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# TREND ANALYSIS OF GREENHOUSE GASES (GHGs) EMISSIONS OVER NIGERIA FROM 2000 - 2021

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**Abstract:** The global climate is changing with attendant devastating consequences on human livelihood and socioeconomic activities. This change has been related to greenhouse gas (GHG) emissions, which primarily include carbon dioxide ($CO_2$), methane ($CH_4$), and nitrous oxide ($N_2O$) and are characterised by spatiotemporal fluctuations over the planet. The objective of the research is to analyse temporal variation of greenhouse gases emissions over Nigeria from 2000 - 2021. Data used were obtained from the archive of the Emissions Database for Global Atmospheric Research (EDGAR). This database provides time-series emissions as national totals using international statistics and a consistent Intergovernmental Panel on Climate Change (IPCC) methodology. Monthly data for a period of 21 years covering 2000-2021 were obtained for Nigeria. Trend analysis was carried out on a monthly, seasonal and annual basis to define the historical emissions trend path over Nigeria using descriptive statistics and the Mann-Kendall test. Results of the monthly analysis from January to December for the given historical years demonstrated steady upward trends for two gases namely $CO_2$ and $N_2O$ which are significant at the 0.05 alpha levels. On the contrary, the $CH_4$ gas emission indicated different trends for different months which are not significant at the 0.05 degree of alpha. Furthermore, similar scenarios of significant upward trends of $CO_2$ and $N_2O$ emissions, but not for $CH_4$ are noticeable with respect to the seasonal and annual time-series. As a result, Nigeria's Nationally Determined Contributions (NDCs) to the United Nations Framework Convention on Climate Change (UNFCCC) have not resulted in a positive commitment to achieve net-zero emissions by 2060.

**Keywords:** Greenhouse Gases, Trend Analysis, Mann-Kendall Test, 21st Century

## Introduction

There is no doubt the global climate is changing with impact on human livelihood and socioeconomic activities. Climate change resulting to global warming is traceable to the advent of industrial revolution in the mid of the 18th century. Since this period, the global temperature has been rising with resultant devastating consequences (Taka et al., 2020; Chen, 2021). The emissions of greenhouse gases (GHGs), which primarily comprise carbon dioxide ($CO_2$), methane ($CH_4$), and nitrous oxide ($N_2O$) and are subject to spatiotemporal fluctuations globally, have been blamed for this change. To

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address the forgoing, the global international community ratify the establishment of the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 during Rio Earth's Summit, but became operational in 1995 (Oda, 2018; Wang and Jiang, 2020). Over the years, the convention's parties have met on an annual basis to fine-tune measures to mitigate the effects of climate change, culminating in the signature of the Paris Agreement during the 21$^{st}$ Conference of the Parties (COP21) in 2015. The Nationally Determined Contribution (NDC) is a commitment that each nation must make under the Paris Agreement, and it must be updated every five years (Taka et al., 2020). The first update of the NDC was welcomed at COP26 in the United Kingdom, where the majority of nations adopted an aggressive emission reduction target to limit the increase in global temperature below 1.5°C (Rourke and Smith, 2019). To create the route towards achieving climate neutrality by 2050, the majority of industrialised nations agreed to reduce GHG emissions by over 50% by 2030 (in comparison to the level in 2005) (Saisirira et al., 2022; William et al., 2022; Xue et al., 2022). Although, it is on record that most of the historical emissions were from the developed countries of Europe and North America particularly USA (Friedrich and Trois, 2015; Mekonnen et al; 2018). African countries as a whole account for less than 4% (Mose, 2017). However, since the beginning of 21st century most developing countries of the world have intensified greenhouse gases emissions due largely to their quest for development. In addition, the percentage of African countries to global emissions is not evenly distributed among but varies from one country to another. For instance, Tchanche (2021) claims that the majority of African countries in sub-Saharan Africa rely on the usage of fossil fuels, which are a significant source of greenhouse gases and other air pollution. These emissions have a detrimental effect on the environment and human health (Baur et al., 2015). According to studies, West Africa's pollution levels are significantly underestimated (Barisa and Rosa 2018), and they are steadily rising as a result of urbanisation and population expansion. Nigeria is one of the African countries that are known to account for a greater percentage of greenhouse gases emissions due mainly of her oil exploitation and teaming population. Nigeria was the most populated nation in Africa according to the United Nations, with 170 million residents as of 2012 (Tunde et al., 2022) with a growth rate of nearly 60% between 1990 and 2008. By the early 21st century, it is anticipated to reach 0.5–1 billion people (Ayetor et al., 2020). Transportation and other anthropogenic activities including bush burning, deforestation, and transportation could also raise atmospheric $CO_2$ levels (Tunde et al., 2022). To address the aforementioned, the government of Nigeria accepted the Paris Agreement in 2017, much as other signatories. Nigeria, which accepted the Paris Agreement, pledged to comply with its Nationally Determined Contribution (NDC) commitment by 2030 to cut its greenhouse gas (GHG) emissions by 20% unconditionally and by 47% conditionally.

Studies that have looked into GHG emissions in Nigeria in the recent past are already in existence. Notably, David and Victor (2017) used the Auto-regressive Distributed Lag (ARDL) Model to analyse the dynamics of carbon dioxide ($CO_2$) emission on Nigerian capacity utilisation. According to the research, it was found that carbon dioxide (CE) emissions are currently statistically significant and positively correlated with average manufacturing capacity utilisation (AMCU) in both the short and long term, indicating that carbon dioxide emissions are consistent with green economics but won't jeopardise future production and consumption. Elemile et al. (2017) investigated diurnal and seasonal variations in carbon dioxide emissions at an open dump in a solid waste management facility, Akure, Nigeria. The result showed that the total amount of trash (paper) produced from all sources was 5,834,005.0 + 5,079633.8 kg during the wet season and 4,266,871.0 + 3,745,337.8 kg during the dry season. There were no appreciable variations in the levels of carbon dioxide in the morning (506.9 +

71.1 and 537.0 + 91.8 ppm), noon (415.0 + 15.9 and 458.5 + 44.1 ppm), afternoon (434.3 + 45.3 and 438.0 + 7.2 ppm for GH only in the wet and dry seasons, respectively), or midday (427.3 + 20.5 and 443.5 + 10.4 ppm). As evidenced by readings ranging from 438.00 to 630.0 ppm in the dry season and 407.3 and 506.99 ppm in the rainy season, the atmospheric $CO_2$ data in the study region clearly demonstrated seasonal and diurnal fluctuations. These readings exceeded the national guideline levels' regulatory cap of 400.00 ppm.

Michael and Atul (2019) applied the agriculture and land use national greenhouse gas inventory software to estimate the total greenhouse gas (GHG) emissions from the Nigerian agriculture sector in 2010. According to the findings, Nigerian agriculture produced about 34.9 million tonnes of carbon dioxide equivalent in total in 2010. The greatest source of GHG emissions in the industry, livestock accounted for almost 69.2% of the total emissions. In comparison to 2010 levels, Nigeria's agricultural GHG emissions are predicted to rise by 94% in 2050. Oliver et al. (2022) studied the $CO_2$ emissions trend and their reduction potential in the Nigerian manufacturing sector from 2010 to 2020. The change in $CO_2$ emissions was divided into pre-determined factors using the Logarithmic Mean Divisia Index, including the effects of carbon intensity, energy intensity, cost structure, asset turnover, asset to equity conversion, equity-funded production, and productive capacity utilisation. The findings indicate that between 2010 and 2020, emissions grew by 1668 1012 GJ. The main causes of increased emissions were energy intensity and equity-funded production, whereas emissions were decreased by the use of the productive capacity. With a few exceptions, the $CO_2$ emissions increased over the whole research. The findings indicate that, in the case of business as usual, drivers at from-level increased $CO_2$ emissions in the absence of a carbon tax policy. Tunde et al. (2022) assessed sources and sectoral trend analysis of $CO_2$ emissions data in Nigeria using a modified Mann-Kendall and change point detection approaches. The data were disaggregated into various emission sources: gaseous fuel consumption (GFC), liquid fuel consumption (LFC), solid fuel consumption (SFC), transport (TRA), electricity and heat production (EHP), residential buildings and commercial and public services (RSCPS), manufacturing industries and construction (MINC), and other sectors excluding residential buildings and commercial and public services (OSEC). A rank-based non-parametric modified Mann-Kendall (MK) statistical approach and a change point detection method were used to conduct the study for a sectorial trend. The findings revealed that TRA had the most $CO_2$ emissions, followed by LFC. Sen's slope was positive for the GFC, LFC, EHP, and OSEC and negative for the SFC, TRA, and MINC. While some sources placed the shift point at a certain year, the trend analysis showed many changes for TRA and OSEC.

However, it is clear from the analysis of the literature that previous researches have used a variety of techniques, including different algorithms, theories, and mathematical models to monitor changes in GHGs including $CO_2$, $CH_4$, and $N_2O$. While some of these researches are solely focused on a certain region of Nigeria, others are just interested in one GHG. Additionally, it is unknown of any studies that have examined the trends in monthly, seasonal, and annual GHG emission over Nigeria. Therefore, this represents the study's research gap. In light of this, the study's objective was to determine the trend in historical emissions trajectory by analysing the monthly, seasonal, and annual variation of greenhouse gas (GHG) emissions over Nigeria from 2000 to 2021.

## Material and Method

### *Study Area*

Nigeria is located in West Africa between the latitudes of 4 degrees and 14 degrees and the longitudes of 3 degrees and 14. Its land area is 923,768 square kilometres. The Republic of Nigeria is bordered to the north by the Republics of Niger and Chad; to the west by the Republic of Benin; and to the east by the Republic of Cameroun, which extends all the way to the Atlantic Ocean's coastlines, forming the southern limits of Nigerian territory. One of the top ten most climate-vulnerable nations in the world is Nigeria. With numerous sources, the land-use change and forestry sectors accounted for 38.2 percent of greenhouse gas emissions, followed by the energy, waste, agricultural, and industrial processes sectors with contributions of 32.6 percent, 14.0 percent, 13.0 percent, and 2.1 percent, respectively.

### *Data Collection*

The Emissions Database for Global Atmospheric Research Seventh Version (EDGARv7.0) repository served as the source of the data. Using global statistics and a consistent Intergovernmental Panel on Climate Change (IPCC) methodology, this database gives time-series emissions as national totals (Crippa et al., 2020, 2021, 2022). Over Nigeria, monthly statistics were gathered over a period of 21 years, from 2000 to 2021.

### *Data Analysis*

It was examined and compared how the monthly, seasonal, and annual emissions of $CO_2$, $CH_4$, and N2O changed over time in ktons/year. For each of the three greenhouse gas emissions, seasonal variations of $CO_2$, $CH_4$, and $N_2O$ were plotted and compared according to the dry season (December, January, and February), transition from dry to wet season (March, April, and May), wet season (June, July, and August), and transition from wet to dry season (September, October, and November). Both descriptive and inferential statistics were employed to attain the research's goal. Inferential statistics (Mann-Kendall test) were used to identify monotonic trends in the historical emissions of the greenhouse gases, while descriptive statistics (Line graph) were used to show the historical time-series emissions of the three greenhouse gases. The Mann-Kendall statistical test has a wide range of applications in environmental studies, and it is widely used to determine the significance of trends in time series (Scherrer et al., 2016; Zobel et al., 2018; Tunde et al., 2022). This is calculated using the following equations:

$$S = \sum_{k=1}^{n-1} \sum_{i=k+1}^{n} \text{sign}\ (x_j - x_k) \qquad (1)$$

$$\text{VAR}\ (S) = \frac{[n(n-1)(2n+5) - \sum_{i=1}^{m} t_{i}(t_i - 1)(2t_i + 5)]}{18} \qquad (2)$$

Where:

n = the number of data points

$t_i$ = the number of ties for the i value and

m = the number of tied values (a tied group is a set of sample data having the same value)

$$Z_s = \begin{cases} \frac{S-1}{\sqrt{VAR(S)}} & if S > 0 \\ 0 & if S = 0 \\ \frac{S+1}{\sqrt{VAR(S)}} & if S < 0 \end{cases} \quad (3)$$

Positive $Z_s$ values represent rising trends, while negative $Z_s$ values show falling trends and 0 values represent no trends. Trends were tested at a certain, significant level. When | $Z_s$ | > $Z_1$ - $\alpha/2$, the null hypothesis is rejected and the time series exhibits a substantial trend. From the typical normal distribution table, $Z_1$ - $\alpha/2$ is derived. A significance threshold of 0.05 was chosen in this investigation. The null hypothesis of no trend is rejected at the 5% level of significance if | $Z_s$ | > 1.96, which led Oguntunde et al. (2012) and Daramola et al. (2017) to draw the conclusion that the time series exhibits a substantial trend.

Using the Mann-Kendall test method, trend analysis was done on a monthly, seasonal, and annual basis to determine the historical emissions trend path over Nigeria. XLSTAT 2022.3.1 software (Addinsoft, 2022) was used to calculate all of the statistical analysis.

## Results and Discussion

### *Monthly Variation of Greenhouse Gases (GHGs) Emissions*

Results of the monthly analysis from the January to December for the given historical years are depicted in Figure 1. It is evident from the graph that $CO_2$ and $N_2O$ monthly emissions

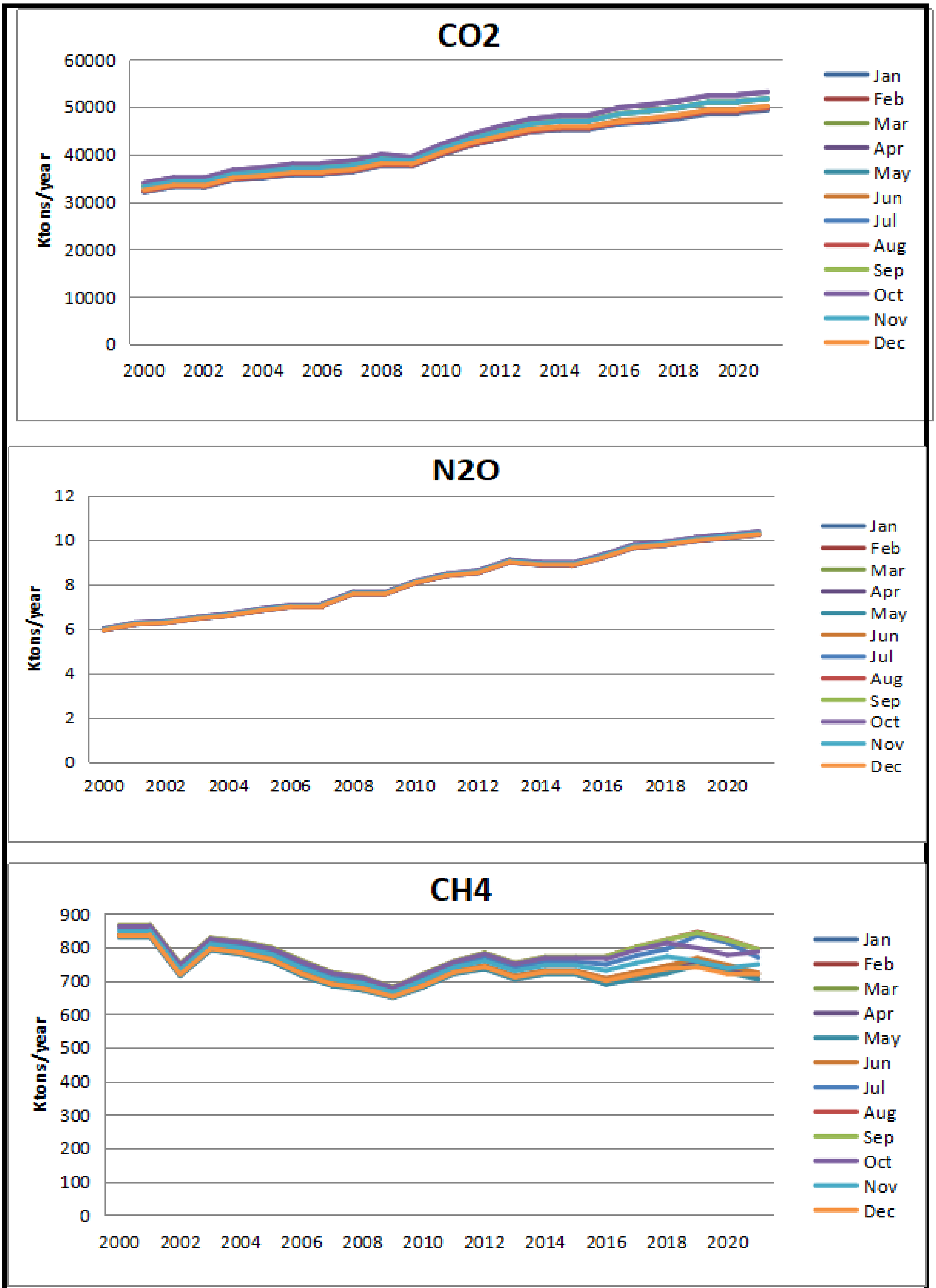


*Figure 1: Monthly greenhouse gases (GHGs) emissions*

*Table 1: Mann Kendall test of monthly greenhouse gases (GHGs) emissions*

| GHGs | Months | Mean | Kendall's Tau | Var(S) | P-value (two test) | Alpha | Test Interpretation |
|---|---|---|---|---|---|---|---|
| CO2 | JAN | 41223.5 | 0.981 | 1096.7 | 0.0001 | 0.05 | Reject Ho↑ |
| | FEB | 41342.4 | 0.981 | 1096.7 | 0.0001 | 0.05 | Reject Ho↑ |
| | MAR | 42951.2 | 0.981 | 1096.7 | 0.0001 | 0.05 | Reject Ho↑ |
| | APR | 43944.7 | 0.981 | 1096.7 | 0.0001 | 0.05 | Reject Ho↑ |
| | MAY | 42902.9 | 0.981 | 1096.7 | 0.0001 | 0.05 | Reject Ho↑ |
| | JUN | 41803.8 | 0.981 | 1096.7 | 0.0001 | 0.05 | Reject Ho↑ |
| | JUL | 41294.5 | 0.981 | 1096.7 | 0.0001 | 0.05 | Reject Ho↑ |
| | AUG | 41471.6 | 0.981 | 1096.7 | 0.0001 | 0.05 | Reject Ho↑ |
| | SEP | 42950.4 | 0.981 | 1096.7 | 0.0001 | 0.05 | Reject Ho↑ |
| | OCT | 43989.4 | 0.981 | 1096.7 | 0.0001 | 0.05 | Reject Ho↑ |
| | NOV | 42916.8 | 0.981 | 1096.7 | 0.0001 | 0.05 | Reject Ho↑ |
| | DEC | 41773.3 | 0.981 | 1096.7 | 0.0001 | 0.05 | Reject Ho↑ |
| CH4 | JAN | 731.4 | -0.086 | 1096.7 | 0.608 | 0.05 | Reject Ha |
| | FEB | 732.0 | -0.086 | 1096.7 | 0.608 | 0.05 | Reject Ha |
| | MAR | 730.6 | -0.095 | 1096.7 | 0.566 | 0.05 | Reject Ha |
| | APR | 723.8 | -0.133 | 1096.7 | 0.415 | 0.05 | Reject Ha |
| | MAY | 721.6 | -0.133 | 1096.7 | 0.415 | 0.05 | Reject Ha |
| | JUN | 733.7 | -0.057 | 1096.7 | 0.740 | 0.05 | Reject Ha |
| | JUL | 764.2 | 0.144 | 1096.7 | 0.487 | 0.05 | Reject Ha |
| | AUG | 777.9 | 0.162 | 1096.7 | 0.319 | 0.05 | Reject Ha |
| | SEP | 778.2 | 0.152 | 1096.7 | 0.349 | 0.05 | Reject Ha |
| | OCT | 770.3 | 0.057 | 1096.7 | 0.740 | 0.05 | Reject Ha |
| | NOV | 746.6 | -0.048 | 1096.7 | 0.786 | 0.05 | Reject Ha |
| | DEC | 727.3 | -0.162 | 1096.7 | 0.319 | 0.05 | Reject Ha |
| N2O | JAN | 8.178 | 0.962 | 1096.7 | 0.0001 | 0.05 | Reject Ho↑ |
| | FEB | 8.186 | 0.962 | 1096.7 | 0.0001 | 0.05 | Reject Ho↑ |
| | MAR | 8.253 | 0.962 | 1096.7 | 0.0001 | 0.05 | Reject Ho↑ |
| | APR | 8.299 | 0.962 | 1096.7 | 0.0001 | 0.05 | Reject Ho↑ |
| | MAY | 8.251 | 0.962 | 1096.7 | 0.0001 | 0.05 | Reject Ho↑ |
| | JUN | 8.220 | 0.962 | 1096.7 | 0.0001 | 0.05 | Reject Ho↑ |
| | JUL | 8.178 | 0.962 | 1096.7 | 0.0001 | 0.05 | Reject Ho↑ |
| | AUG | 8.186 | 0.962 | 1096.7 | 0.0001 | 0.05 | Reject Ho↑ |
| | SEP | 8.253 | 0.962 | 1096.7 | 0.0001 | 0.05 | Reject Ho↑ |
| | OCT | 8.299 | 0.962 | 1096.7 | 0.0001 | 0.05 | Reject Ho↑ |
| | NOV | 8.251 | 0.962 | 1096.7 | 0.0001 | 0.05 | Reject Ho↑ |
| | DEC | 8.200 | 0.962 | 1096.7 | 0.0001 | 0.05 | Reject Ho↑ |

Source: Authors' Computation, 2022

Reject Ho↑: significant increasing trend     Reject Ha: No trend

were consistently on the upward trend. When the two greenhouse gases' shown continuous increase tendencies were subjected to Mann Kendall trend analysis, the results showed a significant trend at the 0.05 alpha levels (Table 1). The monthly CH4 emissions, on the other hand, show very modest upward and downward trends for the various months, which confirms that there is no pattern in the time-series at the 0.05 degree of alpha (Table 1). Future economic expansion in Nigeria, according to Michael and Atul (2019), will undoubtedly have an impact on future increases in GHG emissions. However, despite the significant upward trends recorded for all the months with respect to the CO2 and N2O, variations exist among the months. The month of October accounted for the highest CO2 emission with a mean value of 43989.4 ktons/year followed by the month of April with a mean value of 43944.7 ktons/year (Table 1). The months of January and July were the least in the time-series with mean values of 41223.5 ktons/year and 41294.5 ktons/year respectively.

Furthermore, the time-series analysis of CH4 emissions despite no significant trends, indicated that out of the twelve months of a calender year, eight months comprising the months of January to June as well as November and December were trending toward downward trends with a negative Kendall's tau values; while only four months which encompasses months of July to October were trending towards upward trends with a positive Kendall's tau values (Table 1). The mean values of the CH4 emissions across the months revealed a markedly differences, with the months of September and August responsible for the highest monthly emissions of 778.2 ktons/year and 777.9 ktons/year respectively. Conversely, months of May and April accounted for the least emissions with 721.6 ktons/year and 723.8 ktons/year respectively. In addition, the time-series analysis of N2O emissions just like the other two preceeding greenhouse gases established a distinct variations in the mean emission values across the months. The months of April and October accounted for the highest emissions with the same mean value of 8.299 ktons/year, while the least emissions covers the months of January and July with the same mean value of 8.178 ktons/year (Table 1). More so, a cursory look at the historical monthly emissions pattern of the three greenhouse gases show that the highest and least monthly emissions coincided for the CO2 and N2O, but at variance with the CH4 emissions (Table 1). Hence, it can be presumed from the forgoing that similar causative factors could be responsible for the historical monthly emissions of the CO2 and N2O over Nigeria. These factors might be inconsistence with the underlying monthly emissions of the CH4 greenhouse gas. According to Lacour et al. (2021) CO2 emissions are decreasing elsewhere (e.g. Europe and the Americas); Africa's CO2 emissions are poised to grow in the coming decades. That the increasing population in sub-Saharan Africa coupled with the quest to increase their wealth through GDP growth will result in high levels of CO2 emissions if strict measures to curb emissions are not put in place.

### *Seasonal Variation of Greenhouse Gases (GHGs) Emissions*

Figure 2 depicts analysis of the seasonality pattern of the three greenhouse gas emissions. The chart shows that the seasonal emissions of CO2 and N2O, with the exception of the seasonal emissions of CH4, have maintained a linear trend over the course of the historical era for all the seasons. The seasons are, specifically, the transitional period from the dry to the wet season (March, April, and May), the wet season (June, July, and August), the transitional period from the wet to the dry season (September, October, and November), and the dry season (December, January, and February). Overall, the seasonal greenhouse gases emissions between the years 2000 through 2021 ranges from 100,000 ktons/year to 160,000 ktons/year, 2200 ktons/year to 2600 ktons/year and 18 ktons/year to 32 ktons/year for the CO2, CH4 and N2O respectively with little variations in between the seasons (Figure 2).

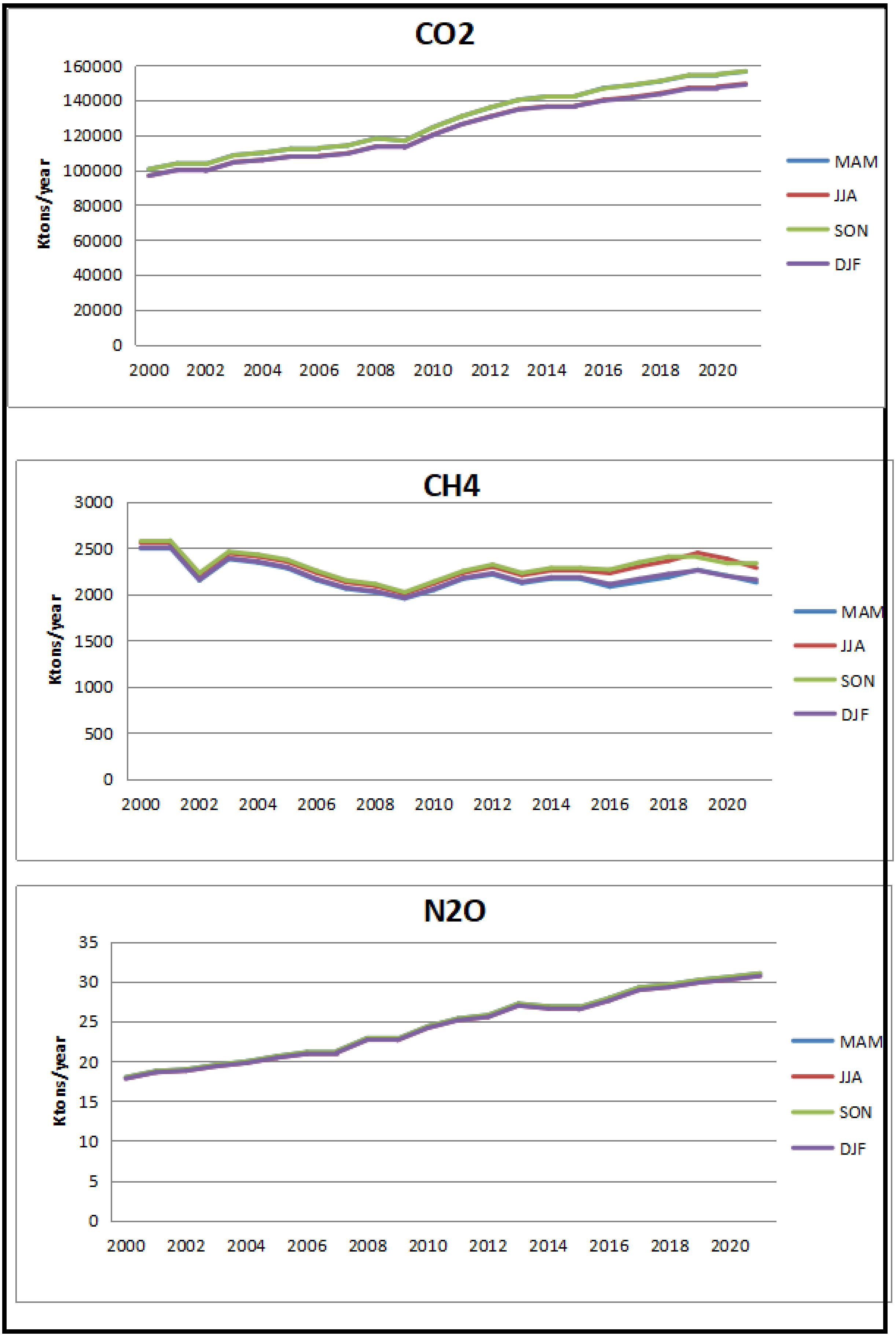


*Figure 2: Seasonal greenhouse gases (GHGs) emissions*

*Table 2: Mann Kendall test of seasonal greenhouse gases (GHGs) emissions*

| GHGs | Seasons | Mean | Kendall's Tau | Var(S) | P-value (two test) | Alpha | Test Interpretation |
|---|---|---|---|---|---|---|---|
| $CO_2$ | MAM | 129797.9 | 0.981 | 1096.7 | 0.0001 | 0.05 | Reject Ho↑ |
| | JJA | 124570.1 | 0.981 | 1096.7 | 0.0001 | 0.05 | Reject Ho↑ |
| | SON | 129856.8 | 0.981 | 1096.7 | 0.0001 | 0.05 | Reject Ho↑ |
| | DJF | 124339.2 | 0.981 | 1096.7 | 0.0001 | 0.05 | Reject Ho↑ |
| $CH_4$ | MAM | 2176.1 | -0.114 | 1096.7 | 0.487 | 0.05 | Reject Ha |
| | JJA | 2275.8 | 0.086 | 1096.7 | 0.608 | 0.05 | Reject Ha |
| | SON | 2295.1 | 0.057 | 1096.7 | 0.740 | 0.05 | Reject Ha |
| | DJF | 2190.6 | -0.095 | 1096.7 | 0.566 | 0.05 | Reject Ha |
| $N_2O$ | MAM | 24.803 | 0.962 | 1096.7 | 0.0001 | 0.05 | Reject Ho↑ |
| | JJA | 24.564 | 0.962 | 1096.7 | 0.0001 | 0.05 | Reject Ho↑ |
| | SON | 24.803 | 0.962 | 1096.7 | 0.0001 | 0.05 | Reject Ho↑ |
| | DJF | 24.563 | 0.962 | 1096.7 | 0.0001 | 0.05 | Reject Ho↑ |

Source: Authors' Computation, 2022

Reject Ho↑: significant increasing trend    Reject Ha: No trend

Furthermore, the emissions time series were subjected to Mann Kendall trend test to determine the presence or otherwise of monotonic trends in the $CO_2$, $CH_4$ and $N_2O$ emissions. The results of the statistical analysis tested at the 0.05 significant levels reveals a significant upward trends from the year 2000 through 2021 for the $CO_2$ and $N_2O$ time series emissions, but not for the $CH_4$ emissions. Consequently, the highest and least emissions between the three greenhouse gases as well as the four seasons were further scrutinized. Under the $CO_2$ emissions, the highest emission occurred during the SON with a value of 129856.8 ktons/year, while the least emission ensued in the DJF with a value of 124339.2 ktons/year. As for the $CH_4$ emissions, the highest emission was also in the SON with a value of 2295.1 ktons/year, but the least emission occurred in the MAM with a value of 2176.1 ktons/year. Similarly, the highest emission for $N_2O$ was observed in two seasons of the SON and MAM with a value of 24.803 ktons/year each, while the least emission was obtained in the DJF with a value of 24.563 ktons/year (Table 2). A comparison of the three greenhouse gases revealed a similarity of peak emissions in the same season of the SON, indicating a consistent seasonality effect on the historical emission trajectory over Nigeria. This is consistent with Elemile et al. (2017), who found that highest $CO_2$ concentrations occurred in the morning during the wet season but not during the dry season. During the dry season, diurnal variation was caused by the fact that most of the burning occurred during this time, and it was usually more effective in the afternoons due to the dryness of the dump waste and the increase in temperature, which makes it more conducive to burning, resulting in an increase in GHG concentration.

***Annual Variation of Greenhouse Gases (GHGs) Emissions***

Annual variation of historical greenhouse gases emissions is presented in a graph (Figure 3).

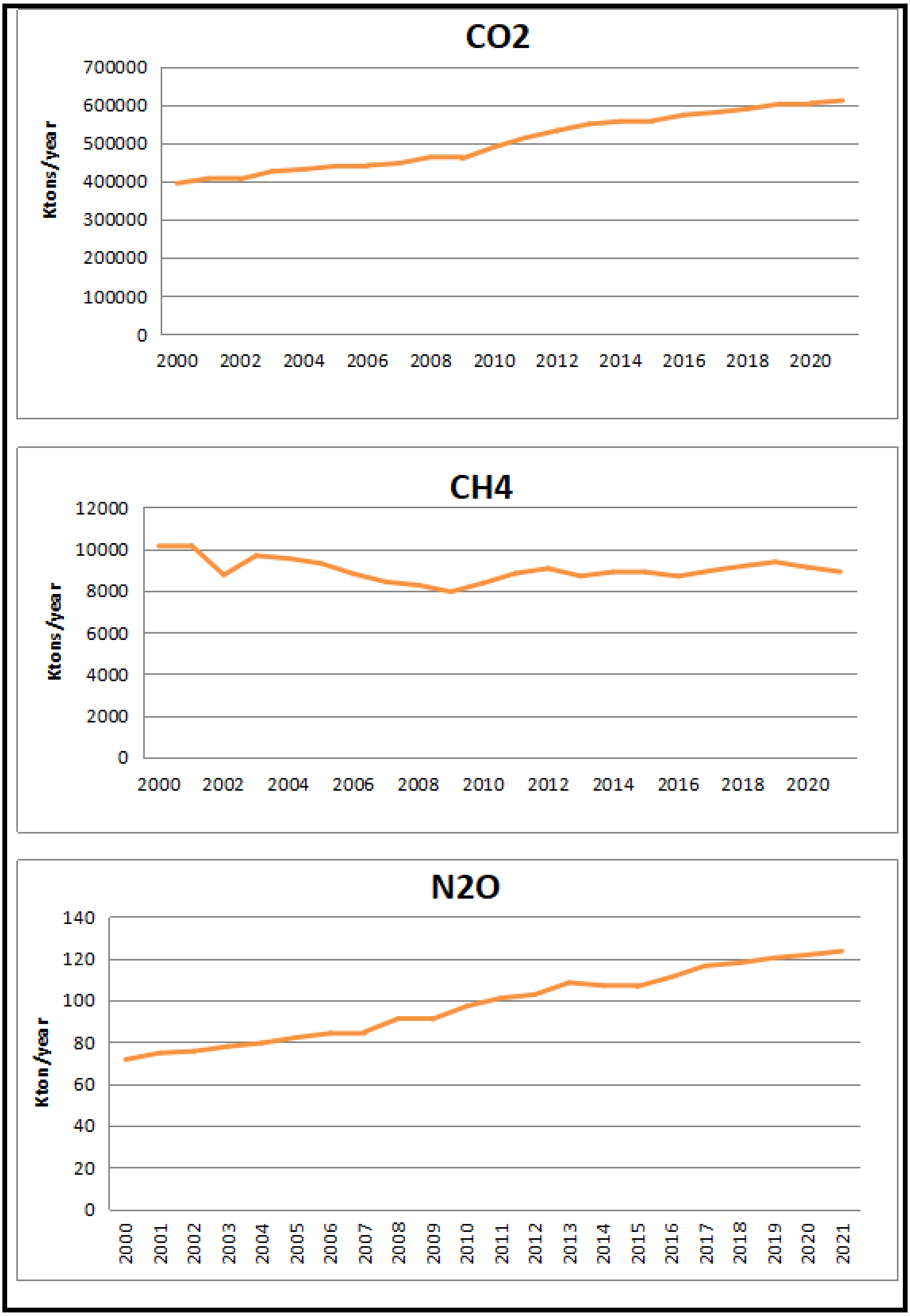


*Figure 3: Annual greenhouse gases (GHGs) emissions*

Figure 3 reveals linear trends for the $CO_2$ and $N_2O$ annual greenhouse gases emissions, while the $CH_4$ annual emissions show a nonlinear trend in the emission time series. On the other hand, Table 3 represented the Mann Kendall trend test for the three greenhouse gases tested at the 0.05 significant levels. A quick scan at the table revealed an upward trend in CO2 annual emissions over the previous years. This is consistent with the findings of Gabriel et al. (2021), who discovered that emissions from low to middle-income nations grew by 130%, primarily beginning in 2000. There is no trend in the emission time series for CH4 yearly emissions. Although the positive value of Kendell's tau (0.010) indicates that it is going upward, it is not significant at the 0.05 level of alpha (Table 3). However, the statistical trend analysis of the N2O annual time-series emissions unlike the CH4 annual emissions follow the similar pattern of the annual CO2 emissions with a significant upward trend tested at the 0.05 significant levels (Table 3).

*Table 3: Mann Kendall test of annual greenhouse gases (GHGs) emissions*

| GHGs | Period | Mean | Kendall's Tau | Var(S) | P-value (two test) | Alpha | Test Interpretation |
|---|---|---|---|---|---|---|---|
| CO2 | Annual | 508563.9 | 0.981 | 1096.7 | 0.0001 | 0.05 | Reject Ho↑ |
| CH4 | Annual | 8937.6 | 0.010 | 1096.7 | 0.976 | 0.05 | Reject Ha |
| N2O | Annual | 98.7 | 0.962 | 1096.7 | 0.0001 | 0.05 | Reject Ho↑ |

Source: Authors' Computation, 2022
Reject Ho↑: significant increasing trend      Reject Ha: No trend

Furthermore, a glance at the table reveals the mean annual values of the historical emissions for the three greenhouse gases namely, CO2, CH4 and N2O which stand at 508563.9 ktons/year, 8937.6 ktons/year and 98.7 ktons/year respectively. Thus, a comparison of the historical yearly time-series emissions of the three greenhouse gases revealed that CO2 accounted for 98% of the emissions, while CH4 and N2O emissions accounted for 1.7% and 0.3%, respectively. These percentage compositions are consistent with what has been documented in the literature, where CO2 emissions dominate as the primary greenhouse gas emitted into the earth's atmosphere. This is supported by the findings of a study conducted by Tunde et al. (2022), which identified the significance of monotonic trends in CO2 emissions from gaseous fuel consumption, solid fuel consumption, electricity and heat production, residential buildings, manufacturing industries, and construction sectors.

## Conclusion

In conclusion, it is clear from this study that emissions of greenhouse gases including carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O) over Nigeria have been rising continuously over the course of the 20th and 21st centuries. Compared to CH4, the increase has been most pronounced for CO2 and N2O. The research' implications necessitate that the Nigerian government intensify its climate action. Nigeria's Nationally Determined Contributions (NDCs) to the United Nations Framework Convention on Climate Change (UNFCCC) as they stand have not resulted in a particularly strong commitment to meeting the nation's net-zero emissions goal by the year 2060.

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