ANALYSIS OF THE EFFECT OF GREENHOUSE GAS EMISSION ON RAINFALL OUTCOMES IN NIGERIA

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ABSTRACT

The Mann-Kendall trend test and Sen's slope were employed in establishing the presence of significant upward trend in the GHGs (Carbon-dioxide (CO_2), Methane (CH_4) and Nitrous-oxide (NO_2)) emission figures. Correlation results showed that significant relationship exist between the GHGs emission quantities and Annual rainfall in the Northern Guinea, Sudan and Sahel Savannah climatic zones. These results further corroborates significant upward shifts of 15.8%, 23.6% and 18.4% observed in average annual rainfall in the aforementioned climatic zones respectively since the 1990s – which is a major cause of incessant flooding experienced in the country since 2012 till date. GHGs emissions predicted up till 2050 showed a steady increase in the emission figures which calls for immediate interventions in order to mitigate recurrent effects of climate change caused by these emissions.

1. INTRODUCTION

The total GHG emissions in Nigeria increased in 2000 by 135% to that of 1990, implying considerable increase in the socioeconomic activities (National Communication on Climate Change, 2014) where energy related activities contributed a major portion of the emission. Anomohanran (2011) revealed that 518.84 million metric tons (mmt) of CO_2 was released into the atmosphere between 1990 and 2009. Although, there was a remarkable decline in the total CO_2 emissions between 1990-1999, from a peak of 30.76mmt in 1992, to a low value of 17.26mmt in 1999. Between 2000 and 2009, greenhouse gas emission increased significantly reaching a peak of 32.56mmt. Furthermore, the study revealed that the average yearly increase in CO_2 emission between 2000-2009 was 4.7% as against the global average rate of 1.9%.

Although as at 2015, Nigeria like many African countries contributes less than 0.25% of global CO_2 emission, it is predicted to be one of the worst hit of the effect of climate change and ranked 146^{th} most prepared nation to the vulnerability to extreme events such as droughts and floods as well as readiness to withstand the shocks and stress of climate change (Notre Dame Global Adaptation Initiative (ND-GAIN), 2016). In many parts of Nigeria, drought and flood are increasingly becoming a major challenge for agricultural production, transportation, habitation and sustainability.

Although several works have been done on assessing changes in the rainfall pattern in Nigeria (see Ogungbenro and Morakinyo (2014), Obisesan and Dosumu, 2016), none of these studies have examined the relationship and impact of greenhouse gas emission on the amount of rainfall received, taking regional climatic differences into consideration. Therefore this study recognizes the climatic disintegration of the study area and studies the relationship between GHG emission and rainfall amount in each region independently.

2. METHODOLOGY

2.1 Mann-Kendall Trend Test and Sen's Slope

The non-parametric Mann-Kendall test is a test of the following hypotheses:

H_0: data come from a population with independent realizations and are identically distributed

H_A: The data follow a monotonic (increasing, stationary or decreasing) trend.

The Mann-Kendall test statistic 'S' follows as:

$$S = \sum_{i}^{n-1} \sum_{j=i+1}^{n} \left(sgn(x_j - x_i) \right)$$

With
$$sgn(x) = \begin{cases} 1, & x > 0 \\ 0, & x = 0 \\ -1, & x < 0 \end{cases}$$

2.2 Pettitt-Mann-Whitney Changepoint Test

The Pettitt-Mann-Whitney test is a modification to the Mann-Whitney U test. The Mann-Whitney statistic 'U' is given as:

$$U_{t,T} = \sum_{i=1}^{t} \sum_{j=t+1}^{T} D_{ij}$$

The most probable change point t is identified where the value of $|U_t|$ is maximum, i.e.:

$$K_T = \max_{1 \le t \le T} |U_{t,T}|$$

2.3 Exponential Smoothing

In the presence of trend in a series, the single exponential smoothing equation breaks down and is subject to significant bias in predicting the series. Hence, the Holt-Winter's double exponential smoothing is employed. We use $\{S_t\}$ to represent the smoothed value for time t, and $\{b_t\}$ is our best estimate of the trend at time t.

$$S_t = \alpha y_t + (1-\alpha)(S_{t-1} + b_{t-1}); \quad 0 \le \alpha \le 1$$
$$b_t = \gamma(S_t - S_{t-1}) + (1-\gamma)b_{t-1}; \quad 0 \le \gamma \le 1$$

Where $s_1 = x_0$, $b_1 = x_1 - x_0$, α is the data smoothing factor and β is the trend smoothing factor. To forecast beyond x_t,

$$F_{t+m} = S_t + mb_t$$

Where S_t is the reference point after which forecast should be made and m is the number of years after t that forecast is sought.

3. RESULTS

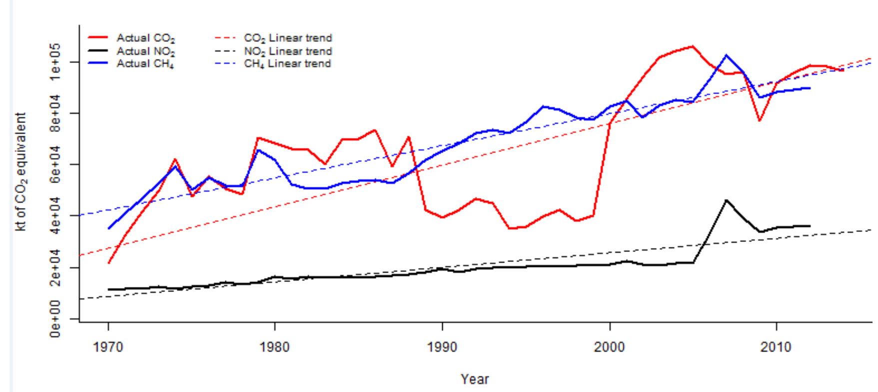

Figure 1: GHGs emission Trend (1970 – 2012)

Figure 1 shows the consistent rise in GHGs . Although there was a notable drop in CO_2 emission between 1990-2000, the rate of emission reached an all-time high in 2005 and just like the other gases, has remained continuously high.

Table 1: Mann-Kendall Trend test and Sen's Slope

GHG	Z	Sen's Slope	P-value	Trend
CO_2	6.43	1,567.99	0.00	Upward (Significant)
CH_4	7.60	1,262.52	0.00	Upward (Significant)
NO_2	8.77	367.72	0.00	Upward (Significant)

The Sen's slope in Table 1 above indicates the magnitude of average yearly increase over the period of study.

Table 2: PMW Changepoint detection in Annual Rainfall

Climatic Zones	Change Year	p-value	1970-change year average (in mm)	Change year to 2012 Average (in mm)	Remark
Swamp forest	2005	0.41	1,818.04	1,939.12	*NS*
Derived savannah	1989	0.09	1,243.66	1,359.79	*NS*
Southern guinea savannah	1974	0.64	992.08	1,081.51	*NS*
Northern guinea savannah	1990	0.01	**949.11**	**1,099.62**	***SIG***
Sudan savannah	1990	0.00	**764.02**	**946.13**	***SIG***
Sahel savannah	1993	0.03	**506.03**	**599.19**	***SIG***

Table 2 above shows that average annual rainfall in the Northern climatic regions (shaded) has significantly increased since the 1990s till date.

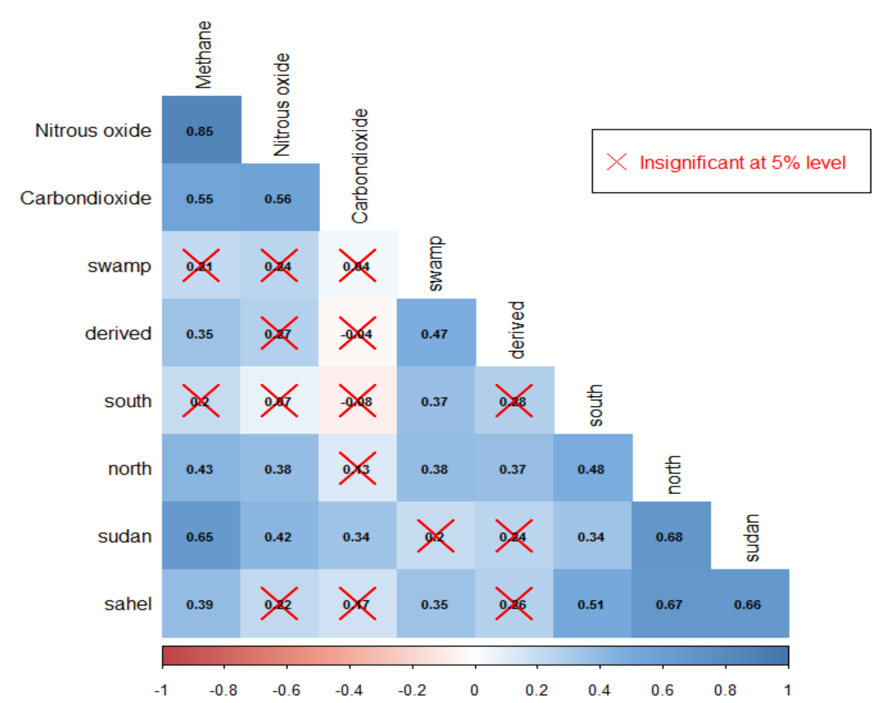

Figure 2: Correlation between GHG emission and Annual Rainfall

Figure 2 shows that there exist significant relationship between the amount of GHG emitted and rainfall amount in the derived and Northern Savannah Climates.

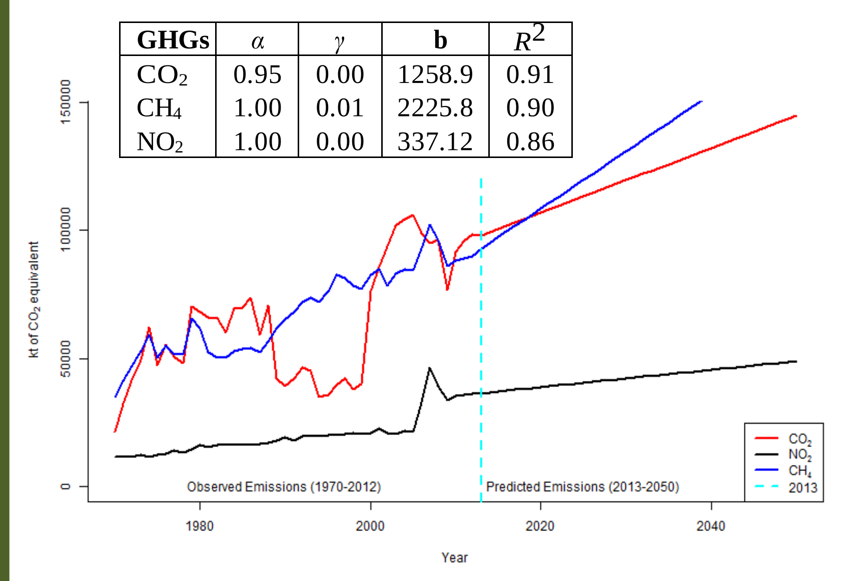

Figure 3: Predicted GHG emission (2013-2050)

Figure 3 shows steady rises in the predicted GHG emission figures.

Table 3: Forecast of Average Annual Rainfall (2013-2050)

Climatic Zones	Change Year	Change year to 2012 Average (in mm)	2013-2050 forecast average (in mm)	Forecast p-value
Swamp forest	2005	1,939.12	2,015.33	0.126*
Derived savannah	1989	**1,359.79**	**1,479.93**	**0.026**
Southern guinea savannah	1974	1,081.51	1,140.27	0.284*
Northern guinea savannah	1990	**1,099.62**	**1,251.49**	**0.0023**
Sudan savannah	1990	**946.13**	**1,193.06**	$\mathbf{3.17 \times 10^{-6}}$
Sahel savannah	1993	**599.19**	**724.71**	**0.005**

**no significant increase in regions rainfall based on increase in Methane emission.*

Forecast in Table 3 above were based on significant relationship that exist between Methane emission and rainfall quantities for each climatic zone based on simple linear regression equation below:

$$Annual\ Rainfall = A + B * (Forecast\ Methane\ emisson)$$

Where "A" and "B" are simple linear regression parameters estimated for each climatic zone.

4. CONCLUSION

The steady rise in the GHG emission figures (especially Methane) calls for immediate interventions in order to mitigate recurring effects of climate change caused by these emissions. This year and beyond, Excessive rainfall should be adequately prepared for as the amount of rainfall has increased and still increasing year-on-year.

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