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Correlational analysis of the trend of vegetation abundance and temperature (1982- 2020) in the ecological zones of Bayelsa and Rivers States, Niger Delta, Nigeria

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Abstract

The study examined the correlational analysis of the trend of vegetation abundance and temperature (1982-2020) in the ecological zones of Bayelsa and Rivers State, Niger Delta, Nigeria. The study made use of MODIS and Landsat imageries for the extraction of the vegetation health values while the temperature data from NIMET were extrapolated using Inverse Distance Weighted from which the unsampled places were provided with the data. Both the descriptive and inferential statistics were employed for study. Findings revealed generally that air temperature had the maximum of 31.39°C from 1982 to 2020 while vegetation abundance was higher in 1982, 1985, 1990. The maximum air temperature in the rainforest was 31.37°C, freshwater swamp was 31.40°C and mangrove was 31.36°C. The mean vegetation abundance was higher in the 3 ecological zones in 1982 while it reduced in 2020 and the mean vegetation abundance was 0.5085 in the entire study area. Air temperature continued to increase over the years at the rate of 0.1684°C and the time (years) contributed 31.33% to the variation. The analysis also shows that air temperature increased at the rate of 0.1837°C over the years under mangrove ecological zone and the time contributed 36.35% to the variation of air temperature. Under the rainforest, it is discovered that vegetation abundance continued to decrease at the rate of 0.0348 mm over the years and 83.16% of the variation could be accountable for by the years. The air temperature negatively and significantly correlated with vegetation abundance ($r=-0.522$; $p<0.05$). The study concluded that the vegetation abundance under the rainforest was the highest and there is a significant variation in the vegetation abundance across the rainforest, freshwater swamp and mangrove. Also, the air temperature in fresh water swamp was highest and followed by that of the rainforest. It is thus recommended that all activities that could contribute to the rise in the air temperature which can lead to global warming such as illegal crude oil refining should be absolutely abolished. Climate change campaign should be continually encouraged.

Keywords: Air temperature; Campaign; Vegetation abundance; Descriptive; Inferential; Rainforest; Freshwater swamp

1. Introduction

Climate and vegetation zones are strongly correlated, as can be seen by a simple visual comparison of climate and vegetation on a global scale: tropical forests are associated with the moist tropics, subtropical deserts with the dry subtropics, temperate/boreal forests with the temperate/boreal regions, and tundra/polar deserts with the Polar regions (Brovkin 2002). Alexander von Humbolt was one of the first geographers to examine the connections between

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previous changes in vegetation and climate on a worldwide scale (Brovkin 2002). The mechanisms that link vegetation and climate are not fully understood, despite the importance of these linkages (Brovkin 2002). In this context, climate is defined as a seasonal pattern of temperature, precipitation, and solar radiation. It largely determines the biogeochemical characteristics of the land surface, such as CO_2 flux, carbon storage in biomass, and soil, as well as the predominant types of terrestrial vegetation, such as grasslands and broadleaved forests. Numerous studies demonstrate how human influence on nature and natural processes has caused climate change in various parts of the world during the past few decades (Solomon et al., 2007).

Nature and humanity are impacted by climate in a variety of ways. However, a region's geographic location can influence its climate, which in turn influences the distribution of plants and animals, human industry, and natural occurrences (Elhag 2006). It is the primary driver of animal and human migration and has an impact on human health and vitality. Plant dynamics and climatic factors must receive equal attention because changes in various climatic parameters may impact and influence plant cover at different levels. More importantly, in order to make realistic and accurate forecasts about how the vegetation or climatic factors will change, it is necessary to identify the possible links between these interrelated components. This can also set up the implementation of safety precautions to reduce the possible hazards related to such shifting climate and ecological circumstances.

Activities like industrialization and urbanization contributed immensely to this changes noticed from 2000-2015. From the findings of Felix *et al.* (2016), on spatial and temporal vegetation dynamics in Rwanda, they identified four different seasons associated with vegetation growth and decline. Mainly raining and dry seasons determines the dynamics of vegetation. AV HRR and MODIS was used for data collection to enable them assess the spatio-temporal dynamics of vegetation greenness. Regression analysis tool was used. It can be deduced from their findings that while some vegetation types were endangered by the season some other thrives. Rwanda was identified with rainfall variability which negatively affects agricultural practices and natural vegetation.

Bowen *et al.* (2017) worked on vegetation dynamics as a result of climatic elements in China. Their investigation covered 16years duration. They used SPOT vegetation and metrological data to study the level of response of vegetation changes to rainfall and temperature as main climatic elements. The statistical tools used are the maximum value composite and linear regression analytical method .From their result, it is cleared that there is significant increase in the vegetation cover of China. Increase in temperature in the region resulted to decrease in vegetation while rainfall tends to be booster for vegetation in the region. Tawaltichai *et al.* (2017) revealed from their investigation on climatic effects on vegetation in Menkong River basin. Data for vegetation dynamics was collected with the use of NDVI and climatic element data from metrological station between 1982 and 2013. The analyses of the data were carried out using coefficient of variation, partial least square regression and correlation analysis. The results revealed an increasing temporal trend for vegetation dynamics and climate variables. Vegetation dynamics is associated with various seasons. Wet season encourages greenness of vegetation while high temperature reduces vegetation and their appearances changes too. Vegetation type also determine the level of response to climatic elements

Mohammad *et al.* (2017) reported that land cover change and vegetation dynamics in Kebbi State and observed that there is perpetual decrease of dense vegetation while farmlands are on the increase. People in this region reduce vegetation because of the quest for agricultural farmlands, expansion of settlements etc. According to Simon *et al.* (2019) also noted that there was a reduction in both annual and seasonal time series NDVI in Eritrea whereby low precipitation with increasing drought length was observed leading to sparse nature of the vegetation. Friday *et al*. (2017) investigated on vegetation changes in the southern part of Nigeria between 1984 and 2014. They obtain their data set from Landsats 4TM, 5TM and 7ETM+ remote sensing instrument and discussion with people of the area and ground trotting of some important vegetation types. Kappa statistics function was used to compare the visualize images as they used image classification. Their result shows great change in vegetation cover in the southern part of Nigeria between 1984 and 2014 and this was traced to urban sprawl, increase in farm activities and industrial activities. Few of the previous studies have investigated to the in-depth the trend and correlational analysis of vegetation abundance and climatic parameters which is the major focus of the present study. Thus, the study examined the correlational analysis of the trend of vegetation abundance and temperature (1982-2020) in Bayelsa and Rivers States, Niger Delta Region, Nigeria.

2. Material and methods

This study was carried out in Bayelsa and Rivers States of the Niger Delta. The Niger Delta is a flat alluvial plane located in Nigeria on the Gulf of Guinea and located with different ecological zones such as rainforest, freshwater swamp and mangrove (Figure 1). The Niger Delta region is located in the Gulf of Guinea between longitude 5°E to 8°E and latitudes 4°N to 6°N.

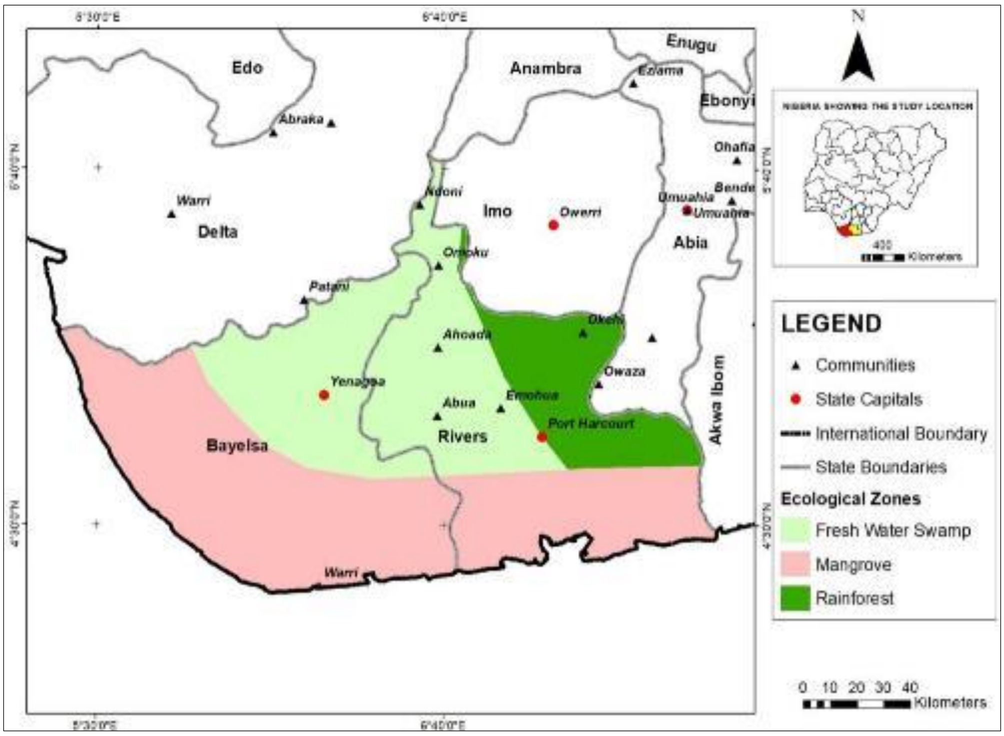

Figure 1 Bayelsa and Rivers State of Nigeria showing the Ecological Zones

The study locations have a Tropical rainforest climate. It experiences regular rainfalls and warm temperatures (Nunez, 2019). It has two seasons, a wet and dry season. The wet season last between 7-8 months; from March to October with a brief break in rainfall usually in the month of August. The dry season usually starts from November and ends in February. The mean annual rainfall is highest at over 4000mm in coastal towns like Brass and Bonny in Bayelsa and Rivers States respectively. It reduces inland to 3000mm in the mid-delta in towns like and Warri in Delta State and Yenagoa in Bayelsa State. In the northern area of Edo and Ondo States annual rainfall is between 1500mm-2000mm. The temperature is relatively high throughout the year while Average monthly maximum and minimum temperatures ranges from 28°C to 33°C and 21°C to 23°C respectively; rising westward and northward. Low relief and poor ground drainage is common in the area. The Niger River delta which Bayelsa and Rivers are inclusive is underlain by soft, young sedimentary rocks, gently undulating plains. These plains become waterlogged in rainy season (Udo et al., 2017). According to NDDC (2006), the nature of the terrain and available dry land, determines the pattern of settlement in the Region. Most settlements comprise largely rural communities. There are four broad ecological zones in the region defined by both relief and hydrological characteristics. Several rivers, estuaries and creeks dissect the region, for instance the River Benue drains into the River Niger at Lokoja en-route to the Atlantic Ocean through the Niger Delta plains. The River Niger diverges into two tributaries known as the River Nun and the River Forecados, and then splits into other distributaries 50-100km from the coast, giving way to a braided river and creek network (Abam, 2001).River Niger is the chief river in the area. At the delta, the River Niger separates into numerous channels and forms a network of distributaries. These rivers drain the area; flowing towards the south to the Atlantic Ocean through the gulf of Guinea. These rivers include the Nun, Forcados, Escravos, Brass, Sambrero, Bonny (Mabogunje, 2017).

The research adopted the longitudinal research design. Secondary data were used for this study. The secondary data were the satellite imagery of vegetation health which is known as Moderate Resolution Imaging Spectroradiometer (MODIS) Terra and Aqua Normalized Difference Vegetation Index (NDVI) of 16 Day L3 Global 250m resolution of downloaded from https://earthexplorer.usgs.gov. Also, landsat imageries were used to generate the NDVI for the earlier years before the year 2000. For the air temperature, the known temperature obtain from NIMET for some specific locations within Nigeria were interpolated using the IDW technique in ArcGIS to produce the temperature of the unsampled places. Zonal statistics were used to generate the minimum, maximum and mean NDVI and air temperature of each year and ecological zones. The study made use of descriptive and inferential statistics. Descriptive statistics were used to describe the mean and standard deviations of the annual vegetation health and temperature across the ecological zones while the inferential statistics in form of correlation statistics and linear regression were used to test the relationship between vegetation abundance and temperature in different ecological zones.

3. Results

It is displayed in Table 1 whereby it is discovered that the air temperature of 1982 was the lowest with a mean value of 26.80°C while the highest mean air temperature was found in 2020 with a mean value of 31.39°C. It is however observed that the mean air temperature did not have a regular pattern of increasing nor decreasing; instead it fluctuated.

The annual mean of air temperature across the rainforest, freshwater and mangrove ecological zones is displayed in Table 2. In the rainforest, it is discovered that the highest air temperature was observed in 2020 with a value of 31.37°C while the lowest was found in 1982. The temperature in the freshwater swamp followed similar trend as the highest air temperature was recorded in 2020 with a mean value of 31.40°C and least was recorded in 1982. In the mangrove ecological zone, it is discovered that the minimum air temperature was recorded in 1985 with a mean value of 26.67 °C and the highest was found 2020 with a mean value of 31.36°C. Comparing the air temperature among the ecological zones, it is discovered that in most of the years used for the study, the air temperature in fresh water swamp was highest and followed by that of the rainforest.

On the other hand, the analysis of vegetation abundance from 1982 to 2020 reveals that mean vegetation abundance was highest in 1982 with a mean value of 0.6561 and followed by 1995 which has a mean value of 0.5847. The lower vegetation abundance is recorded in 2017 and 2020 with the mean values of 0.3180 and 0.3478 respectively.

The analysis also presents the zonal statistics of the NDVI (vegetation abundance of ecological zones shows that the rainforest, freshwater swamp and mangrove have the highest vegetation abundance were highest in 1982 while the lowest was found in 2020 in both rainforest and mangrove while the lowest is found in 2017 with a mean value of 0.3569 in the freshwater swamp. The descriptive statistics of vegetation abundance from 1982 to 2020 shows that the mean vegetation abundance was 0.5085 in the entire study area. It is shown that the mean vegetation abundance in the rainforest was 0.5985, freshwater swamp was 0.5900 while in the mangrove it was 0.4827. The vegetation abundance under the rainforest was the highest.

Table 1 Zonal Statistics of Temperature of the Study Area from 1982 to 2020

Year	Air Temperature (°C)				Vegetation Abundance (NDVI)			
	Minimum	Maximum	Mean	Standard Deviation	Minimum	Maximum	Mean	Standard Deviation
1982	26.42	27.16	26.80	0.12	-0.2000	1.0000	0.6561	0.3
1985	26.68	27.39	26.99	0.14	-0.1999	0.9956	0.5847	0.4
1988	26.88	27.57	27.23	0.12	-0.2000	1.0000	0.5787	0.2
1990	27.02	27.65	27.31	0.12	-0.1999	0.9871	0.5214	0.3
1995	26.69	27.09	26.99	0.06	-0.2000	0.9652	0.5167	0.6
2000	27.06	27.65	27.31	0.13	-0.2000	1.0000	0.5033	0.22
2003	27.38	28.23	27.69	0.19	-0.1999	0.9897	0.4391	0.01
2006	27.36	28.36	27.70	0.21	-0.1404	0.9351	0.5628	0.1
2009	27.22	28.15	27.68	0.17	-0.1999	1.0000	0.5003	0.2
2012	26.89	27.89	27.24	0.22	-0.1999	0.9795	0.5738	0.2
2015	27.04	27.41	27.13	0.08	-0.1999	0.8347	0.5075	0.2
2017	27.30	27.47	27.38	0.03	-0.1999	0.9958	0.3180	0.2
2020	31.30	31.47	31.39	0.03	-0.1972	0.9745	0.3478	0.3

Table 2 Zonal Statistics of the Annual Mean of Air Temperature and Vegetation Abundance of Ecological Zones in the Study Area

Year	Air Temperature °C					
	Rainforest		Freshwater Swamp		Mangrove	
	Mean	SD	Mean	SD	Mean	SD
1982	26.84	0.19	26.86	0.09	26.71	0.07
1985	27.08	0.2	27.05	0.1	26.67	0.2
1988	27.28	0.5	27.29	0.2	27.14	0.3
1990	27.37	0.2	27.36	0.09	27.22	0.06
1995	26.94	0.09	27.01	0.02	27.00	0.06
2000	27.39	0.15	27.37	0.09	27.21	0.09
2003	27.84	0.23	27.77	0.15	27.52	0.07
2006	27.89	0.14	27.77	0.6	27.54	0.04
2009	27.75	0.2	27.75	0.2	27.55	0.1
2012	26.96	0.3	27.16	0.17	27.44	0.2
2015	27.06	0.01	27.15	0.3	27.14	0.09
2017	27.37	0.1	27.40	0.4	27.36	0.01
2020	31.37	0.5	31.40	0.1	31.36	0.2
Vegetation Abundance						
1982	0.8514	0.2	0.8251	0.1	0.6214	0.2
1985	0.8012	0.3	0.7832	0.2	0.6235	0.2
1988	0.7963	0.2	0.7624	0.1	0.5547	0.3
1990	0.6612	0.1	0.6427	0.2	0.5514	0.2
1995	0.6224	0.2	0.6001	0.2	0.5234	0.1
2000	0.5895	0.2	0.5127	0.1	0.4569	0.2
2003	0.4650	0.1	0.4516	0.2	0.4516	0.2
2006	0.5857	0.07	0.5987	0.08	0.5095	0.1
2009	0.5186	0.2	0.5572	0.2	0.4219	0.2
2012	0.6112	0.1	0.6170	0.1	0.5053	0.2
2015	0.4474	0.1	0.5526	0.2	0.4474	0.1
2017	0.4441	0.2	0.3569	0.2	0.3569	0.2
2020	0.3863	0.3	0.4095	0.3	0.2506	0.2

Table 3 Descriptive Statistics of Annual Climate Parameters from 1982 to 2020

	N	Minimum	Maximum	Mean	Std. Deviation
Air Temperature	13	26.80	31.39	27.6031	1.17
Vegetation Abundance	13	0.32	0.66	0.5085	0.09

Table 4 Descriptive Statistics of Annual Climate Parameters and Vegetation Abundance across the Ecological Zones from 1982 to 2020

Climate	Ecology	N	Minimum	Maximum	Mean	Std. Deviation
Air Temperature	Rainforest	13	26.84	31.37	27.6262	1.17634
	Freshwater Swamp	13	26.86	31.40	27.6415	1.16686
	Mangrove	13	26.67	31.36	27.5277	1.18680
Vegetation Abundance	Rainforest	13	0.39	0.85	0.5985	0.148
	Freshwater Swamp	13	0.36	0.83	0.5900	0.141
	Mangrove	13	0.25	0.62	0.4827	0.103

3.1. Trend surface analysis of climate parameters and vegetation health in the study area

The analysis in Figure 2 revealed trend surface analysis of annual air temperature from 1982 to 2020. The analysis revealed that air temperature continued to increase over the years at the rate of 0.1684°C and the time (years) contributed 31.33% to the variation in the trend surface of air temperature in the entire study area. The trend surface analysis of the annual vegetation abundance from 1982 to 2020 is shown in Figure 3 whereby it is found that the vegetation abundance is reducing at the rate of 0.018 over time while the time contributed 55.39% to variation of the reduction of the vegetation abundance from 1982 to 2020.

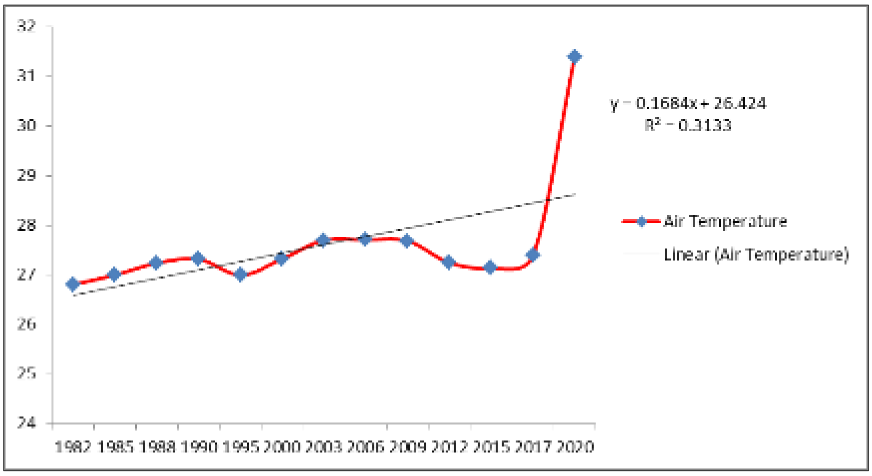

Figure 2 Trend Surface of Annual Air Temperature from 1982 to 2020

The trend surface of the air temperature between 1982 and 2020 across the ecological zones in the study area is shown in Figure 4. The analysis reveals that the air temperature continue to increase at the rate of 0.163°C under the freshwater swamp and time contributed 29.68% to the variation in the increase of the air temperature under the fresh water swamp of the study area. The analysis also shows that air temperature increased at the rate of 0.1837°C over the years under mangrove ecological zone and the time contributed 36.35% to the variation of air temperature. Under the rainforest, it is discovered that air temperature continued to increase at the rate of 15.74°C over the years and 27.14% could be attributed to years causing the variation in the air temperature. The analysis revealed in Figure 5 that the vegetation abundance continued to decrease at the rate of 0.0304 under the freshwater swamp and time contributed 70.14% to the variation in the increase of vegetation abundance under the fresh water swamp of the study area. The analysis also shows that vegetation abundance decreased at the rate of 0.0235 m/s over the years under the mangrove ecological zone and the time contributed 7.84% to the variation of vegetation abundance. Under the rainforest, it is discovered that vegetation abundance continued to decrease at the rate of 0.0348 mm over the years and 83.16% of the variation could be accountable for by the years.

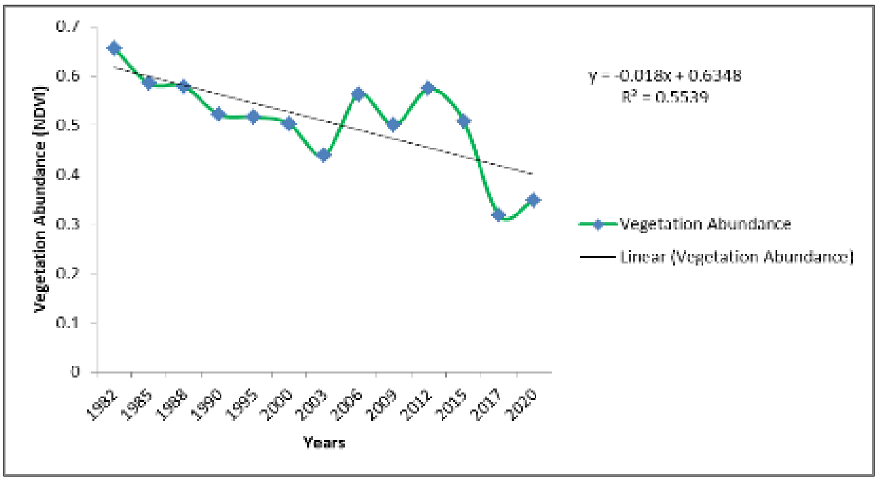

Figure 3 Trend Surface of Annual Vegetation Abundance from 1982 to 2020

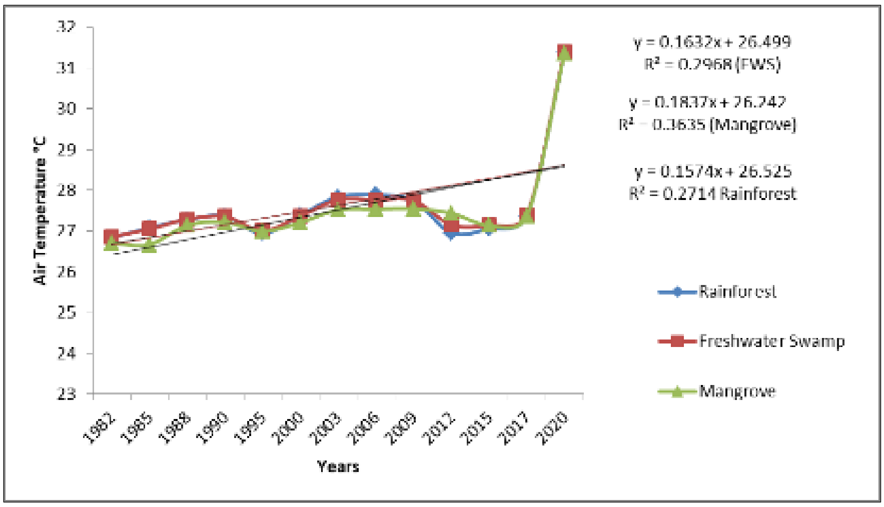

Figure 4 Trend of Air Temperature between 1982 and 2020 across Ecological Zones in the Study

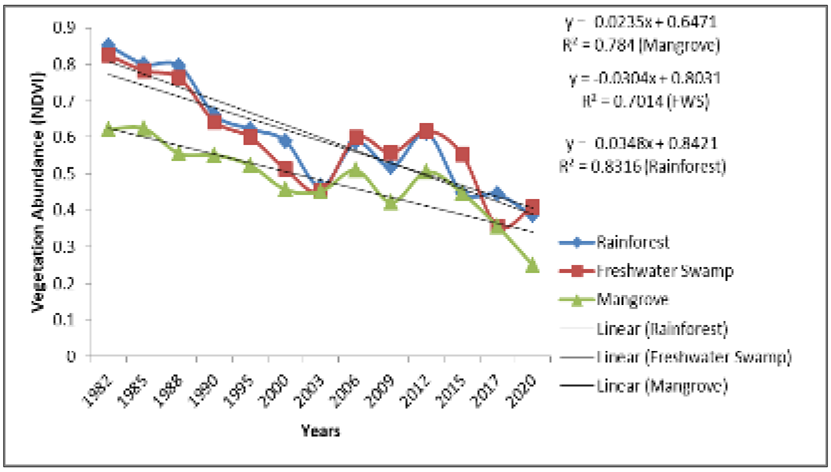

Figure 5 Trend of Vegetation Abundance between 1982 and 2020 across Ecological Zones in the Study

3.2. Relationship between temperature variability and vegetation health across the ecological zones of Rivers and Bayelsa States, Nigeria

Table 5 displays the temperature parameters and vegetation abundance across the ecological zone. These data was used to compute the correlation and linear regression to determine the relationship existing between the climate parameters and vegetation abundance. The correlation statistics in Table 6 shows that the air temperature negatively and significantly correlated with vegetation abundance (r=-0.522; p<0.05). The linear regression shown in Table 7 reveals that air temperature and vegetation abundance had regression coefficient (R) of 0.522 and it the variation in the vegetation abundance in the study area. The coefficient of the linear regression analysis displayed in Table 8 shows that the regression equation can read thus:

$$Y_{vegetation\ abundance} = 2.312 - 0.064AT\ (p<0.05) \text{………. Eq 1.}$$

Table 5 Climate Parameters and Vegetation Abundance Across the Ecological Zones

Air Temperature	Vegetation Abundance
26.84	0.8514
27.08	0.8012
27.28	0.7963
27.37	0.6612
26.94	0.6224
27.39	0.5895
27.84	0.465
27.89	0.5857
27.75	0.5186
26.96	0.6112
27.06	0.4474
27.37	0.4441
31.37	0.3863
26.86	0.8251
27.05	0.7832
27.29	0.7624
27.36	0.6427
27.01	0.6001
27.37	0.5127
27.77	0.4516
27.77	0.5987
27.75	0.5572
27.16	0.617
27.15	0.5526
27.4	0.3569
31.4	0.4095
26.71	0.6214

26.67	0.6235
27.14	0.5547
27.22	0.5514
27	0.5234
27.21	0.4569
27.52	0.4516
27.54	0.5095
27.55	0.4219
27.44	0.5053
27.14	0.4474
27.36	0.3569
31.36	0.2506

Table 6 Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.522[a]	0.272	0.253	0.12081

a. Predictors: (Constant), Air Temperature

Table 7 Coefficient of Regression

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.312	0.472		4.896	.000
	Air Temperature	0-.064	0.017	-0.522	-3.720	.001

a. Dependent Variable: Vegetation Abundance

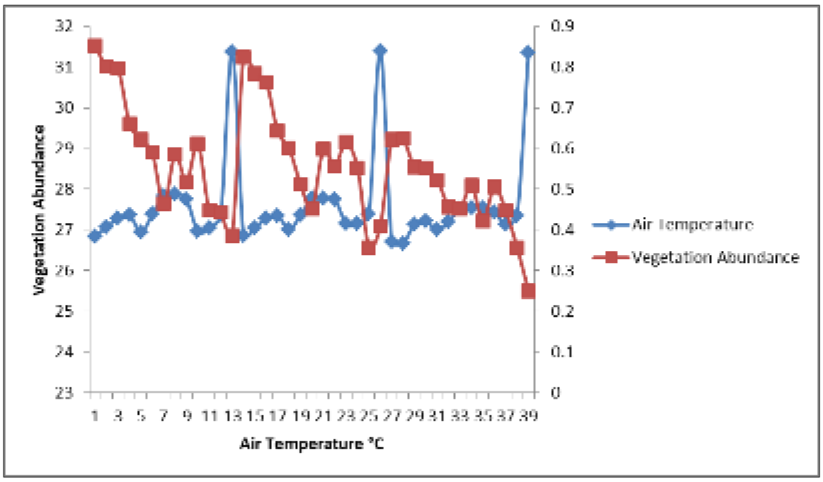

Figure 6 Relationship between Air Temperature and Vegetation Abundance

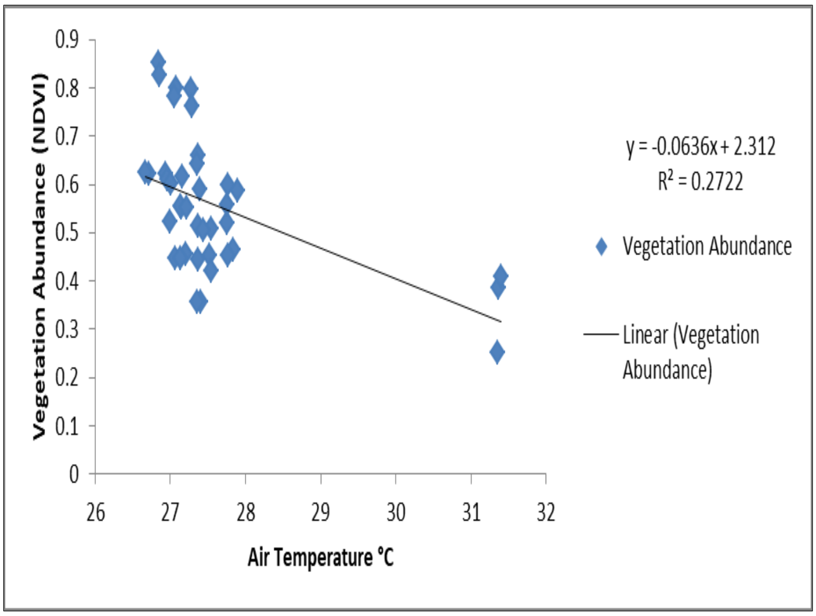

Figure 7 Scatter diagram showing the relationship between air temperature and vegetation abundance

Figure 7: Scatter diagram between Vegetation abundance and Air Temperature between 1982 and 2020 across the Ecological Zones in the Study Area.

4. Discussions of Findings

Findings showed that vegetation abundance reduced with time and air temperature increased especially in 2020. This is likely to be caused by human activities. It is related to the findings of Chauvier et al. (2021). Also, understanding the vegetation-environment relationship is essential, especially for improving knowledge of the effect of global change on ecosystems and the feedback of ecosystem to climate (Arneth, 2015; Austin, 2013; Huete, 2016). Understanding on responses of vegetation to climate change could improve predictions of the future consequences of climate change on ecosystems, biodiversity, and our own food security and welfare (Huete, 2016). The vegetation-environment relationship also can quantitatively disclose the interactions between driving factors and environmental processes and patterns, and thus help identify the main factors leading to environment changes (Sohoulande Djebou, et al., 2015).

5. Conclusion

The study concluded that the vegetation abundance under the rainforest was the highest and there is a significant variation in the vegetation abundance across the rainforest, freshwater swamp and mangrove. Also, the air temperature in fresh water swamp was highest and followed by that of the rainforest. It is thus recommended that all activities that could contribute to the rise in the air temperature which can lead to global warming such as illegal crude oil refining should be absolutely abolished. Climate change campaign should be continually encouraged.

Compliance with ethical standards

Disclosure of conflict of interest

There is no conflict of interest among the authors.

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