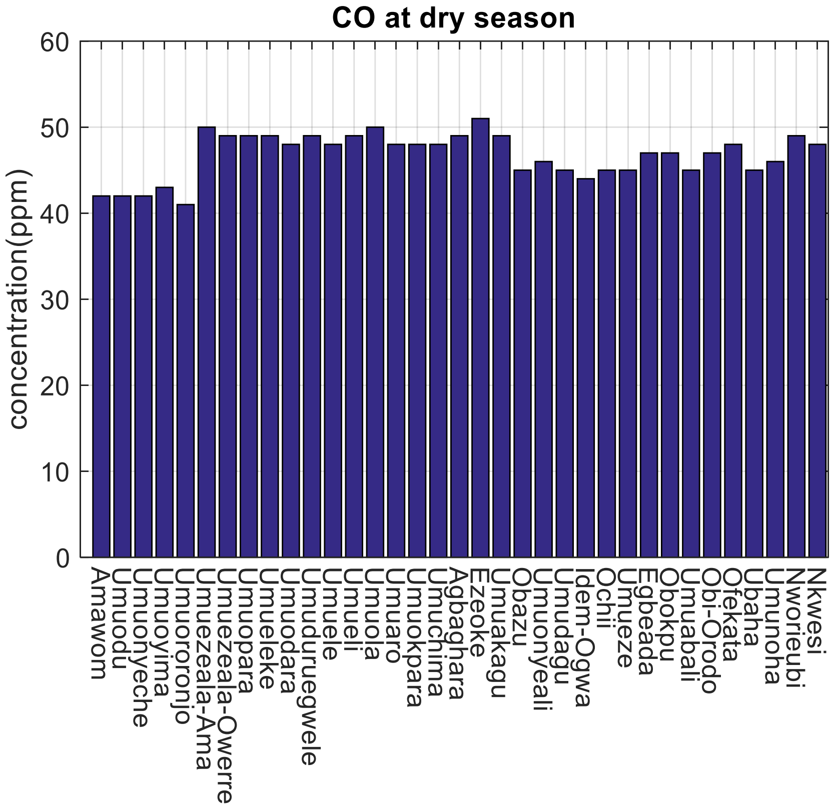
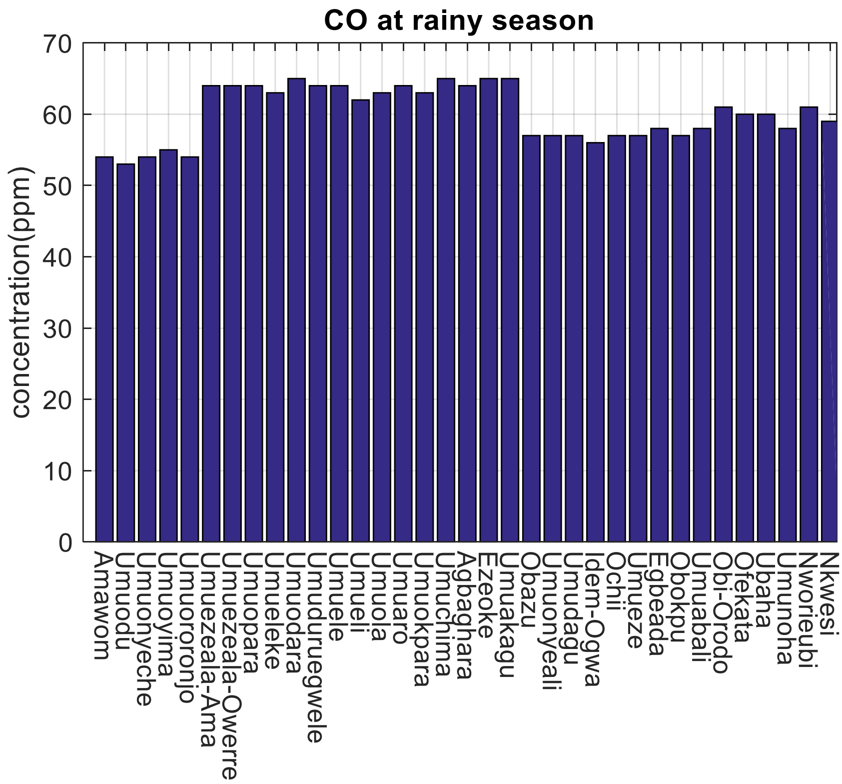


Figure 5. Carbon Monoxide MATLAB Comparison Model.

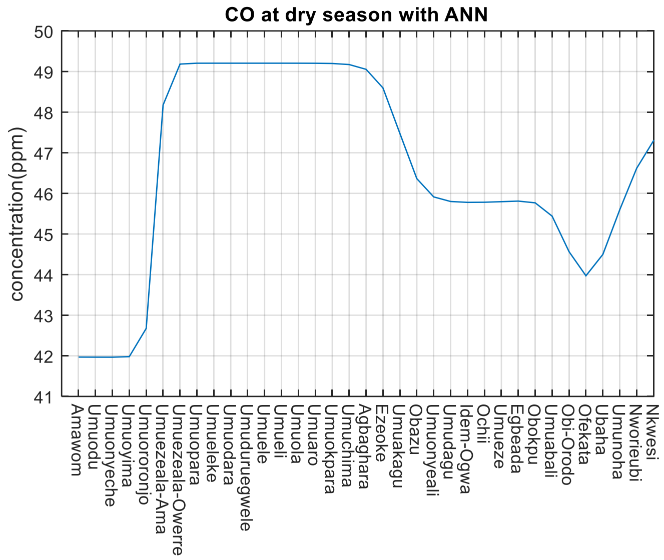


Dry Seasons

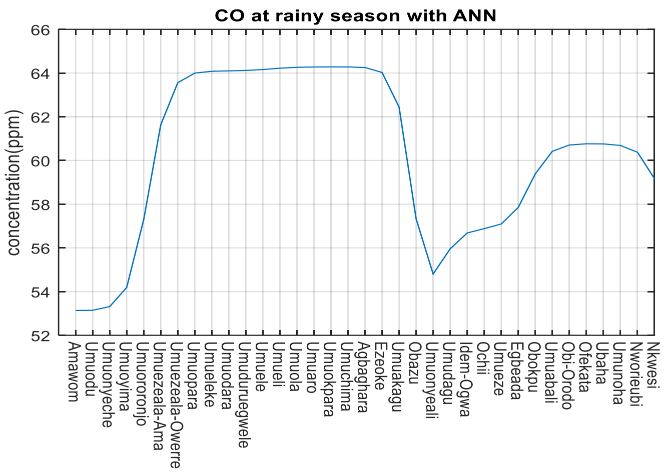


Rainy Seasons

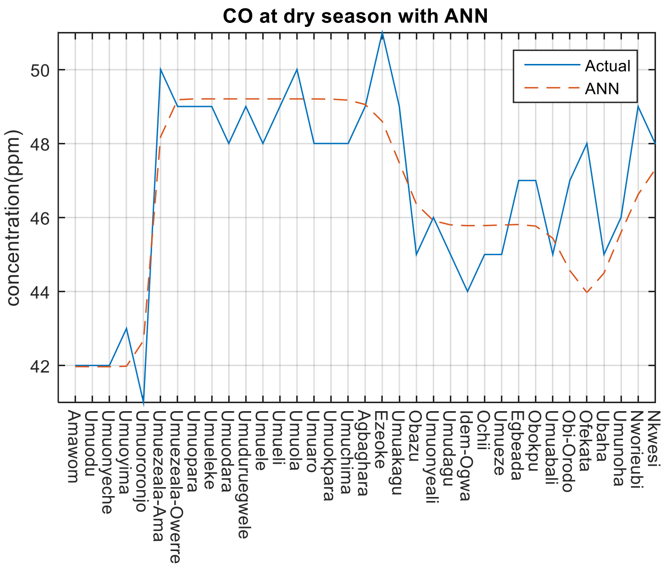
Figure 6. Carbon Monoxide Comparison Bar Chart.



ANN Predicted CO at Dry Seasons



ANN Predicted CO at Rainy Seasons



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ISSN: 2229-6999 (Online), ISSN: 2321-5208 (Print)

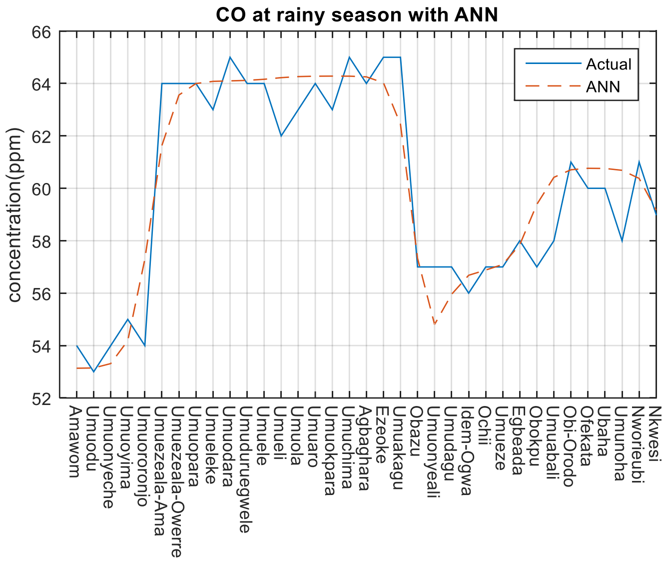


Figure 7. Comparative Analysis of Actual and Predicted CO.

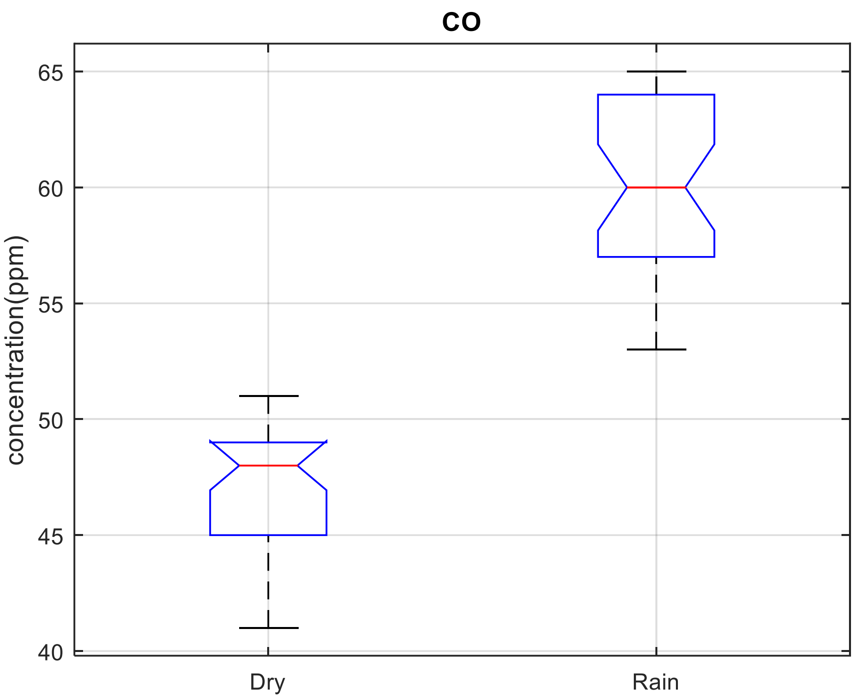


Figure 8. Carbon Monoxide Box & Whiskers Comparative Plot Dry and Rainy Seasons.

Table 7. Carbon Monoxide ANOVA Table.

ANOVA Table

Source	SS	df	MS	F	Prob>F
Columns	3102.23	1	3102.23	284.08	5.60542e-26
Error	742.57	68	10.92		
Total	3844.8	69			

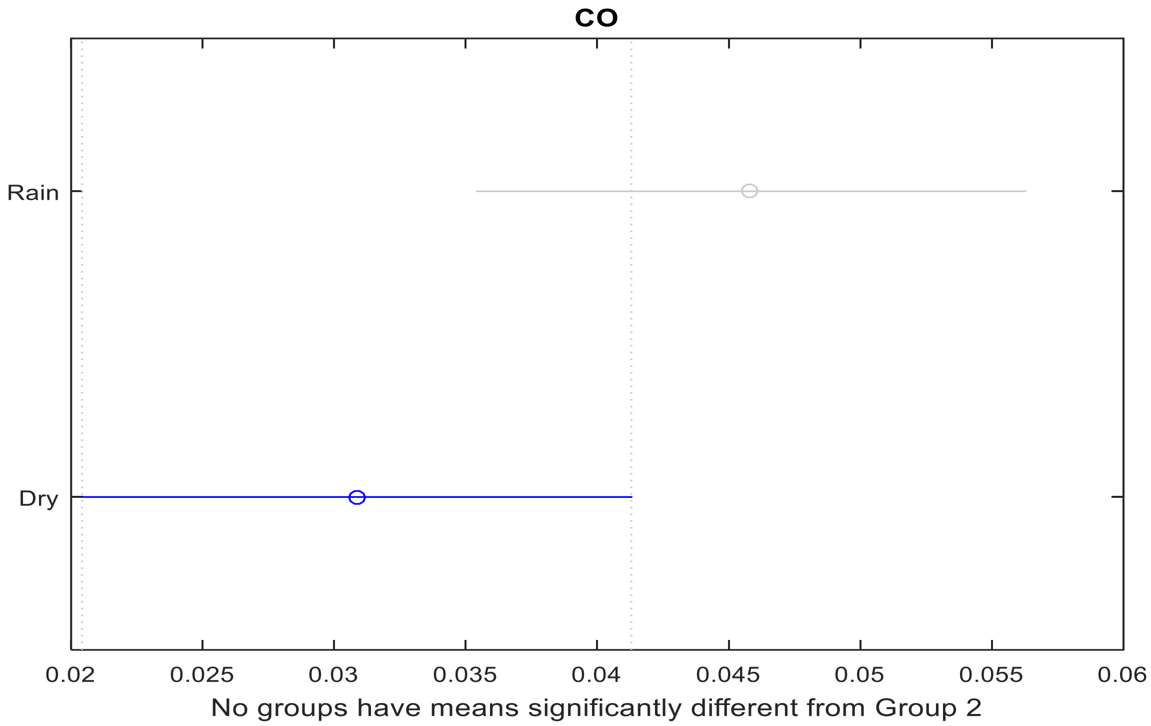
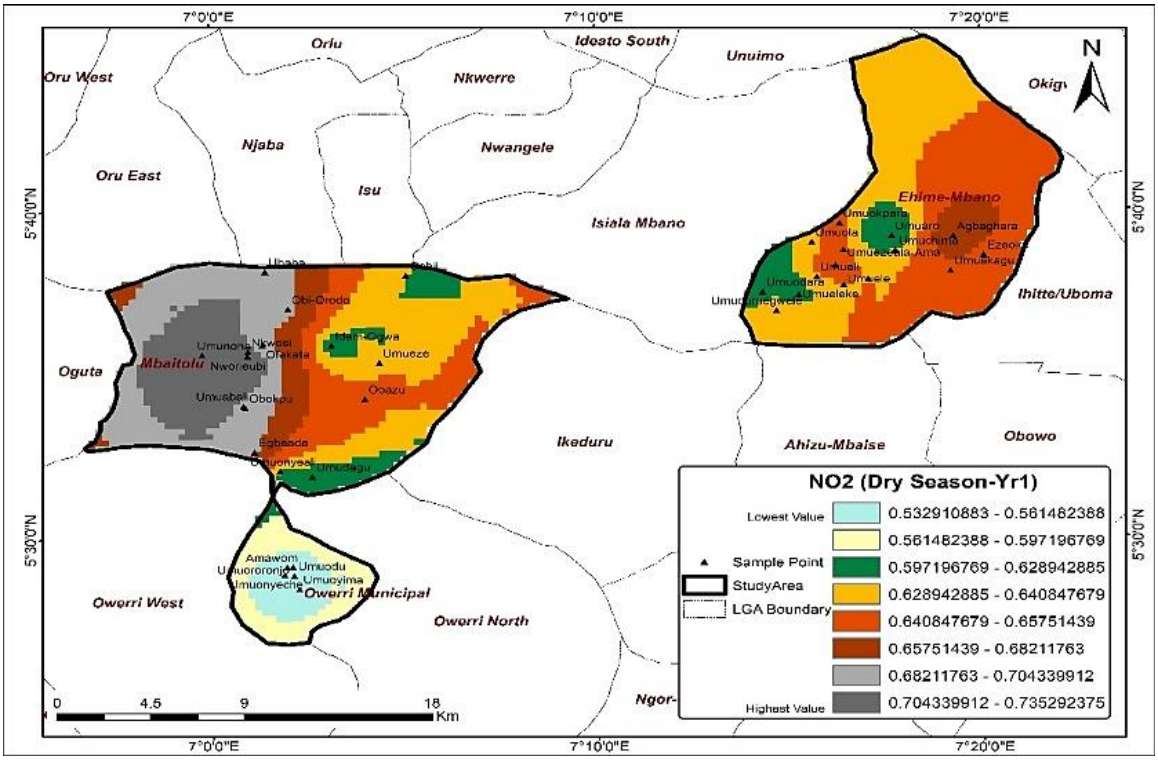


Figure 9. Carbon Monoxide Mean Comparative Analysis Dry and Rainy Seasons.

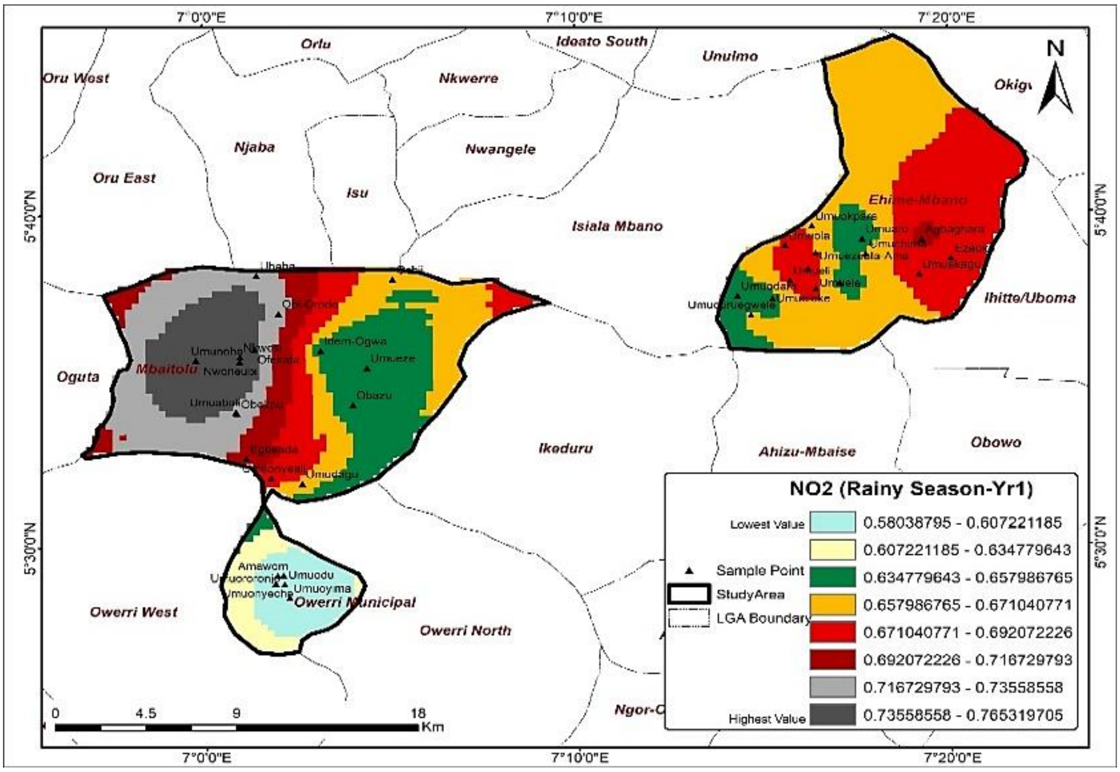
Table 8. Mean Values NO_2 (ppm) for both years

S/N	Sampling Area	YR1 Dry	YR2 Dry	Dry Mean	YR1 Rainy	YR2 Rainy	Rainy Mean
	Owerri Municipal L.G.A						
1.	Amawom	0.55	0.62	0.59	0.58	0.78	0.68
2.	Umuodu	0.54	0.58	0.56	0.58	0.78	0.68
3.	Umuonyeche	0.53	0.56	0.55	0.60	0.77	0.69
4.	Umuoyima	0.54	0.57	0.56	0.58	0.75	0.67
5.	Umuororonjo	0.55	0.56	0.56	0.59	0.76	0.68
	Ehime Mbano L.G.A.						
	Umuezeala						
6.	Umuezeala-Ama	0.63	0.65	0.64	0.66	0.84	0.75
7.	Umuezeala-Owerre	0.64	0.65	0.65	0.65	0.85	0.76
8.	Umuopara	0.65	0.66	0.66	0.68	0.84	0.76
	Umueze II						
9.	Umueleke	0.62	0.63	0.63	0.65	0.85	0.75
10.	Umuodara	0.62	0.65	0.64	0.65	0.86	0.76
11.	Umuduruegwele	0.64	0.64	0.64	0.66	0.87	0.77
	Umunakanu						
12.	Umuele	0.64	0.68	0.66	0.68	0.83	0.76
13.	Umueli	0.64	0.65	0.65	0.68	0.85	0.77
14.	Umuola	0.63	0.66	0.65	0.67	0.84	0.76
	Umunumo						
15.	Umuaro	0.60	0.63	0.62	0.64	0.83	0.74
16.	Umuokpara	0.65	0.68	0.67	0.67	0.85	0.76

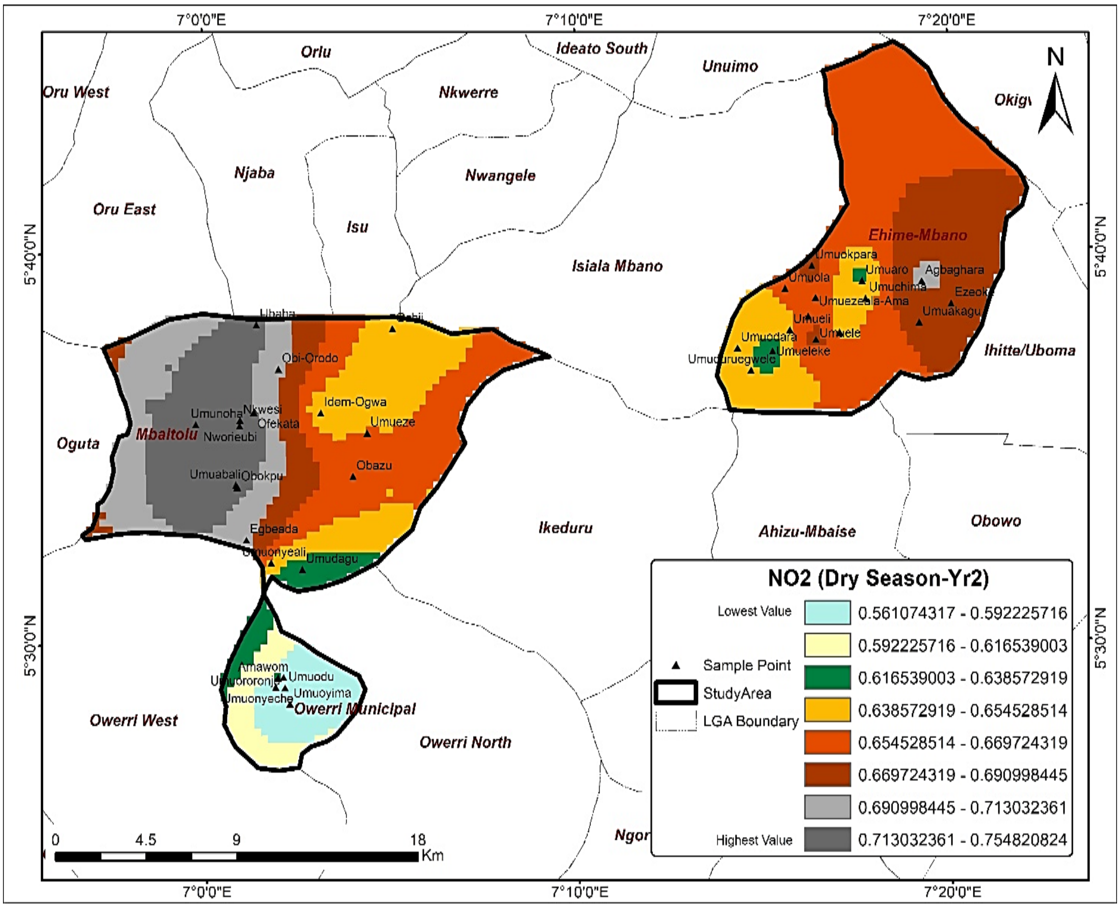
17.	Umuchima	0.63	0.65	0.64	0.66	0.85	0.76
	Nsu						
18.	Agbaghara	0.68	0.70	0.69	0.70	0.80	0.75
19.	Ezeoke	0.65	0.68	0.67	0.68	0.83	0.76
20.	Umuakagu	0.63	0.65	0.64	0.65	0.85	0.75
	Mbaitoli L.G.A						
	Mbieri						
21.	Obazu	0.65	0.67	0.66	0.65	0.87	0.76
22.	Umuonyeali	0.63	0.65	0.64	0.68	0.86	0.77
23.	Umudagu	0.62	0.63	0.63	0.67	0.87	0.77
	Ogwa						
24.	Idem-Ogwa	0.62	0.64	0.63	0.65	0.91	0.78
25.	Ochii	0.65	0.68	0.67	0.68	0.92	0.80
26.	Umueze	0.63	0.65	0.64	0.67	0.93	0.80
	Ubomiri						
27.	Egbeada	0.69	0.70	0.70	0.71	0.90	0.81
28.	Obokpu	0.70	0.72	0.71	0.73	0.91	0.82
29.	Umuabali	0.68	0.70	0.69	0.71	0.86	0.79
	Orodo						
30.	Obi-Orodo	0.69	0.70	0.70	0.73	0.93	0.83
31.	Ofekata	0.69	0.71	0.70	0.74	0.90	0.82
32.	Ubaha	0.70	0.72	0.71	0.73	0.86	0.80
	Ifakala						
33.	Umunoha	0.72	0.72	0.72	0.75	0.87	0.81
34.	Nworieubi	0.74	0.76	0.75	0.77	0.93	0.85
35.	Nkwesi	0.71	0.74	0.73	0.75	0.86	0.81



NO_2 at Dry Season Year 1



NO₂ at Rainy Season Year 1



NO₂ at Dry Season Year 2

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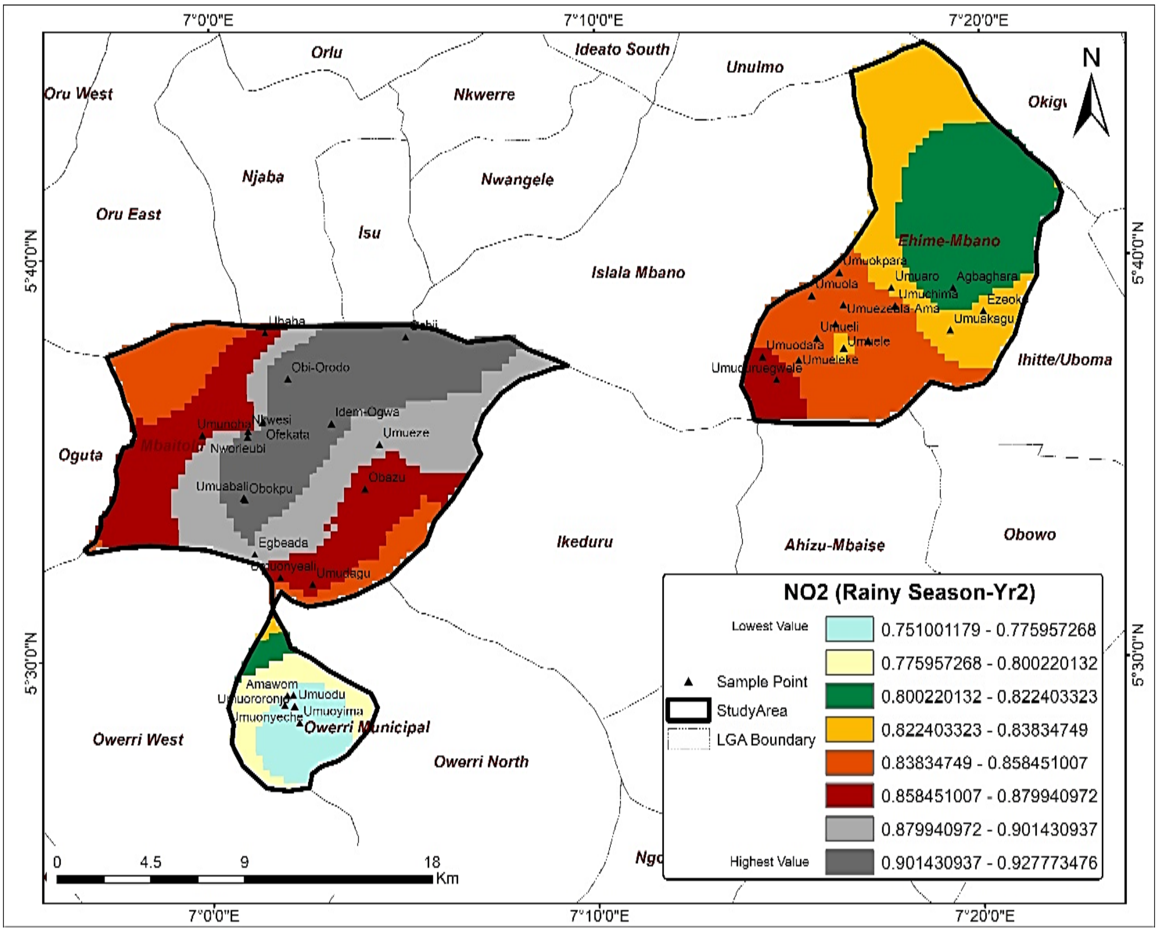
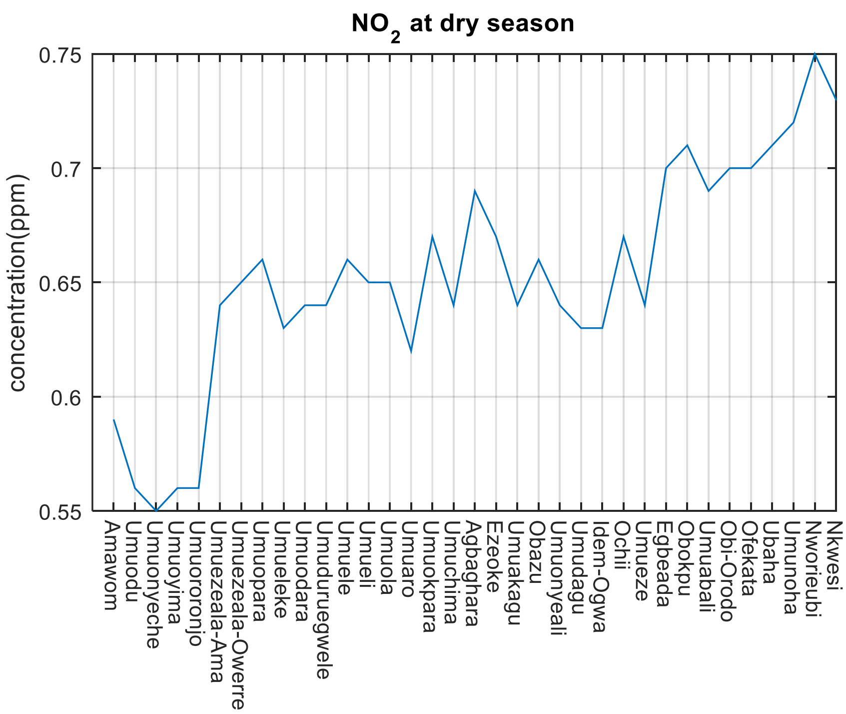
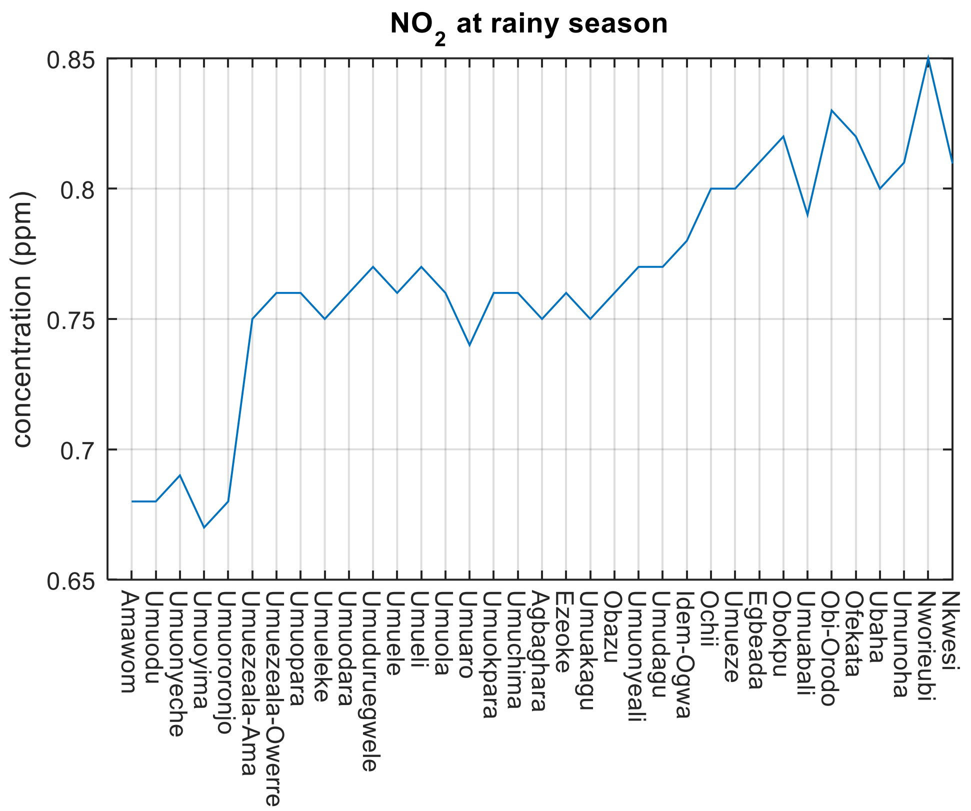


NO_2 at Rainy Season Year 2

Figure 10. Nitrogen Dioxide GIS Comparison Model.



Nitrogen Dioxide at Dry Seasons



Nitrogen Dioxide at Rainy Seasons

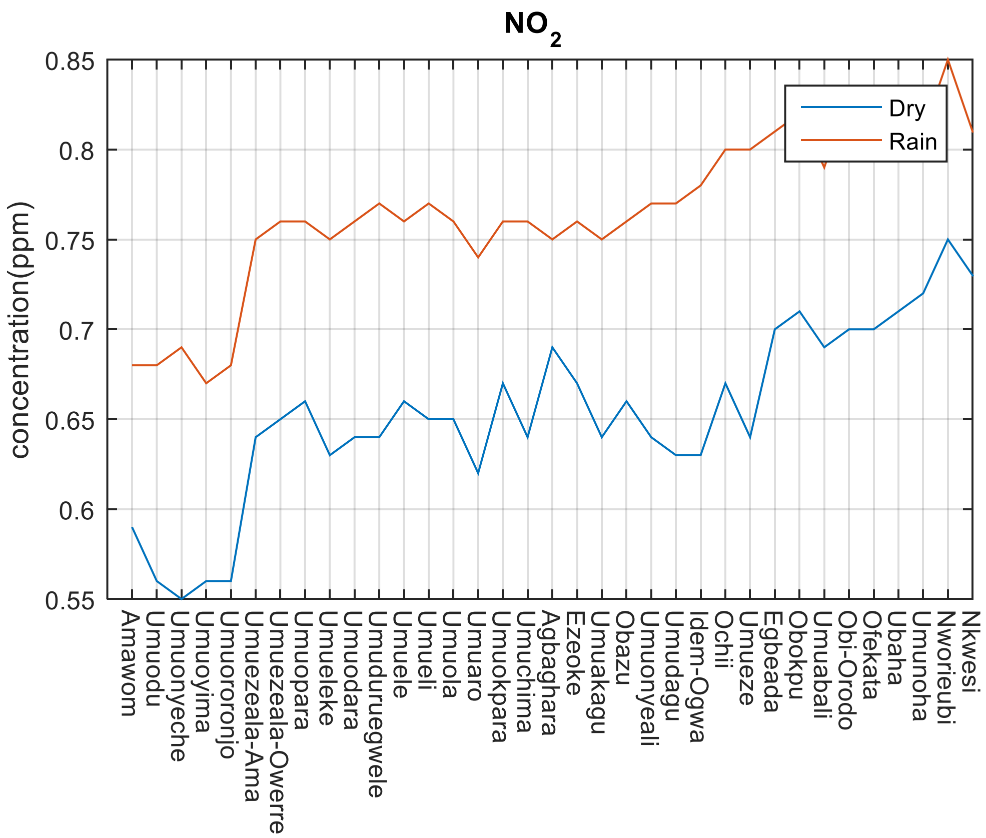


Figure 11. Nitrogen Dioxide MATLAB Comparison Model.

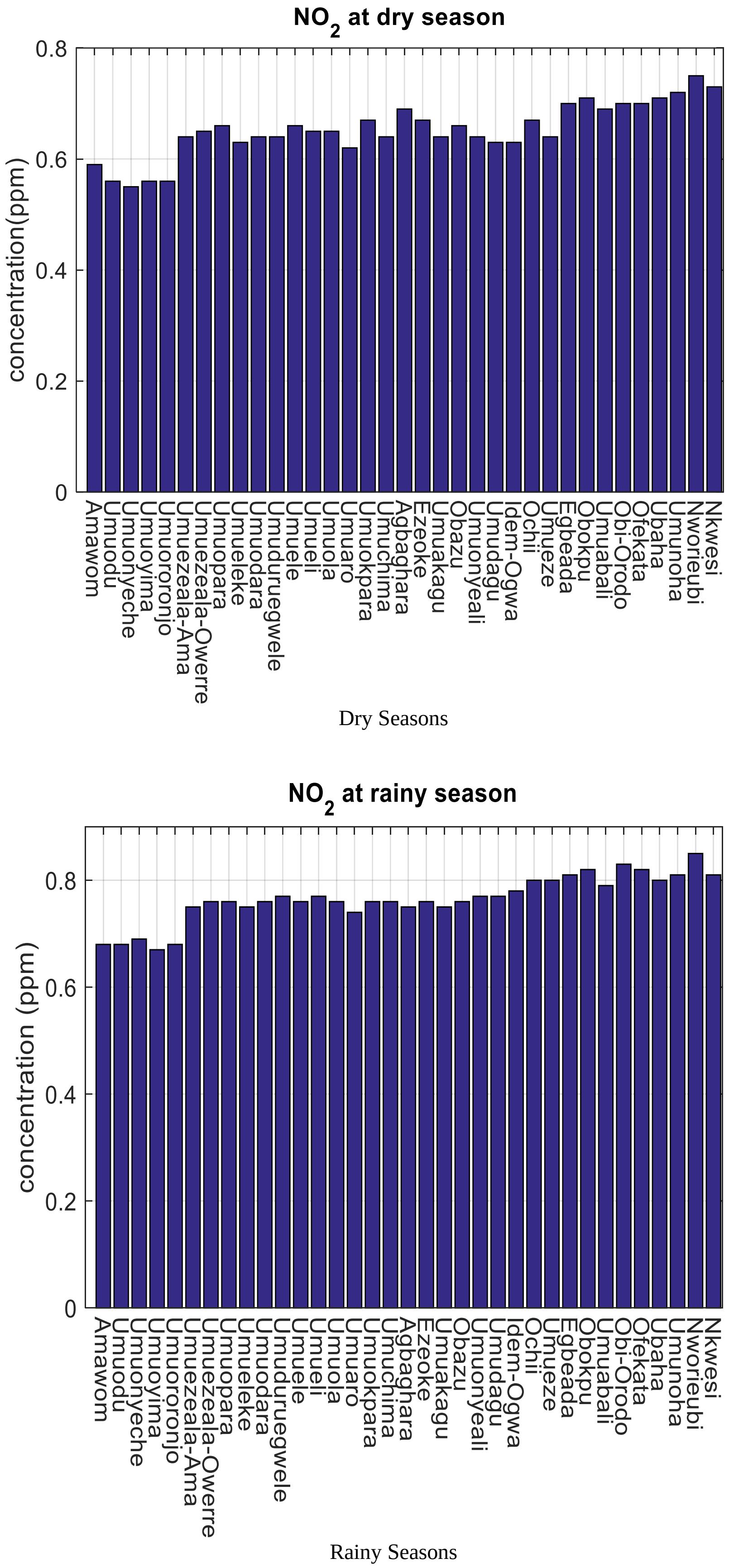
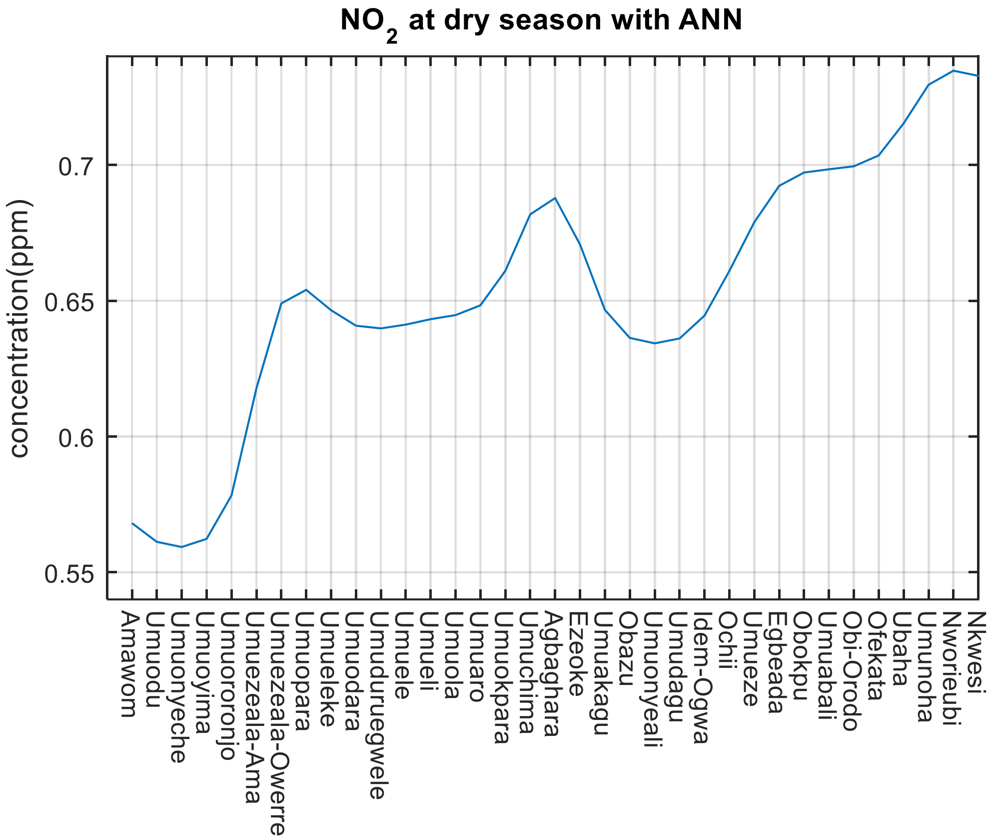
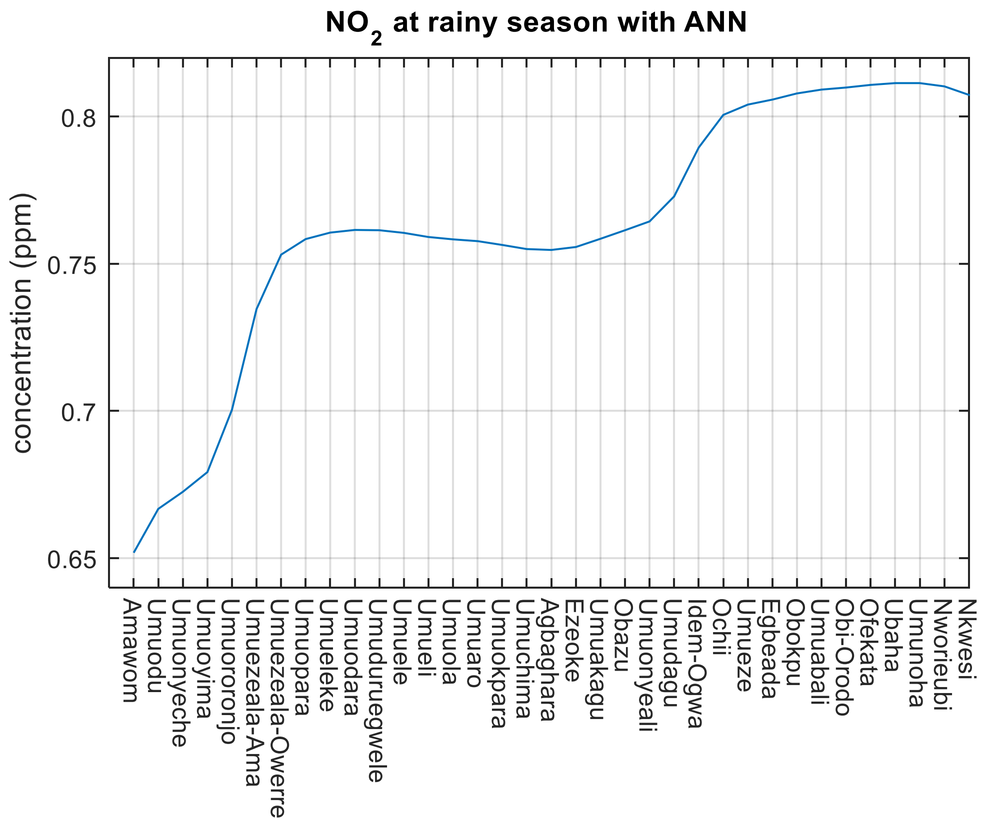


Figure 12. Nitrogen Dioxide Comparison Bar Chart.



ANN Predicted NO_2 at Dry Seasons



ANN Predicted NO_2 at Rainy Seasons

Journal of Modern Chemistry & Chemical Technology
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ISSN: 2229-6999 (Online), ISSN: 2321-5208 (Print)

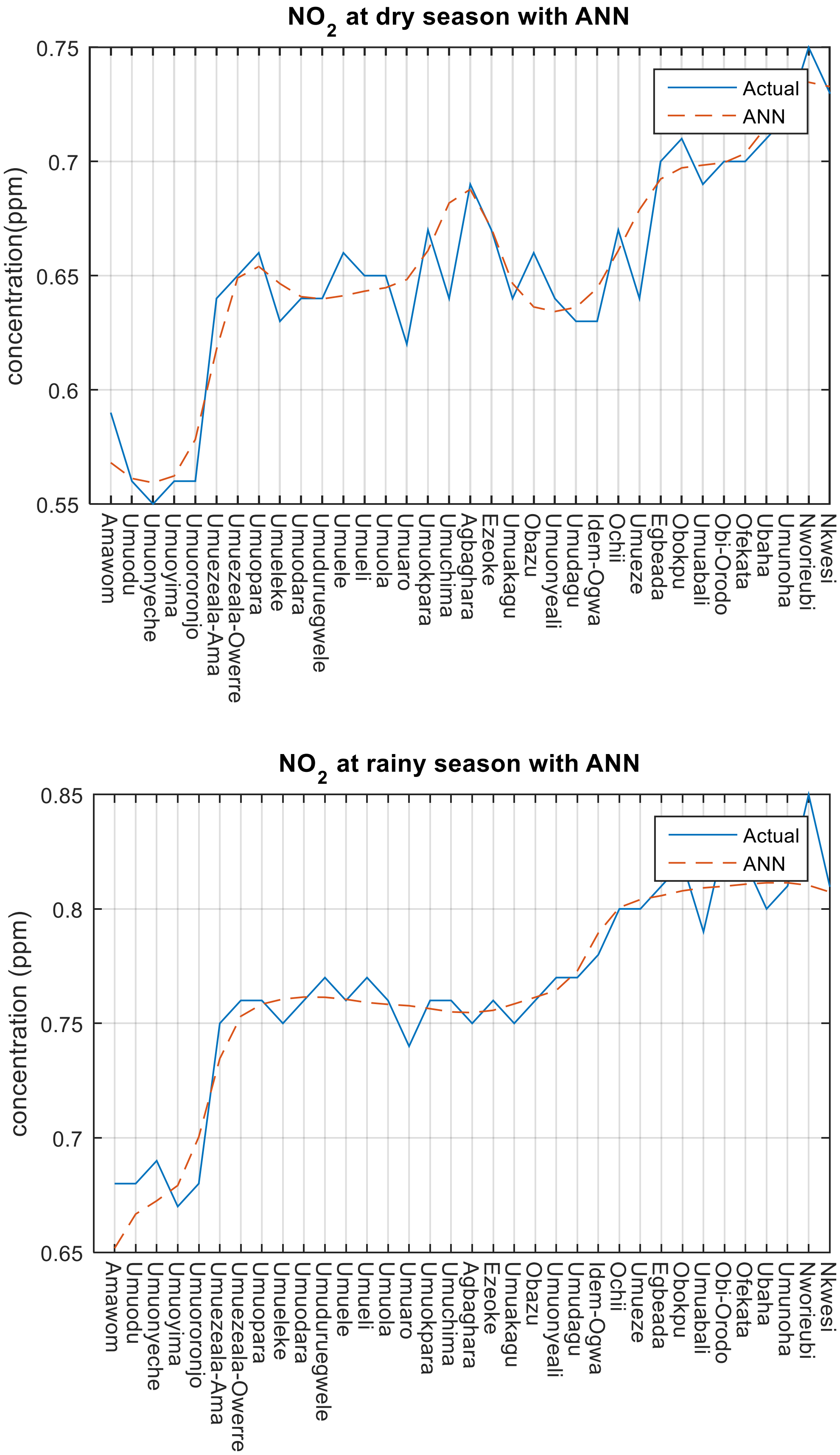

Figure 13. Comparative Analysis of Actual and Predicted NO_2

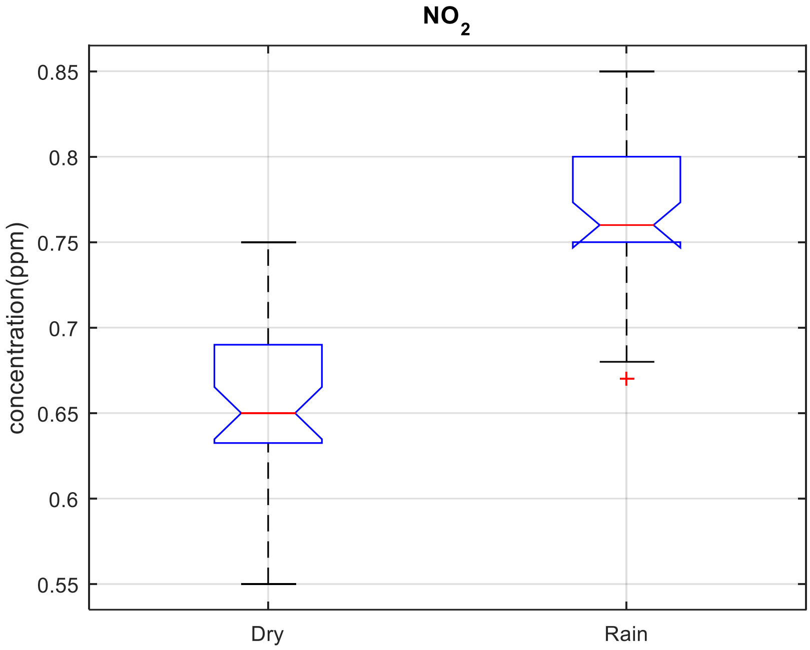

Figure 14. Nitrogen Dioxide Box & Whiskers Comparative Plot Dry and Rainy Seasons.

Table 9. Nitrogen Dioxide ANOVA Table.

ANOVA Table

Source	SS	df	MS	F	Prob>F
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Error	0.14739	68	0.00217		
Total	0.36803	69			

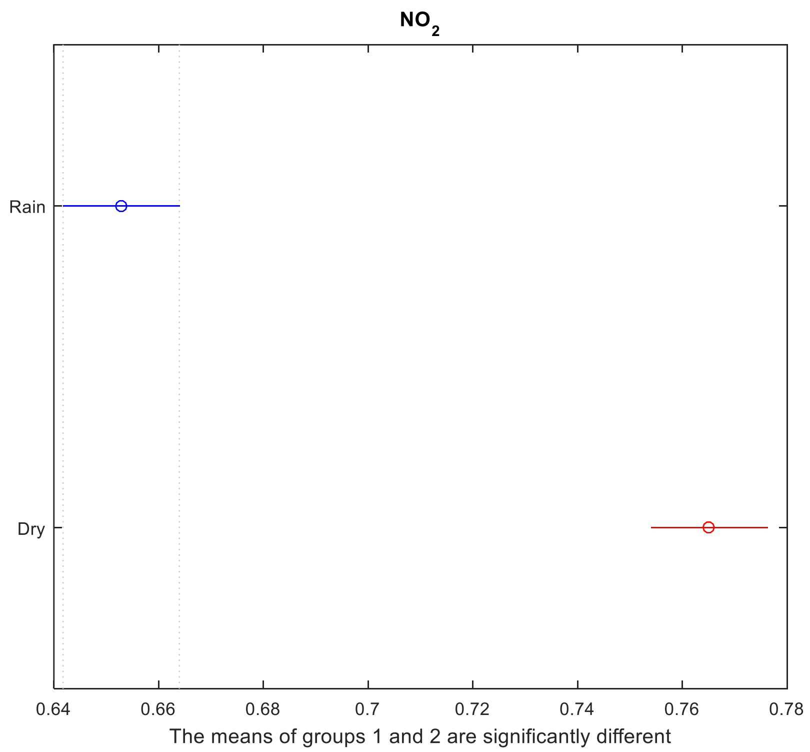
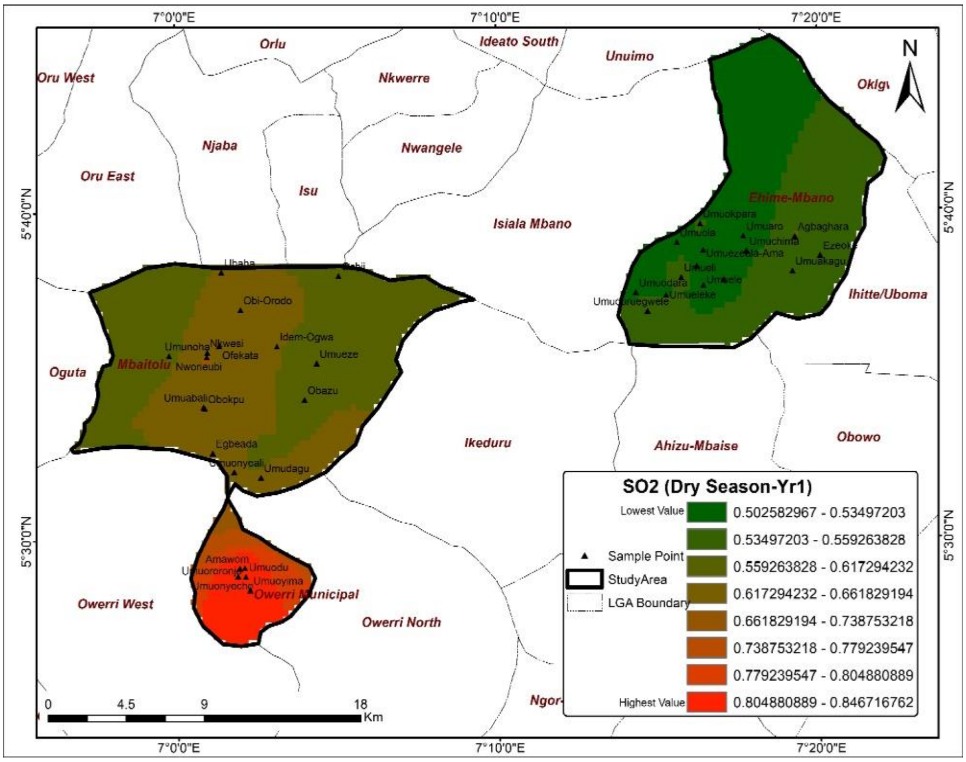


Figure 15. Nitrogen Dioxide Mean Comparative Analysis Dry and Rainy Seasons.

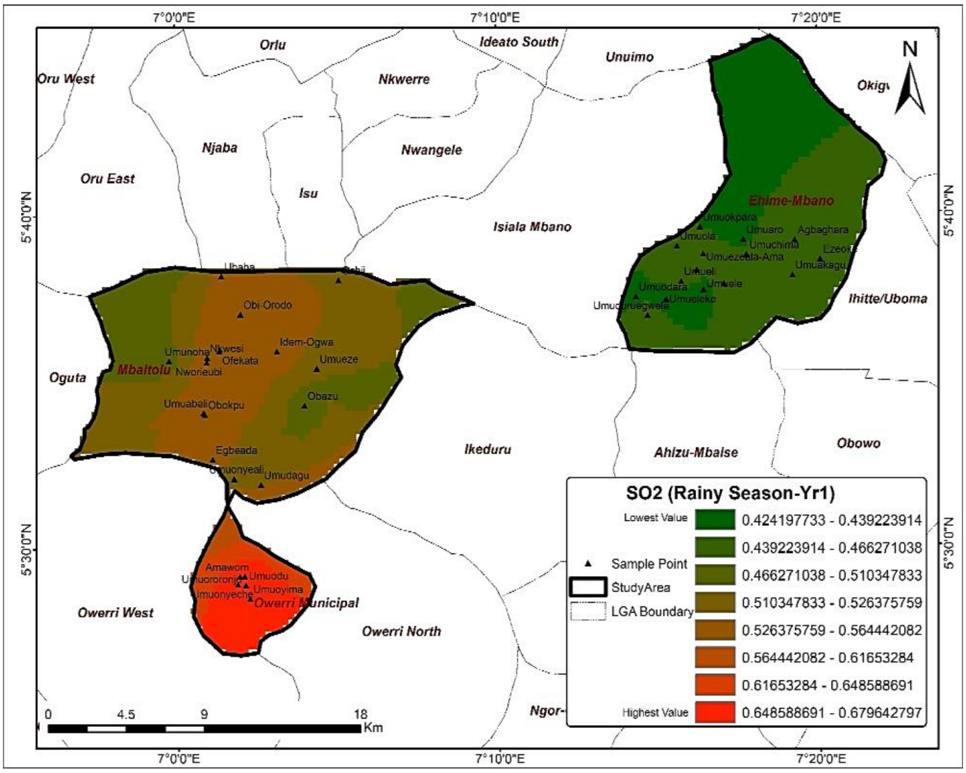
Table 10. Mean Values SO_2 (ppm) for both years.

S/N	Sampling Area	YR1 Dry	YR2 Dry	Dry Mean	YR1 Rainy	YR2 Rainy	Rainy Mean
	Owerri Municipal L.G.A						
1.	Amawom	0.82	0.90	0.86	0.67	0.75	0.71
2.	Umuodu	0.82	0.88	0.85	0.68	0.78	0.73
3.	Umuonyeche	0.85	0.88	0.87	0.67	0.76	0.72
4.	Umuoyima	0.82	0.87	0.85	0.67	0.78	0.73
5.	Umuororonjo	0.85	0.86	0.86	0.68	0.77	0.73
	Ehime Mbano L.G.A.						
	Umuezeala						
6.	Umuezeala-Ama	0.51	0.55	0.53	0.42	0.51	0.47
7.	Umuezeala-Owerre	0.53	0.58	0.56	0.45	0.50	0.48
8.	Umuopara	0.53	0.56	0.55	0.45	0.51	0.48
	Umueze II						
9.	Umueleke	0.53	0.55	0.54	0.43	0.48	0.46
10.	Umuodara	0.52	0.54	0.53	0.43	0.51	0.47
11.	Umuduruegwele	0.56	0.58	0.57	0.45	0.50	0.48
	Umunakanu						
12.	Umuele	0.52	0.55	0.54	0.43	0.52	0.48
13.	Umueli	0.55	0.57	0.56	0.45	0.50	0.48
14.	Umuola	0.52	0.56	0.54	0.47	0.48	0.48
	Umunumo						
15.	Umuaro	0.50	0.53	0.52	0.43	0.49	0.46
16.	Umuokpara	0.54	0.57	0.56	0.44	0.50	0.47
17.	Umuchima	0.53	0.56	0.54	0.45	0.50	0.48
	Nsu						
18.	Agbaghara	0.56	0.58	0.57	0.46	0.50	0.48
19.	Ezeoke	0.55	0.57	0.56	0.45	0.52	0.49
20.	Umuakagu	0.55	0.58	0.57	0.45	0.50	0.48
	Mbaitoli L.G.A						
	Mbieri						
21.	Obazu	0.60	0.63	0.62	0.50	0.51	0.50
22.	Umuonyeali	0.62	0.64	0.63	0.51	0.52	o.52
23.	Umudagu	0.62	0.64	0.63	0.52	0.51	0.52
	Ogwa						
24.	Idem-Ogwa	0.62	0.65	0.64	0.54	0.53	0.54
25.	Ochii	0.65	0.65	0.65	0.55	0.51	0.53
26.	Umueze	0.61	0.65	0.63	0.52	0.54	0.53
	Ubomiri						
27.	Egbeada	0.65	0.67	0.66	0.55	0.56	0.56
28.	Obokpu	0.64	0.68	0.66	0.54	0.50	0.52
29.	Umuabali	0.62	0.66	0.64	0.53	0.53	0.53
	Orodo						
30.	Obi-Orodo	0.64	0.67	0.66	0.54	0.53	0.54
31.	Ofekata	0.63	0.65	0.64	0.54	0.54	0.54
32.	Ubaha	0.62	0.65	0.64	0.53	0.55	0.54
	Ifakala						

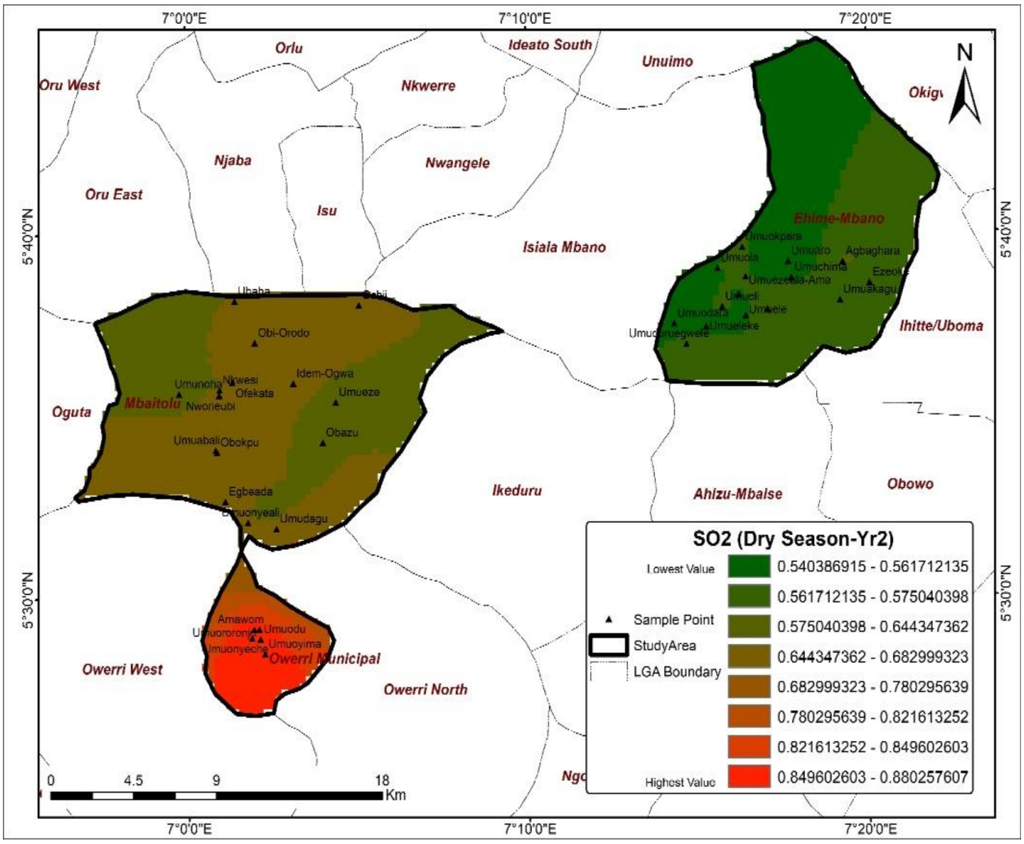
33.	Umunoha	0.60	0.63	0.62	0.50	0.53	0.52
34.	Nworieubi	0.67	0.65	0.66	0.54	0.55	0.55
35.	Nkwesi	0.64	0.64	0.64	0.54	0.54	0.54



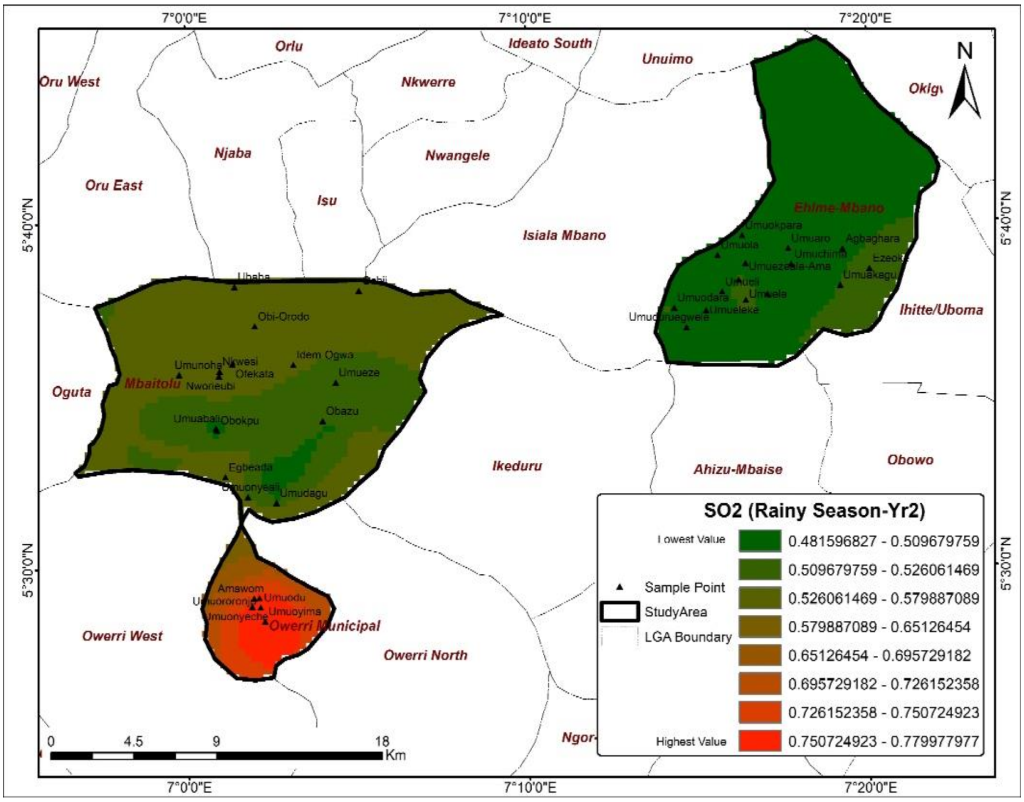
SO2 at Dry Season Year 1



SO2 at Rainy Season Year 1

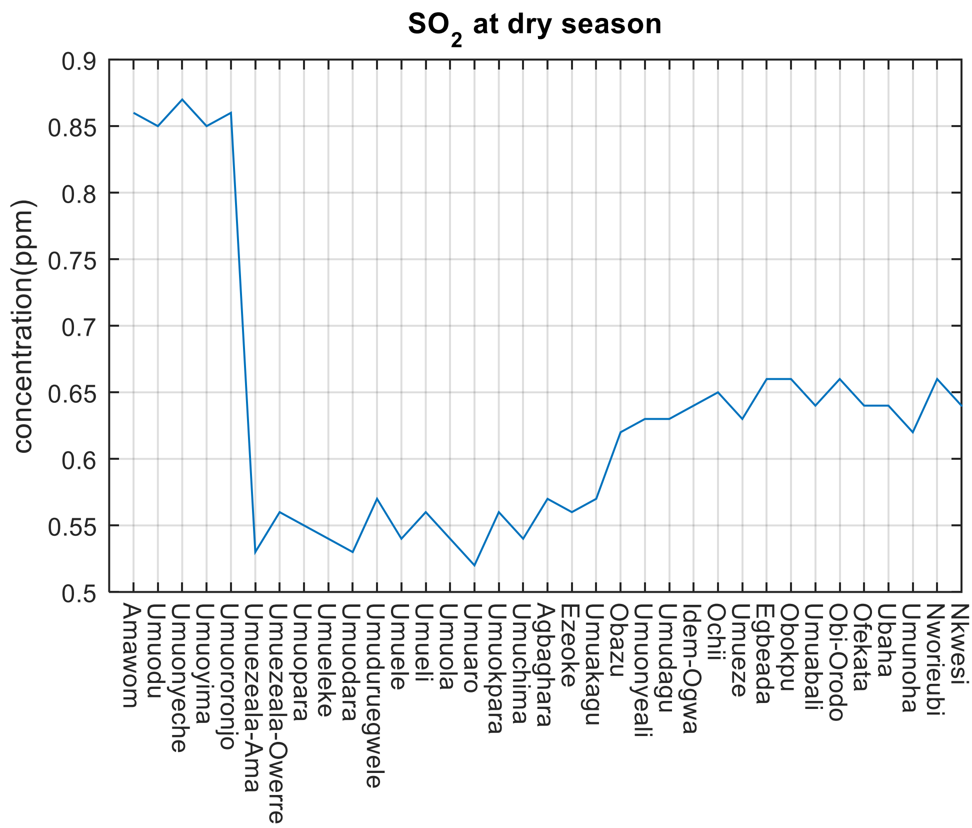


SO_2 at Dry Season Year 2

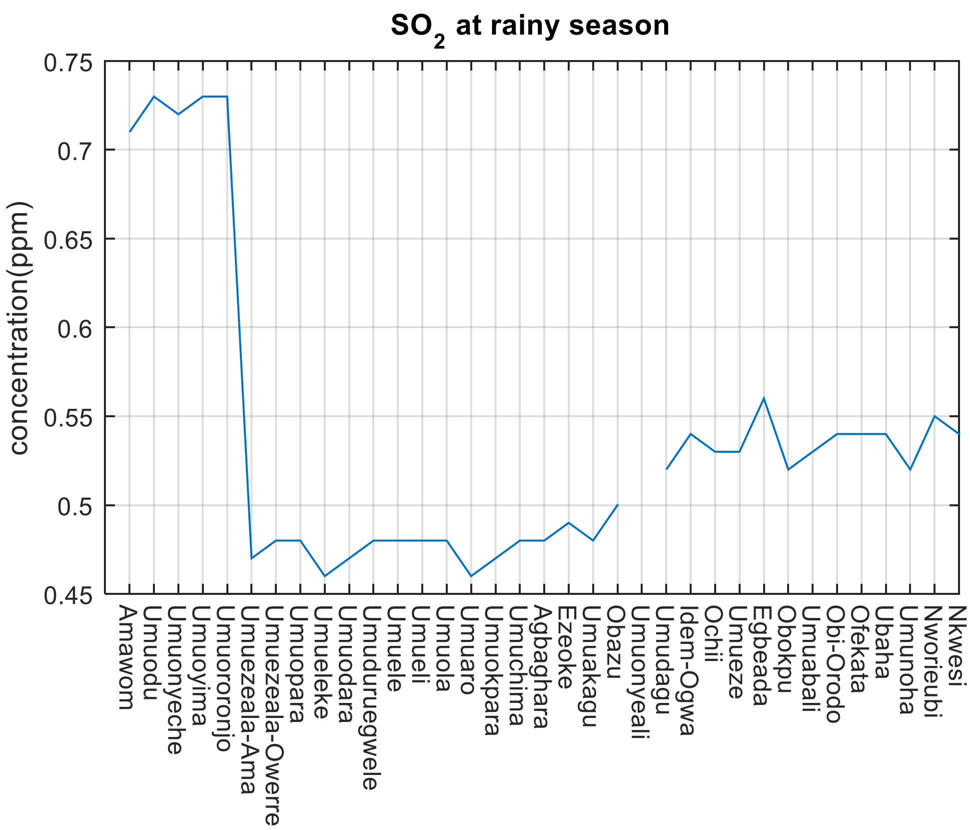


SO_2 at Rainy Season Year 2

Figure 16. Sulphur Dioxide GIS Comparison Model.



Sulphur Dioxide at Dry Seasons



Sulphur Dioxide at Rainy Seasons

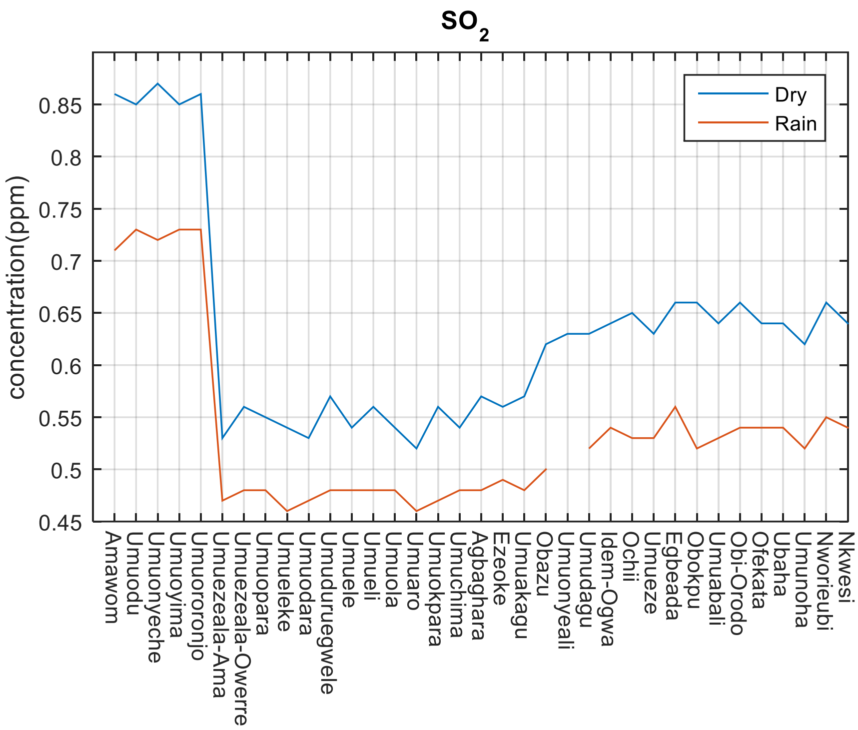
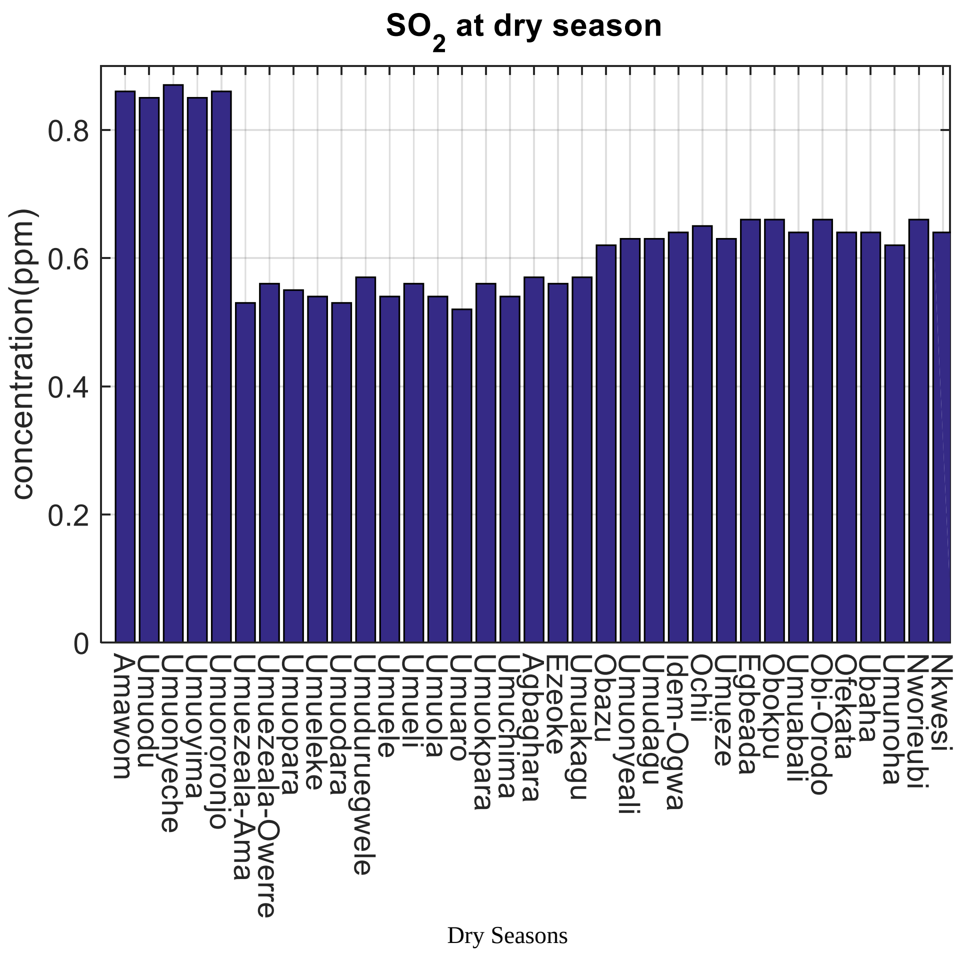
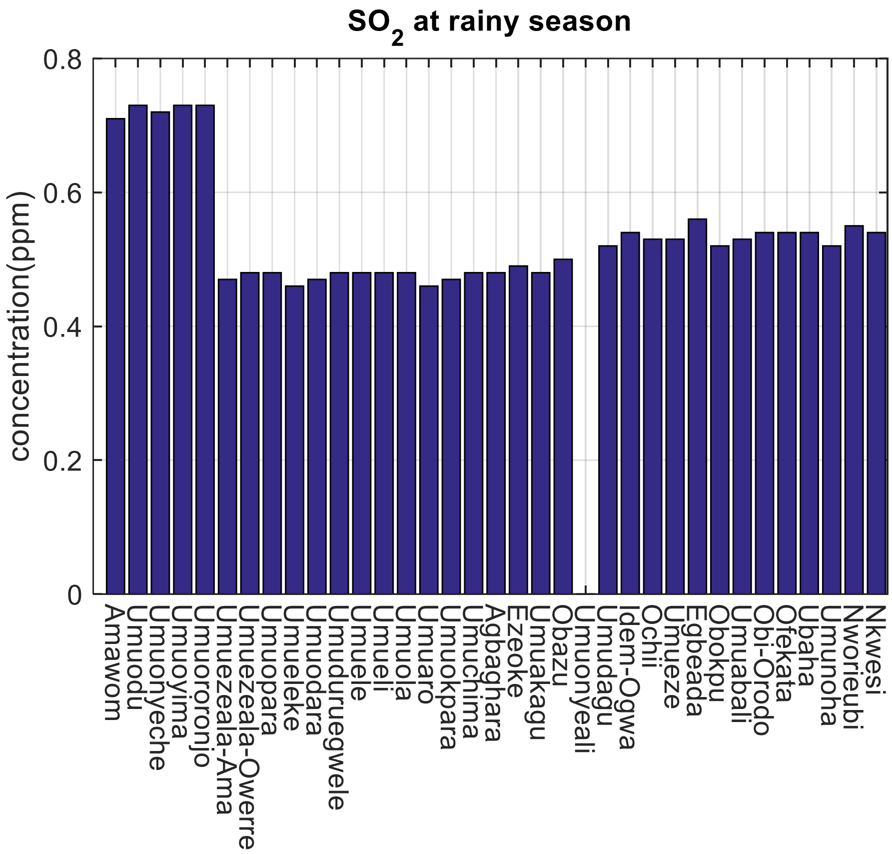


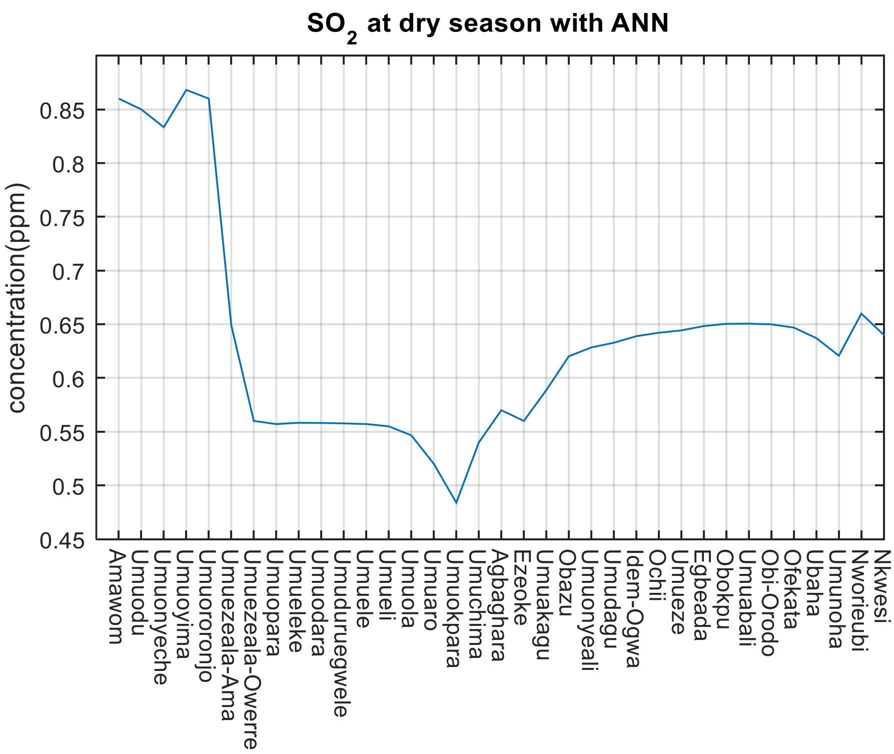
Figure 17. Sulphur Dioxide MATLAB Comparison Model.



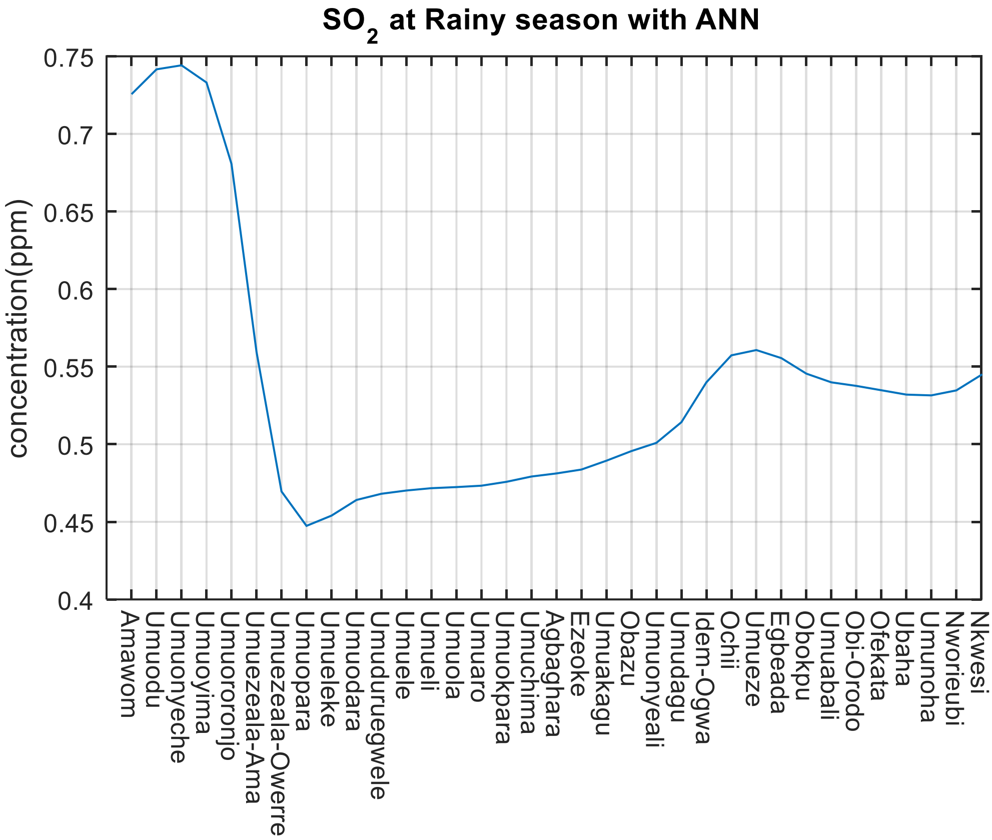


Rainy Seasons

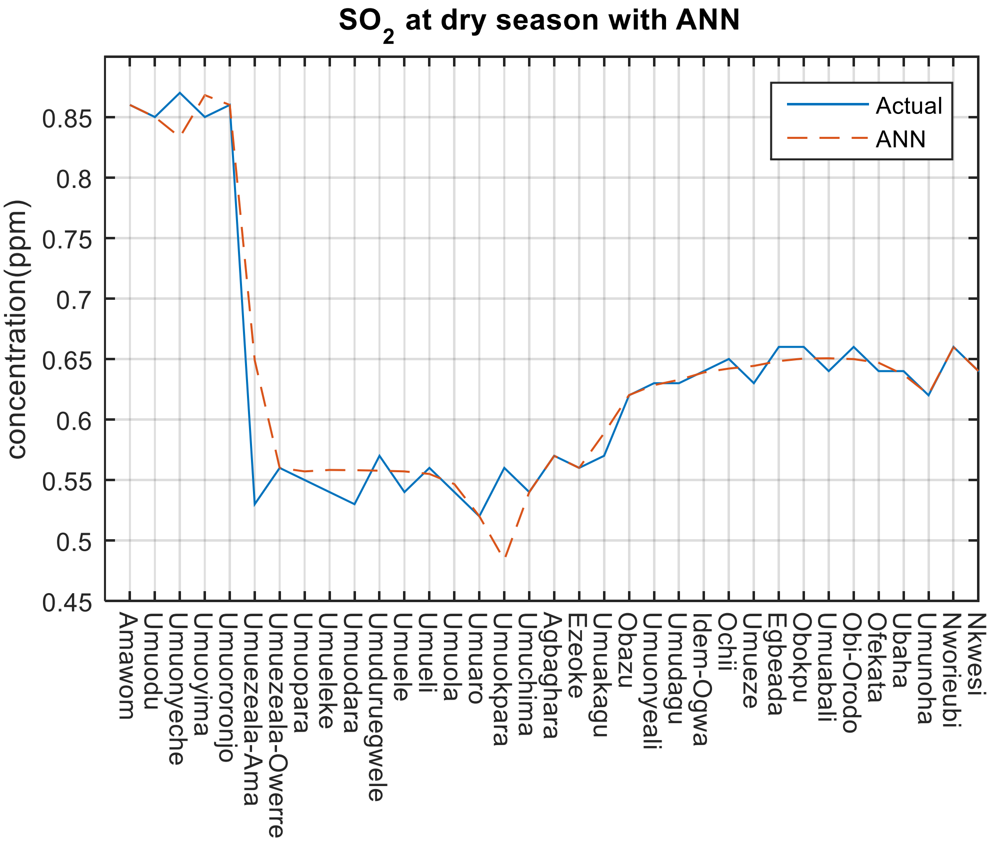
Figure 18. Sulphur Dioxide Comparison Bar Chart.



ANN Predicted SO_2 at Dry Seasons



ANN Predicted SO_2 at Rainy Seasons



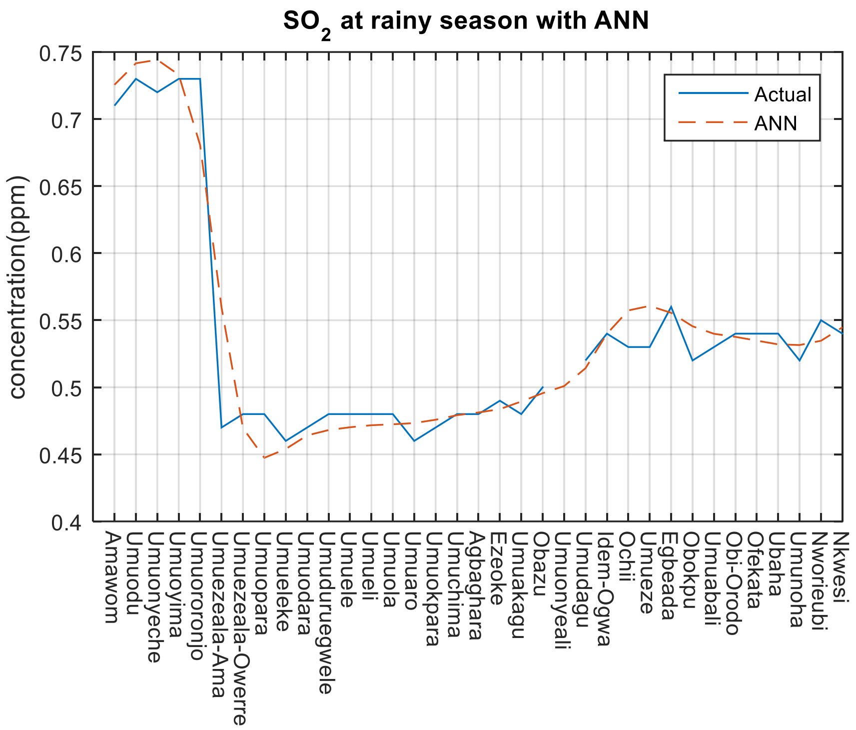


Figure 19. Comparative Analysis of Actual and Predicted SO_2

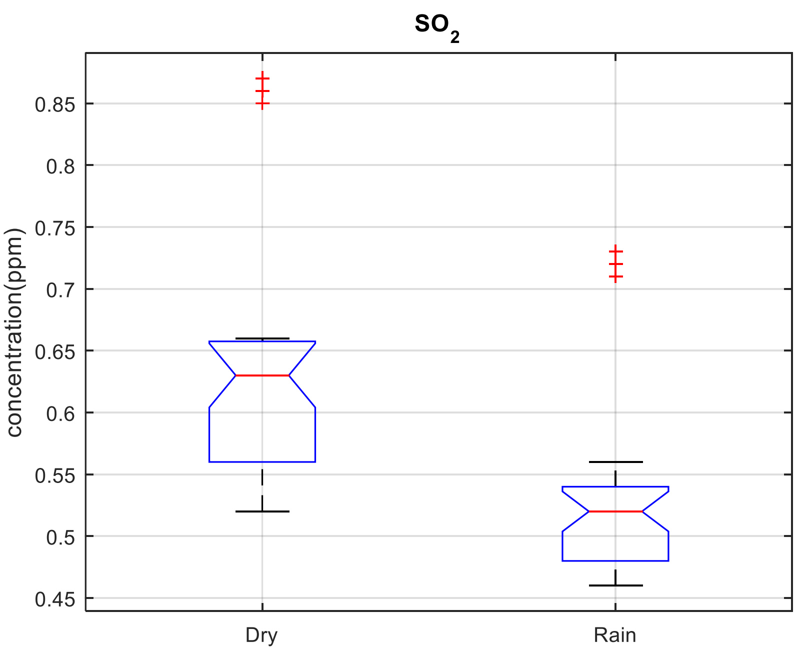


Figure 20. Sulphur Dioxide Box & Whiskers Comparative Plot Dry and Rainy Seasons.

Table 11. Sulphur Dioxide ANOVA Table

ANOVA Table

Source	SS	df	MS	F	Prob>F
Groups	0.16219	1	0.16219	18.08	6.70735e-05
Error	0.60094	67	0.00897		
Total	0.76312	68			

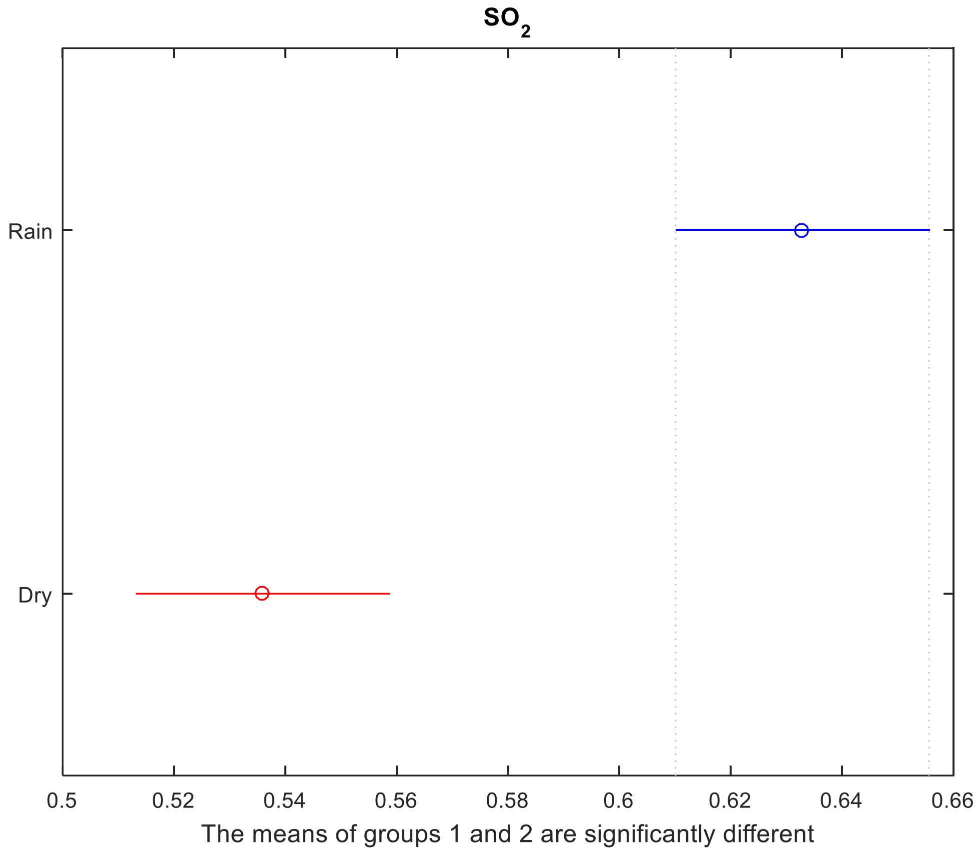
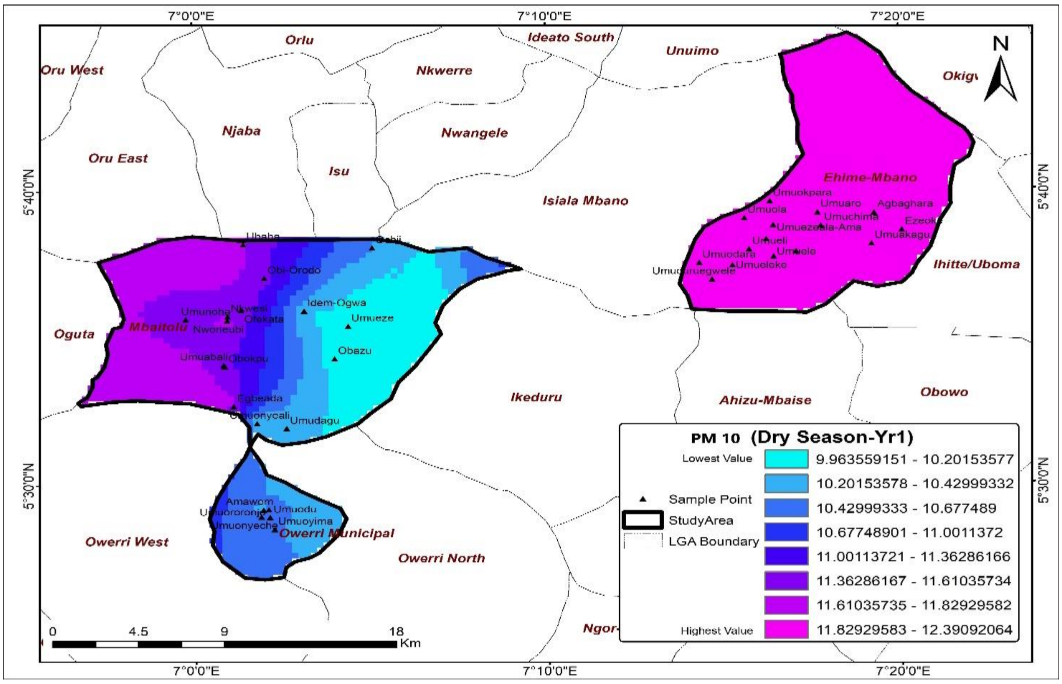


Figure 21. Sulphur Dioxide Mean Comparative Analysis Dry and Rainy Seasons.

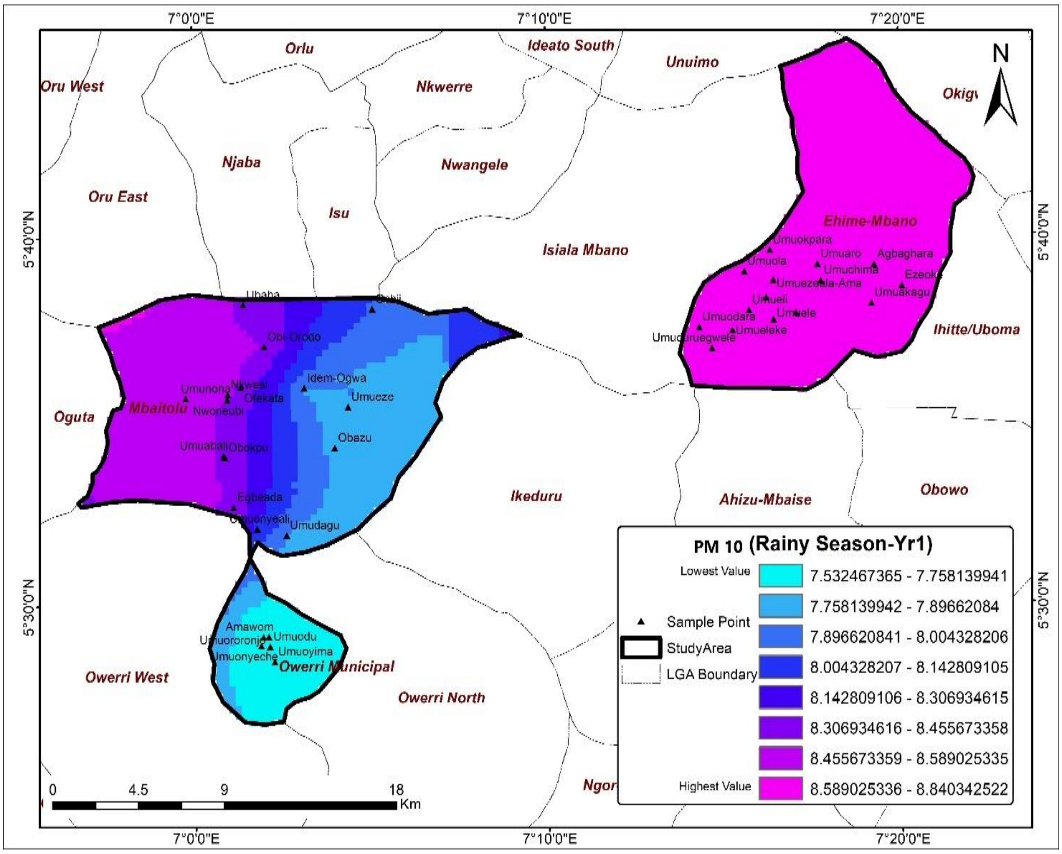
Table 12. Mean Values PM_{10} (ppm) for both years

S/N	Sampling Area	YR1 Dry	YR2 Dry	Dry Mean	YR1 Rainy	YR2 Rainy	Rainy Mean
	Owerri Municipal L.G.A						
1.	Amawom	10.35	11.05	10.70	7.36	7.70	7.53
2.	Umuodu	10.54	11.08	10.81	7.52	7.69	7.61
3.	Umuonyeche	10.54	11.16	10.80	7.55	7.72	7.64
4.	Umuoyima	10.44	11.15	10.78	7.50	7.71	7.61
5.	Umuororonjo	10.54	11.00	10.77	7.53	7.68	7.61
	Ehime Mbano L.G.A.						
	Umuezeala						
6.	Umuezeala-Ama	12.34	12.88	12.61	8.77	9.01	8.89
7.	Umuezeala-Owerre	12.39	12.82	12.61	8.65	8.86	8.76
8.	Umuopara	12.10	12.80	12.45	8.70	8.85	8.78
	Umueze II						
9.	Umueleke	12.17	12.80	12.49	8.54	8.85	8.70
10.	Umuodara	12.16	12.84	12.51	8.57	8.90	8.74
11.	Umuduruegwele	12.24	12.82	12.53	8.54	8.92	8.73
	Umunakanu						
12.	Umuele	12.30	12.86	12.58	8.60	8.85	8.73
13.	Umueli	12.37	12.87	12.62	8.61	8.85	8.73
14.	Umuola	12.20	12.80	12.50	8.63	8.78	8.71
	Umunumo						

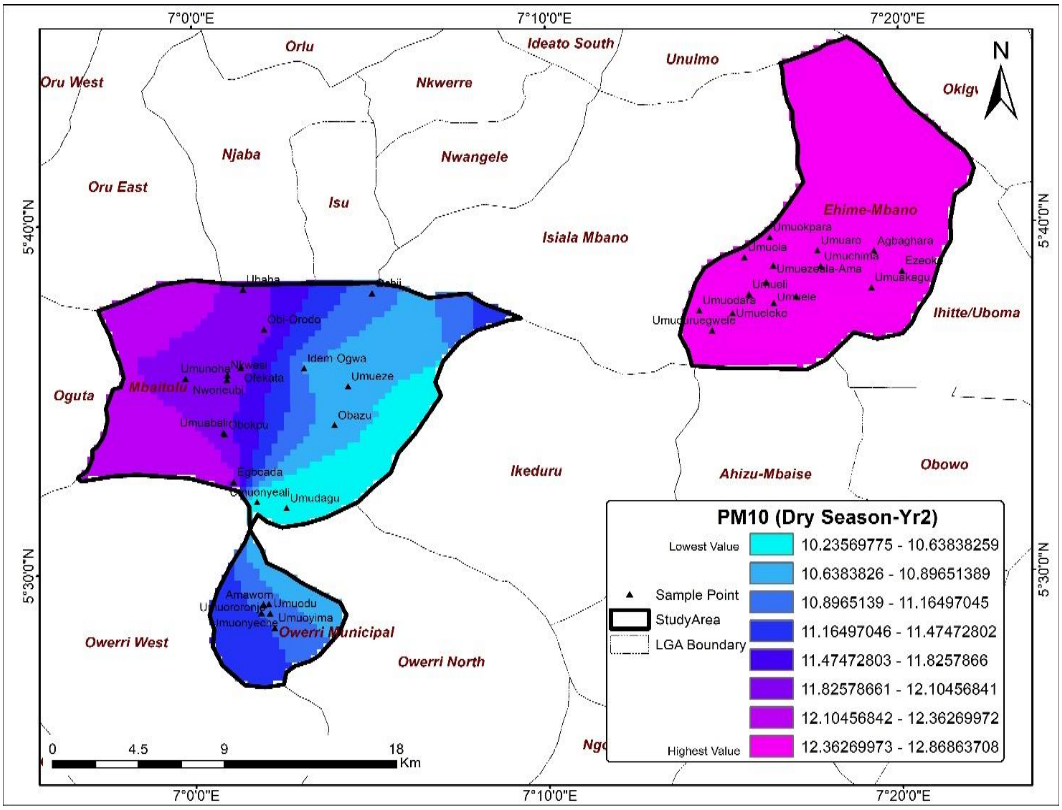
15.	Umuaro	12.15	12.75	12.45	8.55	8.86	8.71
16.	Umuokpara	12.30	12.83	12.57	8.56	8.95	8.76
17.	Umuchima	12.30	12.70	12.50	8.58	8.84	8.71
	Nsu						
18.	Agbaghara	12.30	12.74	12.52	8.65	8.94	8.80
19.	Ezeoke	12.12	12.72	12.42	8.63	9.02	8.83
20.	Umuakagu	12.11	12.80	12.46	8.60	8.95	8.78
	Mbaitoli L.G.A						
	Mbieri						
21.	Obazu	10.12	10.78	12.45	7.32	8.42	7.87
22.	Umuonyeali	10.21	10.21	10.21	7.34	8.46	8.10
23.	Umudagu	10.33	10.33	10.33	7.35	8.45	7.90
	Ogwa						
24.	Idem-Ogwa	10.23	10.87	10.55	7.25	8.52	7.89
25.	Ochii	10.38	10.88	10.63	7.21	8.53	7.87
26.	Umueze	10.33	10.93	10.63	7.24	8.55	7.90
	Ubomiri						
27.	Egbeada	11.70	12.20	11.95	8.18	8.68	8.43
28.	Obokpu	11.45	11.91	11.68	8.20	8.65	8.43
29.	Umuabali	11.55	12.15	11.85	8.21	8.70	8.46
	Orodo						
30.	Obi-Orodo	11.50	11.95	11.73	8.05	8.85	8.45
31.	Ofekata	11.56	11.96	11.76	8.06	8.76	8.41
32.	Ubaha	11.63	11.95	11.79	8.04	8.75	8.40
	Ifakala						
33.	Umunoha	11.47	11.93	11.70	8.24	8.81	8.53
34.	Nworieubi	11.69	12.04	11.87	8.35	8.85	8.43
35.	Nkwesi	11.46	12.01	11.74	8.31	8.80	8.56



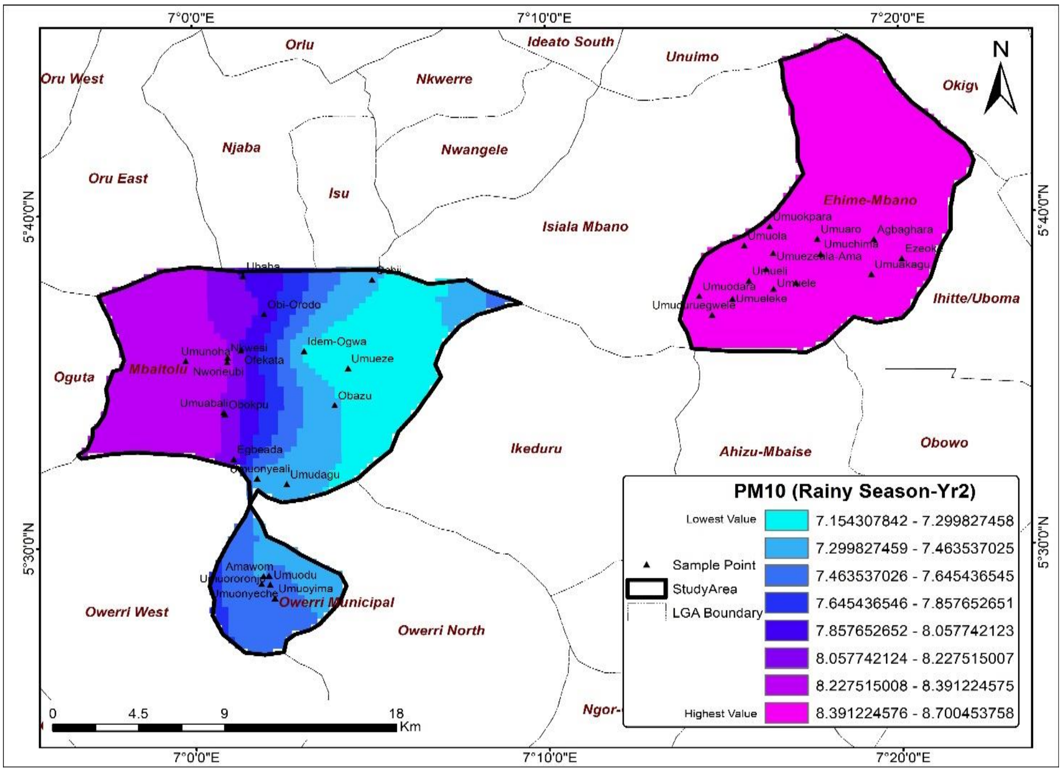
PM_{10} at Dry Season Year 1



PM$_{10}$ at Rainy Season Year 1

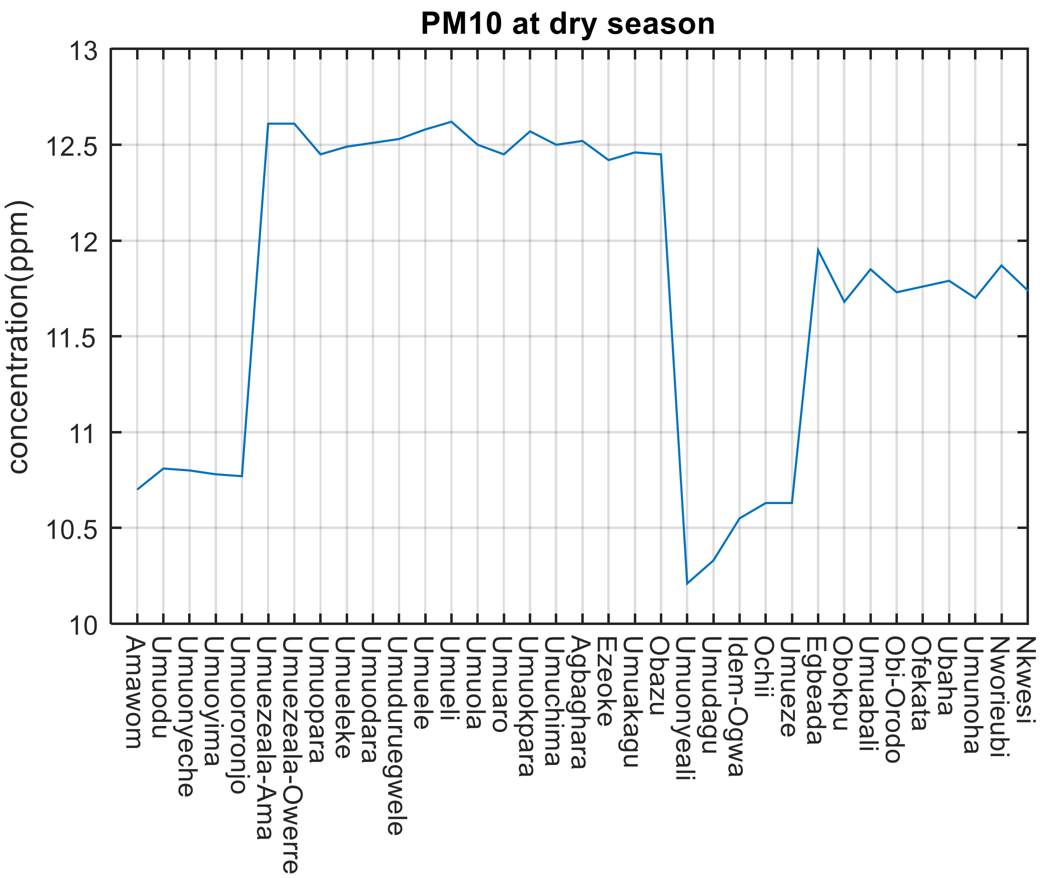


PM$_{10}$ at Dry Season Year 2

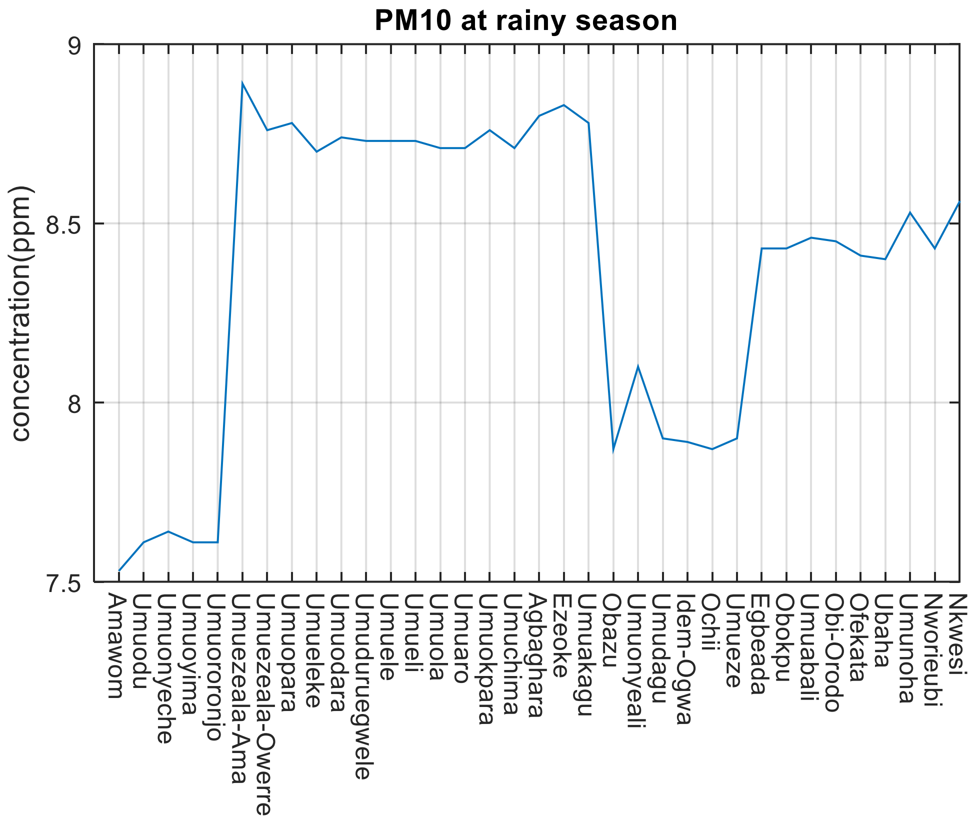


PM_{10} at Rainy Season Year 2

Figure 22 Particulate Matter GIS Comparison Model.



PM_{10} at Dry Seasons



PM10 at Rainy Seasons

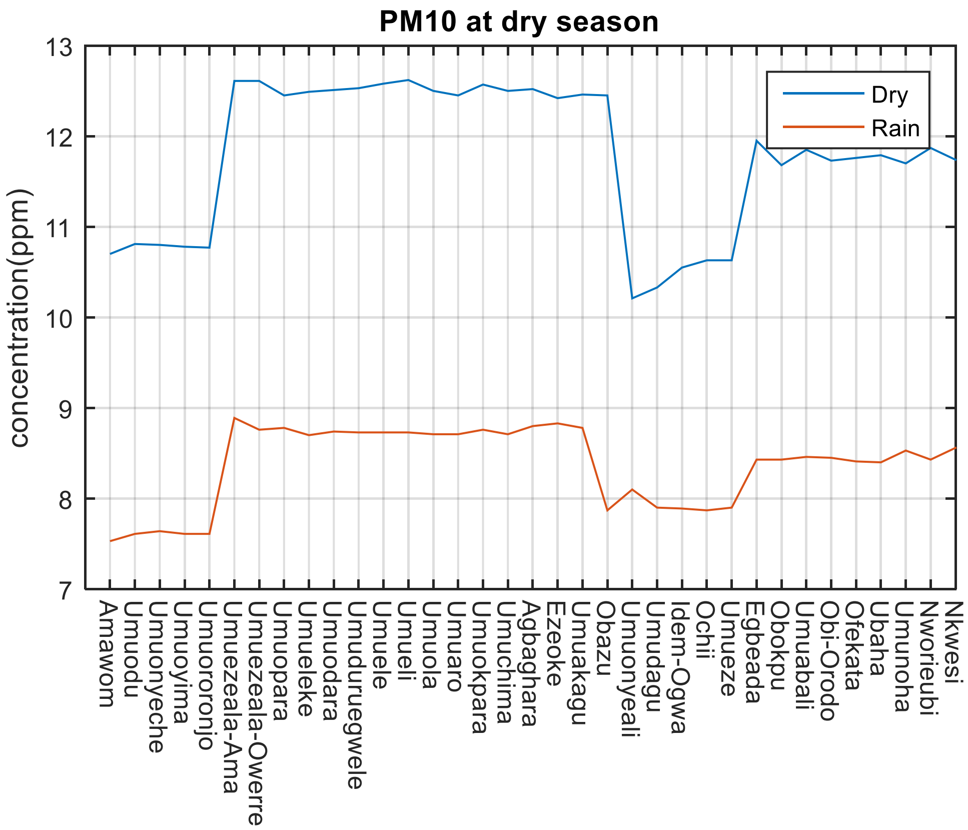
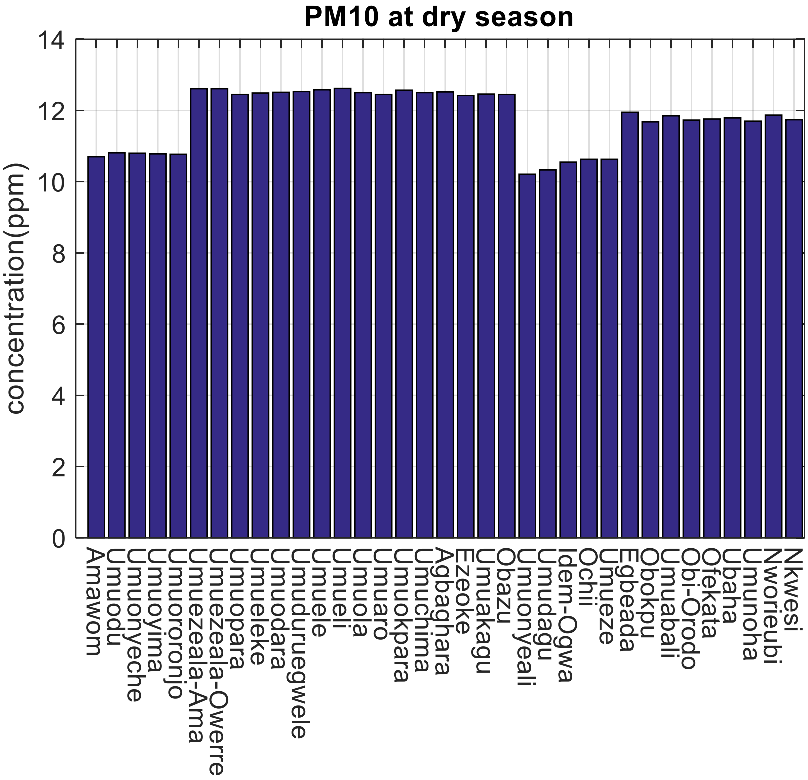
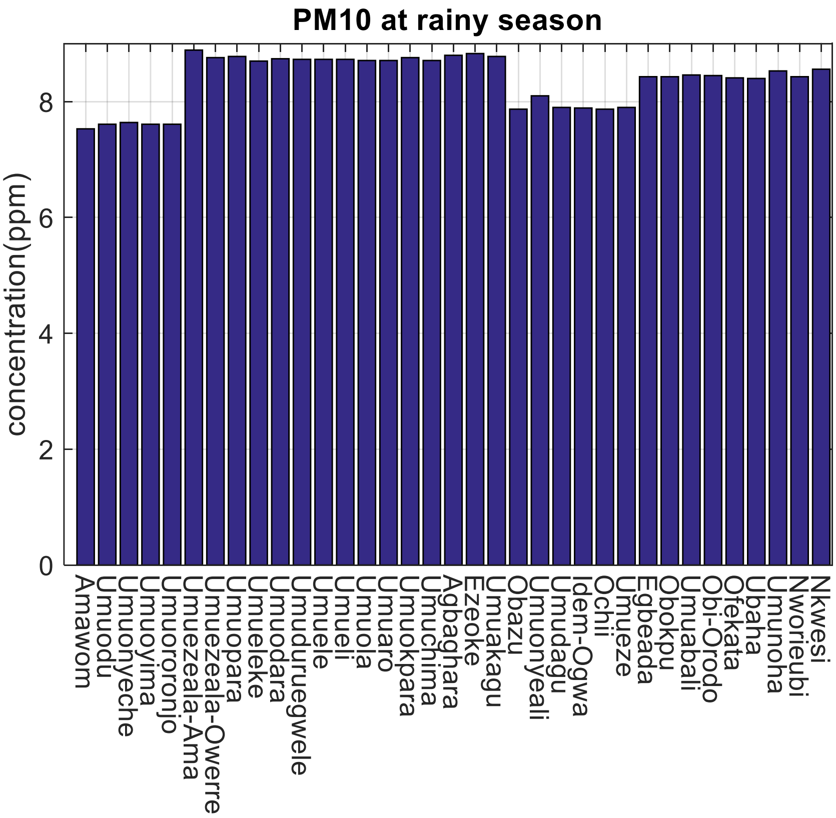


Figure 23. Particulate Matter MATLAB Comparison Model.

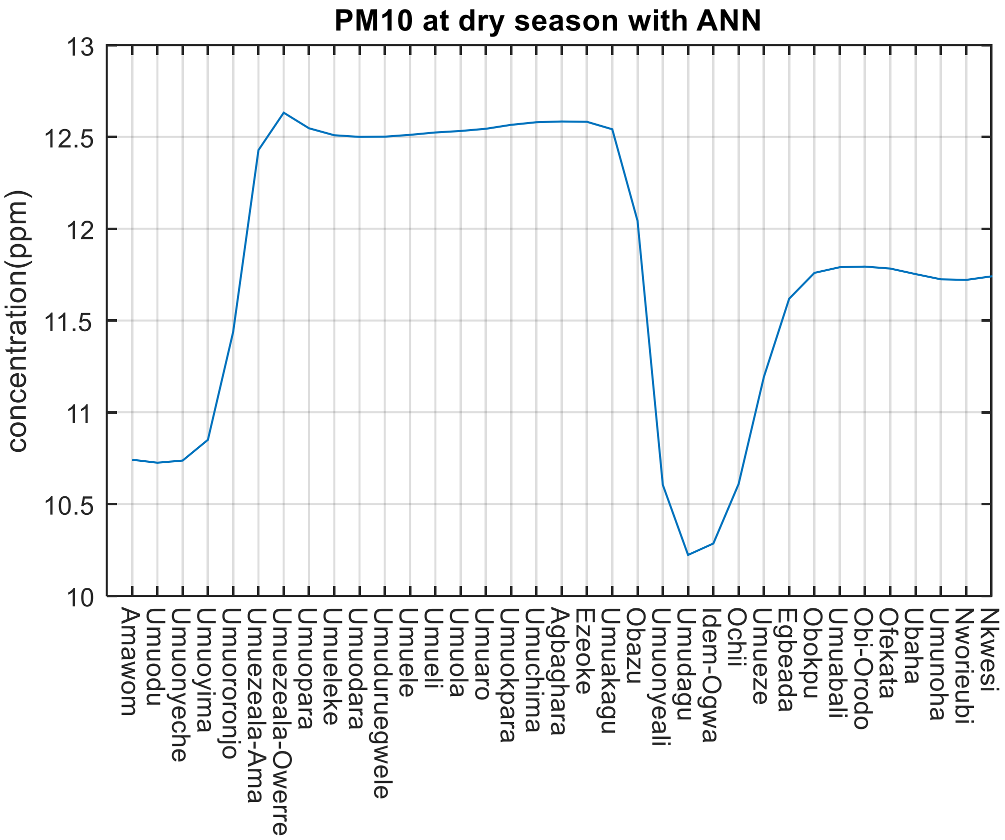


Dry Seasons

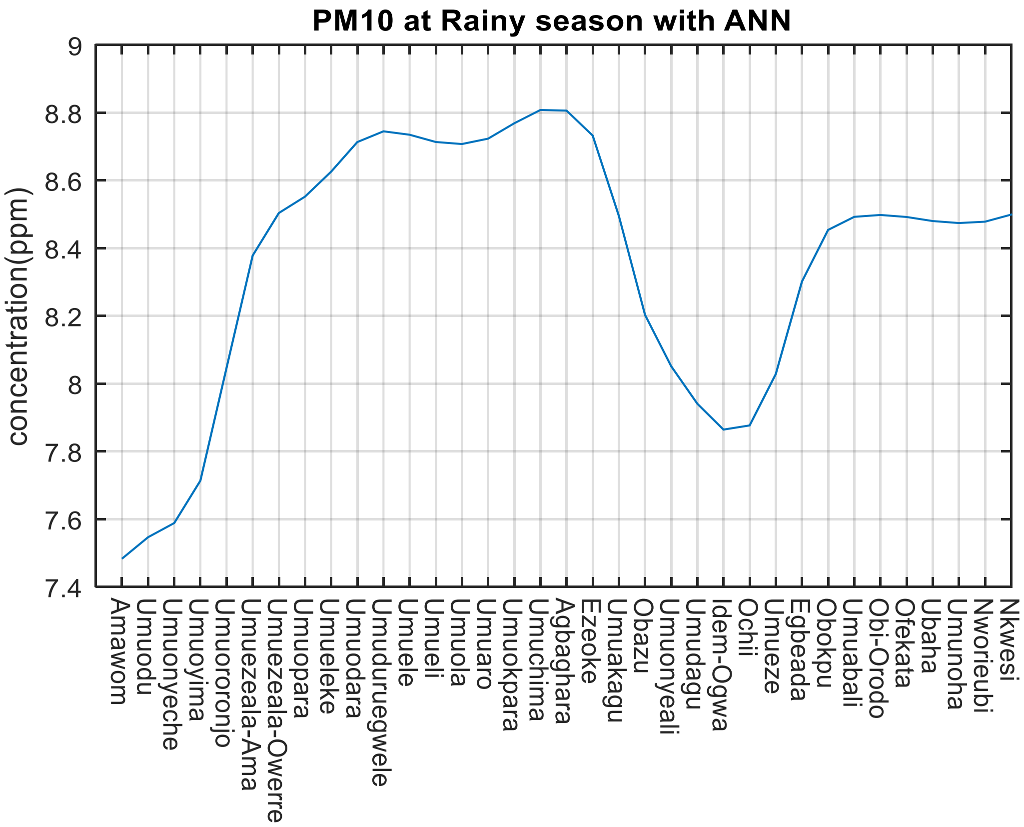


Rainy Seasons

Figure 24. Particulate Matter Comparison Bar Chart.



ANN Predicted PM_{10} at Dry Seasons



ANN Predicted PM_{10} at Rainy Seasons

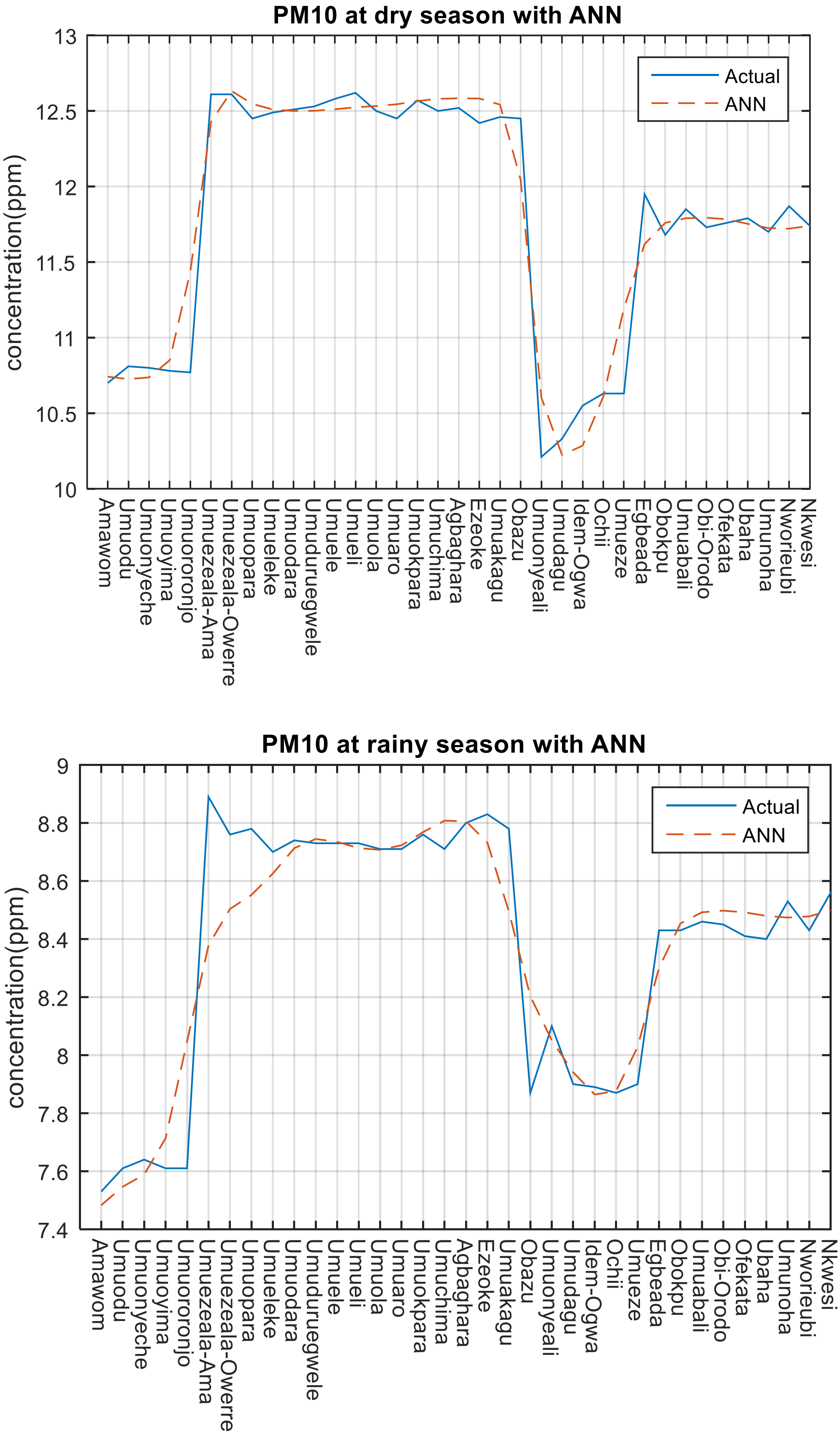


Figure 25. Comparative Analysis of Actual and Predicted PM_{10}

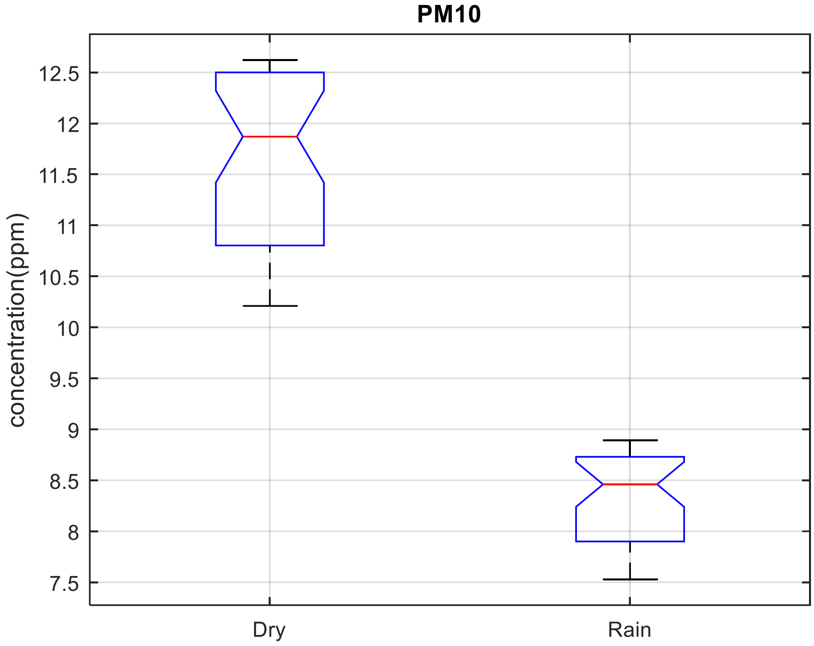


Figure 26. Particulate Matter Box & Whiskers Comparative Plot Dry and Rainy Seasons.

Table 13. Particulate Matter ANOVA Table.

ANOVA Table

Source	SS	df	MS	F	Prob>F
Columns	204.208	1	204.208	475.25	2.12638e-32
Error	29.219	68	0.43		
Total	233.427	69			

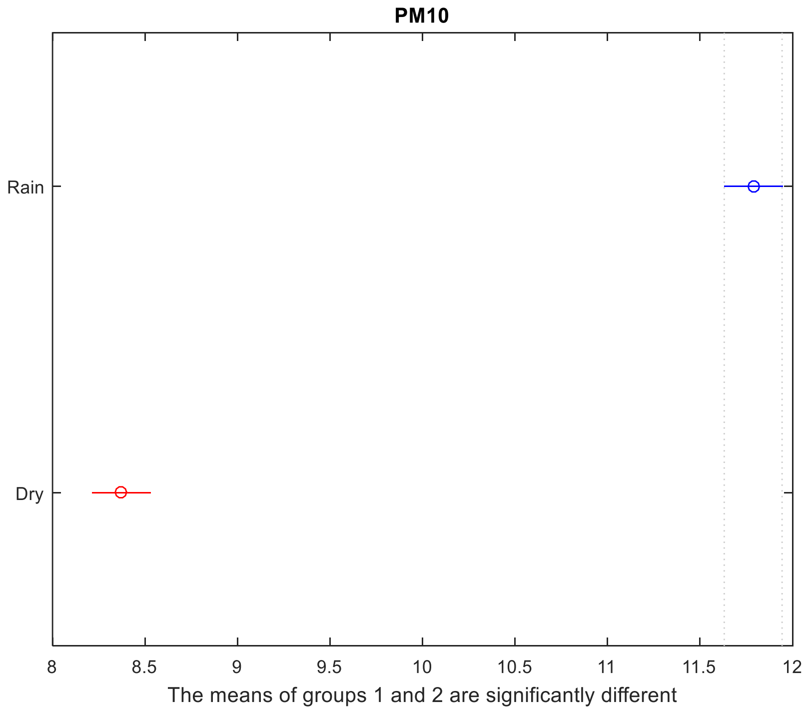


Figure 27. Particulate Matter Mean Comparative Analysis Dry and Rainy Seasons

Table 14. Air Quality Index (AQI).

AQI Category	AQI Rating	PM_{10} (μg/m^3)	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)
Very good (0-15)	A	0–50	0–2	0–0.02	0–0.02
Good (16-31)	B	51–75	2.1–4.0	0.02–0.03	0.02–0.03
Moderate (32-49)	C	76–100	4.1–6.0	0.03–0.04	0.03–0.04
Poor (50-59)	D	101–150	6.1–9.0	0.04–0.06	0.04–0.05
Very poor (100 or over)	E	> 150 or (0.15 mg/m^3)	> 9.0	> 0.06	> 0.06

Table 4.49 Source; USEPA, 2022.

Table 15. Summary of AQI rating for ambient air quality for the Dry Seasons

S/N	Sampling AREA	AQI (CO)	AQI (NO_2)	AQI (SO_2)	AQI (PM_{10})	AQI OVERALL
	Owerri Municipal L.G.A					
1.	Amawom	E	E	E	E	E
2.	Umuodu	E	E	E	E	E
3.	Umuonyeche	E	E	E	E	E
4.	Umuoyima	E	E	E	E	E
5.	Umuororonjo	E	E	E	E	E
	Ehime Mbano L.G.A.					
	Umuezeala					
6.	Umuezeala-Ama	E	E	E	E	E
7.	Umuezeala-Owerre	E	E	E	E	E
8.	Umuopara	E	E	E	E	E
	Umueze II					
9.	Umueleke	E	E	E	E	E
10.	Umuodara	E	E	E	E	E
11.	Umuduruegwele	E	E	E	E	E
	Umunakanu					
12.	Umuele	E	E	E	E	E
13.	Umueli	E	E	E	E	E
14.	Umuola	E	E	E	E	E
	Umunumo					
15.	Umuaro	E	E	E	E	E
16.	Umuokpara	E	E	E	E	E
17.	Umuchima	E	E	E	E	E
	Nsu					
18.	Agbaghara	E	E	E	E	E
19.	Ezeoke	E	E	E	E	E
20.	Umuakagu	E	E	E	E	E
	Mbaitoli L.G.A					
	Mbieri					
21.	Obazu	E	E	E	E	E
22.	Umuonyeali	E	E	E	E	E
23.	Umudagu	E	E	E	E	E
	Ogwa					
24.	Idem-Ogwa	E	E	E	E	E
25.	Ochii	E	E	E	E	E
26.	Umueze	E	E	E	E	E

	Ubomiri					
27.	Egbeada	E	E	E	E	E
28.	Obokpu	E	E	E	E	E
29.	Umuabali	E	E	E	E	E
	Orodo					
30.	Obi-Orodo	E	E	E	E	E
31.	Ofekata	E	E	E	E	E
32.	Ubaha	E	E	E	E	E
	Ifakala					
33.	Umunoha	E	E	E	E	E
34.	Nworieubi	E	E	E	E	E
35.	Nkwesi	E	E	E	E	E

Table 16. Summary of AQI rating for ambient air quality for the Rainy Seasons.

S/N	Sampling Area	AQI (CO)	AQI (NO_2)	AQI (SO_2)	AQI (PM_{10})	AQI OVERALL
	Owerri Municipal L.G.A					
1.	Amawom	E	E	E	E	E
2.	Umuodu	E	E	E	E	E
3.	Umuonyeche	E	E	E	E	E
4.	Umuoyima	E	E	E	E	E
5.	Umuororonjo	E	E	E	E	E
	Ehime Mbano L.G.A.					
	Umuezeala					
6.	Umuezeala-Ama	E	E	E	E	E
7.	Umuezeala-Owerre	E	E	E	E	E
8.	Umuopara	E	E	E	E	E
	Umueze II					
9.	Umueleke	E	E	E	E	E
10.	Umuodara	E	E	E	E	E
11.	Umuduruegwele	E	E	E	E	E
	Umunakanu					
12.	Umuele	E	E	E	E	E
13.	Umueli	E	E	E	E	E
14.	Umuola	E	E	E	E	E
	Umunumo					
15.	Umuaro	E	E	E	E	E
16.	Umuokpara	E	E	E	E	E
17.	Umuchima	E	E	E	E	E
	Nsu					
18.	Agbaghara	E	E	E	E	E
19.	Ezeoke	E	E	E	E	E
20.	Umuakagu	E	E	E	E	E
	Mbaitoli L.G.A					
	Mbieri					
21.	Obazu	E	E	E	E	E
22.	Umuonyeali	E	E	E	E	E
23.	Umudagu	E	E	E	E	E
	Ogwa					

24.	Idem-Ogwa	E	E	E	E	E
25.	Ochii	E	E	E	E	E
26.	Umueze	E	E	E	E	E
	Ubomiri					
27.	Egbeada	E	E	E	E	E
28.	Obokpu	E	E	E	E	E
29.	Umuabali	E	E	E	E	E
	Orodo					
30.	Obi-Orodo	E	E	E	E	E
31.	Ofekata	E	E	E	E	E
32.	Ubaha	E	E	E	E	E
	Ifakala					
33.	Umunoha	E	E	E	E	E
34.	Nworieubi	E	E	E	E	E
35.	Nkwesi	E	E	E	E	E

DISCUSSION

Air quality assessment using GIS and MATLAB was carried out on data collected from 35 select locations within the study area in both the dry and the rainy seasons for a 2-year analytical periodto investigate the effect of seasonal variation on the concentration levels of various pollutants for air quality assurance. Another factor could be due to scavenging of the atmospheric pollutants emitted from natural and anthropogenic sources by rain events. Seasonal changes to rainwater can present as colour changes, straining, new odours and metallic taste. It is important to identify what is causing these fluctuations.

The investigation indicated that the mean values of Temperature, pH, Alkalinity, Total Hardness, Chloride (Cl^-), Electrical conductivity (EC), Sulphur dioxide (SO_2), Particulate matter (PM_{10}), Cadmium (Cd), Zinc (Zn), Iron (Fe) and Lead (Pb) are peak in dry seasons and lowest in rainy the seasons while the average concentration of Phosphate (PO_4^{3-}) showed the same trend with Sulphate (SO_4^{2-}), Nitrate (NO_3^-), Carbon monoxide (CO) and Copper (Cu) with higher levels during the rainy seasons. Average Total Dissolved Solid (TDS) remain fairly constant in both seasons.

MATLAB Comparison Model, Bar Charts, Artificial Neural Network (ANN), Box & Whiskers Plot, the Multi-Comparative Graph and ANOVA Table Discussion

If the data sets are plotted as points, the line that joins them is the model. If the points are perfectly fit by the line, it means the model utilized is in order and represents the outcome of the acquired data.The bar charts illustrate the rate at which the concentrations occur.ANOVA best description lies on the multi-comparative graph which normally has 2 lines of different colours. If the lines in the graph have different colours, it means that the data compared (mean data of the dry and the rainy seasons of pollutants) vary significantly or are significantly different indicating that the concentration level of the pollutant is affected by seasonal change. If the lines have one colour (maybe blue and the other one is blurred), it means data compared are insignificantly different (concentration level of the pollutant is not affected by seasonal change) because it's a one-way ANOVA. The outcome of the ANOVA is affirmed by the multi-comparative graph.

If the tip of the boxes in the Box and Whiskers plot are not at the same level, it shows that the data sets are significantly different from each other. Both the "Box and Whiskers plot" and the "Multi-Comparative graph" affirms presented information, explaining one and the same thing –The ANOVA Table. The emphasis on determining the significant level of the data that are being compared is based on the multi-comparative graphs. If the multi-comparative graphs states clearly that there are significant differences, it means the ANOVA table suggests the same.Artificial Neural Network (ANN), a tool in MATLAB 2015 application is plotted with actual data to see if it will track the actual data. If the lines follow the same pattern, it means ANN tracked the actual data properly and can be used to represent/gather information or data with regards to pollutant concentration in all the areas considered. If it does not, it means ANN cannot be utilized to represent that data. Once, you use ANN to model, you can predict with them to generate values of their own with which to plot their graphs. The line movement or plots shows clearly the discrepancies.

Seasonal Variations of Carbon Monoxide (CO)

Table 6 shows concentration levels measured during the rainy seasons 53 – 65 ppm is higher than that measured during the dry season 41 – 51 ppm. These concentration levels for both seasons exceeded WHO [35], NAAQSand FEPA [36] Standard of 50 ppm, 35 ppm, 9 ppm respectively for carbon monoxide in the atmosphere. The AQI (CO) rating for both seasons were **E** and falls under the category of poor air quality [37].

In Figure 5, it is seen that the rainy seasons was the season most polluted with CO suggesting that the atmosphere contained more CO pollution during the rainy seasons. Maximum average CO concentration of 65 ppm were recorded in Umuodara –Umueze II, Umuchima –Umunumo, Ezeoke and Umuakagu –Nsu, all in Ehime Mbano L.G.A.

Interpretation of pollution concentration mapped with Arc GIS package, Figure 4 also show that CO was present throughout the year. Studies showed that average CO concentration tend to be higher in the rainy season, which is the season with lowest ventilation capability. This finding can be supported by the fact that outdoor CO concentration increases with lower temperature, high relative humidity and decreased atmospheric mixing height. Figure 4, CO GIS Comparison Model showed that CO concentrations are evenly spread with slightly higher concentration during the rainy seasons.

Obtained values from CO ANOVA anlysis on Table 7 which is affirmed by the Multi-Comparative graph in Figure 9 shows that the compared data are insignificantly different since the lines of the graph have only one colour (blue). This indicate that there was no significant variation in CO concentration level in both seasons thus, CO concentration in the atmosphere was not affected by seasonal change.

Seasonal Variations of Nitrogen Dioxide (NO_2)

For the study period, the average range concentration for the dry seasons of NO_2 was 0.55–0.75 ppm while the rainy seasons was 0.68–0.85 ppm. A peak reading of 0.85 ppm was noted during the rainy season. The hot spot is identified at Nworieubi. The high level NO_2 concentrations found is due to burning of fossil fuels, microbial action on nitrogenous organic matter found in wastes littering the environment and from chemical fertilizers used for agricultural purposes. The FEPA (Stationary sources) and NAAQS (Ambient limit) NO_2 values for Nigeria is 0.06 ppm and 0.1 ppm respectively [36] thus, the NO_2 levels at all sampling points exceeds both FEPA and NAAQS limit for Nitrogen dioxide in the atmosphere. The AQI NO_2 ratings for both seasons were **E** which falls under the category of poor air quality. Interpretation from the NO_2 pollution Map in Figure 10 shows the distribution pattern similar for both seasons. Figure 11, NO_2 MATLAB Comparison Model shows both seasons as having similar concentration level distribution, with the rainy season experiencing higher variation in concentration levels. Values from NO_2 ANOVA analysis on Table 9, shows that data sets are significantly different. This is affirmed by Figure 14, the NO_2 Box and Whiskers plot (since the tip of the boxes not at the same level) and Figure 15, NO_2 Multi-Comparative graph (the 2 lines of the graph having different colours–Blue and Red), implying that NO_2 concentration in the atmosphere was affected by seasonal change.

Seasonal Variation of Sulphur Dioxide (SO_2)

The mean range SO_2 readings recorded for the dry seasons was 0.54–0.87 ppm and for the rainy seasons 0.46–0.73 ppm as shown in Table 10. The highest reading was recorded in Umuonyeche, Owerri Municipal during the dry season. These concentration levels for both seasons were however, seen to exceed the NAAQS Standard of 0.5 ppm but falls within FEPA Standard of 26 ppm for SO_2 in the atmosphere. The presence of high number of diesel engine vehicles and equipment in the state could be a major source. Consequently, the hot spot areas should be areas of concern because these emitted gases will eventually form acid rain which will affect the environment, causing corrosion of materials, damage to food crops, nutrient leaching and drinking water contamination. The AQI (SO_2) rating for both seasons were **E** falling under the category of poor air quality. Figure 15 interprets the data as having slight variation in the air SO_2 concentration levels in both seasons. Values obtained from SO_2 ANOVA analysis on Table 11 which is affirmed by Figure 20, SO_2 Box and Whiskers plot and Figure 21, SO_2 Multi-Comparative plot showed that data sets were significantly different, indicating that atmospheric SO_2 concentration was affected by change in season.

Seasonal Variations of Particulate Matter (PM_{10})

The existing coarse particle standard has been in place since 1987. Table 12 showed the mean range of PM_{10} in the dry seasons was 10.21–12.62 ppm which was higher than that of the rainy seasons 7.53–8.89 ppm. The highest reading of 12.62 ppm occurred in the dry season. From the interpretation of pollution concentration mapped in Figure 22, PM_{10} was shown to be present throughout the year with the dry season been more polluted. Particulate matter is released mostly by fossil fuel combustion, motor vehicles, bush burning and industrial activities. Comparing the values to FEPA and NAAQS of 0.25 ppm and 0.15 ppm respectively for particulate matter in the atmosphere, PM_{10} concentration levels were higher than both FEPA and NAAQS standards. The AQI PM_{10} rating for both seasons were **E** and it falls under category of poor air quality, this is in agreement with [38]. ANOVA analysis on Table 13 affirmed by the Box and Whiskers plot on Figure 26 and the Multi-Comparative graph on Figure 27 interprets the concentration values of the pollutant in the dry seasons as varying significantly from that of the rainy seasons indicating that Particulate matter concentration of the atmosphere was affected by seasonal change.

CONCLUSION

The study used GIS (IDW) and MATLAB 2015 software to generate air pollution models which were applied in the Monitoring and Modeling of Atmospheric Change Indices. The dry seasons were more polluted by SO_2 and PM_{10}than the rainy seasons. This is due to the atmospheric pollutants emitted from natural and anthropogenic sources in the dry seasons and lower pollutant emission during the rainy seasons as a result of frequent rainfall. The GIS pollution distribution mapping showed hot spot locations for all the pollutants, mainly in the industrial Metropolis indicating that anthropogenic activities were the primary source of the pollutants. The gaseous pollutants exceeded the WHO limit, NAAQS and FEPA standards. Recently, there were reports on the use of Nano materials in remediating air pollution. Though these studies have demonstrated their efficacy in laboratory settings, more research is necessary for the full understanding of how Nano technology can significantly affect the remediation of air contaminants in real case scenario. The Imo State Environmental Protection Agency (ISEPA) should therefore, as a matter of urgency, consider these technologies to detect and control the emission of these gases into the atmosphere now and in the future.

Suggestions for Further Study

1. An empirical Model should be deployed in the prediction of pollution factors with the outcome compared to the outcome of the Artificial Neural Network (ANN) Model.
2. Other Artificial Intelligence Models should be used and compared to determine the best Model that represents environmental pollutants obtained from the field.

Declarations Conflict of Interest

The authors declare that they have no conflict of interest.

Consent for Publication

All authors agreed to publish this research work.

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