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Modeling Rainfall with Respect to Land Cover and Population in the Niger Delta Area Nigeria for the Period 1990-2040

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ABSTRACT

Anthropogenic activities including oil exploration have led to environmental issues in the Niger Delta, Nigeria over the years, leading to the deterioration of aquatic and riparian ecosystems. This has affected health, fishing, subsistence farming, and the economy of residents of this region. The objectives of this study were to model rainfall with respect to the percentage land cover type and forecast the percentage land cover type in 2040 for the river Niger-Delta. The objectives were met by reviewing literature related to this study, data acquisition, and modeling. The data was accessed from Google Earth Engine and the World Bank climate websites. ArcGIS, Microsoft Excel and SPSS software were used to analyze the data. Land cover and rainfall data was modeled over ranges of time and data pairs from each variable for similar years were extracted and used to model the variation of rainfall versus land cover types. The land cover and rainfall data analyses are presented in the analysis section of this paper. The percentages of land cover in the study area under water and built-in were found to have increased while that under mangrove and vegetation were found to increase respectively between 1990 and 2040. Communities residing in the study region are highly vulnerable to the impacts of floods and water pollution by industries for half of each year. This study suggested several policies for the Niger-Delta well-being and protection of the region's residents with respect to floods and related issues.

INTRODUCTION

Water flooding in the Niger Delta region is not new. However, the fact that the population in the region increasing, could imply that the number of human lives and property under the risk of flooding could be on the rise. As people settle in the region, some land covered by vegetation is converted to developed land to carter for human settlement and industrial expansion. This leads to soil compaction and an increase in the quantity of surface runoff into streams and rivers during rainfall. Communities that live in the Niger Delta region are highly vulnerable to impacts of floods for about 50% of each year. Land cover under vegetation, especially forest contributes to reducing pollutants in water, protecting the water quality, and controlling the quantity of silt in surface water bodies, etc. (Twumasi and Merem, 2006) The increase of silt in surface water bodies reduces their depth, leading to an increase in flooded areas. The variation between human population and land cover under vegetation, and human population and surface area covered by water temporally in the Niger Delta has not been published, which contribute to the gap in this study. Vegetation land cover, especially forest, plays a major role in protecting surface water from pollution. Hence, its destruction of could result in deterioration of surface water quality. As human population increases, the demand for land to develop residential and business structures increases, leading to a decrease in the vegetation land cover through the conversion of some of it to developed land. The main objectives of this study were to model rainfall with respect to the percentage land cover type and forecast the percentage land cover type in 2040 for river Niger-Delta.

This study assesses and models the temporal relationship between land cover and increase human population in the Niger Delta region of Nigeria. Also, similar assessments and modeling can be carried out for other places of the world where human settlements interact with rivers, streams, and lakes, etc. This study proposed policies for the mitigation of the regions' environmental degradation by anthropogenic activities based on the modeling on the results of the study.

LITERATURE REVIEW

Lower Niger River Drainage Basin

River Niger is the third longest river in Africa (4 200 km^2). Its basin has a total surface of 2.2 million km^2, and hence, the ninth largest in the world. It is also an important linkage between West and Central Africa and among the nine ABN countries, some of which are among the poorest in the world (Diallo, 2003). The river flows through four climatic zones (humid tropical, dry tropical, semi-arid and arid zones), regions of rainfall spanning from 4 000 mm in the Guinea Gulf to 200 mm in the Sahel, respectively. Along the regions that the river flows through, rainfall is very variable in time and space (Adeaga *et al.*, 2012). Its watershed is affected by a widespread environmental degradation process and a deterioration of the natural resource base. Some of the main environmental threats are unsustainable agricultural

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and ranching practices, bush fires, deforestation, pollution from different sources; aeolian and water erosion of rangelands; silting of water courses; and the proliferation of aquatic plants (water hyacinth, water lettuce, etc. (Diallo, 2003).

The lower Niger Basin system has an area of area is about 629,545 square kilometers, with a discharge contribution of about 117 cubic kilometers per year, which is about 64.3% of the river's total flow (Andersen, and Golitzen, 2005). The system begins at the en¬try point of the River Niger into Nigeria at approximately 162 km north of Lake Kainji and then extends to the outlet into the Gulf of Guinea through the Niger Delta region at about 75 km downstream of the Ni¬gerian border, the Niger river is joined by the Sokoto River. It then extends upstream with a broad floodplain for approximately 387 km (Laë *et al.*, 2004). The rivers Rima, Kaduna, Gbako, Gurara and Anambra are among the other tributaries of the River Niger in Nige¬ria. The Niger forms a confluence with the Benue River at Lokoja in its lower course, af¬ter which the Benue River remains its major tribu¬tary, as well as significant local precipitation, which strongly increases the flow (Laë *et al.*, 2004).

The rainfall received annually by the lower Niger basin has been estimated to be between 1,000 and 4,000 mm with inter-an¬nual rainfall variability ranging from 10% to 20% (Laë *et al.*, 2004). The Niger River has been subjected to several natural and anthropogenic perturbations since the 19th century resulting from the Sahelian drought of the 1970s (Laë *et al.*, 2004). Extensive environmental pollution caused by increased anthropogenic activi¬ties including, untreated industrial and human effluent and waste in the lower Niger basin, especially downstream of the confluence at Lokoja is evidently clear (Adeaga *et al.*, 2017).

Water Pollution

Oil spills in the Niger Delta have occurred frequently and the resultant contamination of the surrounding environment has caused significant tension between the residents of the delta and the international companies operating there. Oil pollution has a negative impact on water bodies and agricultural land when it occurs leading to the destruction of the aquatic ecosystems (Twumasi and Merem, 2006; Merem *et al.*, 2017). Crops on affected lands rarely survive.

Impact of Climate Change

A report by (Bernstein *et al.*, 2008) explained that because of global changes, the change of temperature on a global level is expected to increase between 0.2 to 0.5°C per 10 years. Expansions of seas due to thermal energy and decrease of polar ice through melting is expected. The changes will result in a rise of the sea level by approximately 3 to10 cm per decade during the next century (Bernstein *et al.*, 2008), leading to increases in soil erosion by water at alarming rates. The effects of climate change are threatening the way of life for millions of people along the Niger River. According to a head of the Niger Basin Observatory, decades of drop in rainfall in the 1970s and 80s left water levels at up to 30 percent below normal, but in recent times, the trend has shifted and increasingly heavy rainfall during the wet season is making it difficult for people to live along the river. According to (Amosu *et al.*, 2012), apart from climate change, coastal environment is subject to various anthropogenic impacts, which have been frequently associated with high human population, industrial and agricultural activities.

Impact of Forests to Rivers

Forests play a major role in protecting surface water bodies. Loss of forest cover can affect surface water bodies in multiple ways. According to (Neary *et al.*, 2009), forests are the major source for the highest quality and most sustainable water resources. The forested land cover, which involved multiuse forests including timber production, has been found to be absolutely/positively correlated to good water quality. In Nigeria, after mass deforestation during the settlement and post-settlement periods, forest cover has generally been decreasing progressively (Neary *et al.*, 2009).

Forest lands provide economic and environmental resources. Forests provide for, wood products (fuel wood lumber building poles, etc.), plus food for animal and humans (Saleem, 2003). Environmental resource of forests includes, biodiversity, wildlife habitat, climate benefits, water quantity and quality, and aesthetics' component. The ecological importance of forests can be recognized in their beneficial contribution on water catchment areas, where they have a regulatory effect. Forests also protect soils from erosion, hence, protecting canals and dams from siltation.

Although it may by argued that biodiversity and other ecological features are equally important, natural forests are the most stable systems that offer hydrologically services on earth. Forestry and related development projects should attempt to capture the hydrologic and erosion control benefits of natural forest systems (Saleem, 2003). Hence, with proper management, forests can maintain or improve Stream, dam, or river water quality.

Sand Mining in Nigeria

Sand was among the top four highest mined solid minerals in Nigeria in 2017 (Abdulazeez, 2021). The figure released of 1.3 million metric tons is likely to have been very far less than the actual quantity of sand mined in the country, since this practice is mainly informal, illegal, unrecorded, and unchecked in many states and local governments (Abdulazeez, 2021). According to) (Lawal, 2011), sand mining is rapidly becoming an ecological problem as demand increases in many states of Nigeria's industry and construction sectors. The practice is carried out both legally and illegally leading to environmental devaluation It occurs both on small and large-scale in major parts of the country. According to studies by (Ezekiel, 2010) and (Isah, 2011), it was estimated that the country's housing deficit was 16 million. Hence, the demand for sand for construction in developing areas such as Ado-Ekiti the capital of Ekiti state in southwest Nigeria was expected to rise (Omole, 1998) A study to investigate the degree of land degradation due to sand and laterite excavations in eleven selected locations in Ondo State Nigeria was carried out by (Ofunim-Omoruyi *et al.*, 2017). This study revealed that there was significant loss of forest in the excavated areas compared to unexcavated (control) locations. The study also showed that the level of reclamation of the excavated areas by the operators was zero. (Aromolaran, 2012), many people who lived on agricultural land in Ogun State, Nigeria supported the good uses of sand however, the negative impacts on their land were more than the benefits.

MATERIAL AND METHODS

This study aimed at analyzing the land coverage by water and built-in, and built-in area versus land cover area under water respectively for the study area in River Niger Delta, in the lower region of the river. The methods that were used to collect and analyze the data for the study are presented here. The study area was bounded by the following coordinates, coordinates, 5026'58.12" N, 50 17' 33 .69" E, 50 26' 58.12 "N,60 43' 45.1" E, C 40 35' 38. 69" N, 60 43'48 .4 "E, 40 35' 38. 69 "N, and 40' 45.60 "E, respectively.

Collection of Land Cover Data

A region of Nigeria bordering the Atlantic Ocean provided the area for this study. All the data for the area was acquired from Google Earth Engine (GEE, https:// earthengine.google.org)). The images for this study were downloaded from Google Earth Engine (GEE, https:// earthengine.google.org) which is a cloud platform that stores satellite imagery and supports geospatial analysis on a global scale. The area of interest was imported into the coding platform (Gorelick *et al.*, 2017) and the remote sensing data acquired by Landsat and Sentinel-2 (MSI) was used for 1992, 2000, 2013 and 2020. Specifically, images from the Landsat Enhanced Thematic Mapper (ETM+) were selected for this analysis. The Landsat images were atmospherically corrected surface reflectance images with a resolution of 30m. Scanlines in Landsat was corrected using the fix Landsat 7 scanline tool in ArcMap. The Sentinel-2 image consisted of 13 UINT16 spectral bands top of atmosphere (TOA) images scaled by 10000. These images were exported into Google drive and imported in the GIS environment for further analysis.

Image Processing

The different scenes obtained from Sentinel 2 were mosaiced in ArcMap to get a single image for the year 2020. The image clipping tool in ArcMap was used to subset the images to the shapefile of the study area for the Southern Niger Delta region in Nigeria. The Supervised classification tool was used in ArcMap to classify the images into four different Land use/cover types, Vegetation, mangroves, developed area and water bodies were the main Land use / cover types classified as these are the predominant land uses in the area. Figure 1, Figure 2, Figure 3, and Figure 4 display the raw images of the study area for 1990, 2000, 2010 and 2020, respectively.

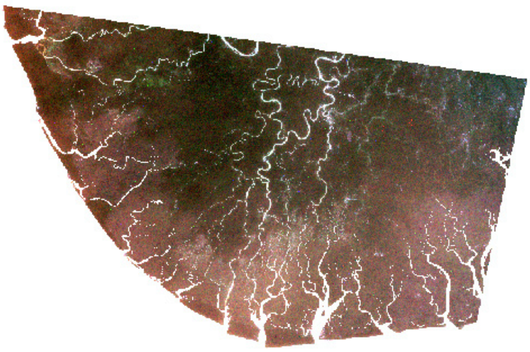

Figure 1: 1990 Raw Imagery for Niger Delta Area

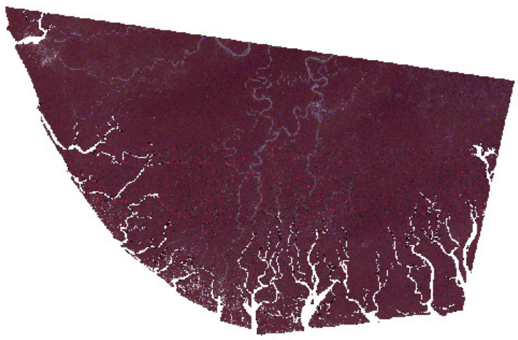

Figure 2: 2000 Raw Imagery for Niger Delta Area

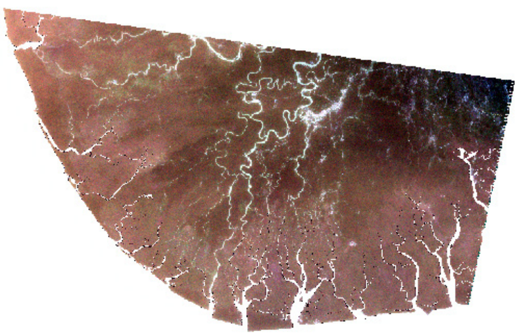

Figure 3: 2010 Raw Imagery for Niger Delta Area

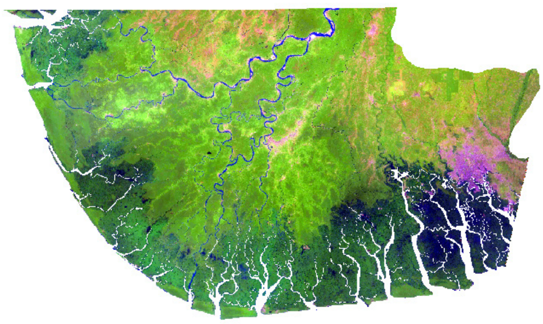

Figure 4: 2020 Raw Imagery for Niger Delta Area

Table 1: Details of Satellite Data for Niger Delta

Date	1990	2000	2010	2020 (Two scenes)
Cloud cover	1992-01-09	2002-12-30	2002-12-30	2020-01-03
				COPERNICUS/S2/20200103T095401_20200103T100437_T31NHF/ COPERNICUS/S2/20200103T095401_20200103T100437_T31NGF
Image-ID	LANDSAT/ LT05/C0 1/T1_ TOA/LT05_189057_19920109	LE07_L1TP_189057_20021230_20170127_01_T1	LE07 L1TP_189057_ 20130110_20200908_02_T1	COPERNICUS/S2/20200103T095401_20200103T100437_T31NHF/ COPERNICUS/S2/20200103T095401_20200103T100437_T31NGF

Acquisition of Cata of Climate Data

Climate data can be downloaded from either visiting (Climate Change Data Portal, 2021) or the Climate Change Knowledge Portal (Zemorglio). When the Climate Change Knowledge Portal was opened, the following were displayed (Figure 5).

Since the study area was in Nigeria, it was selected by clicking on the country icon and then clicking on map labeled Nigeria. Once the map of Nigeria has been clicked the data download process is initiated by clicking on the download button.

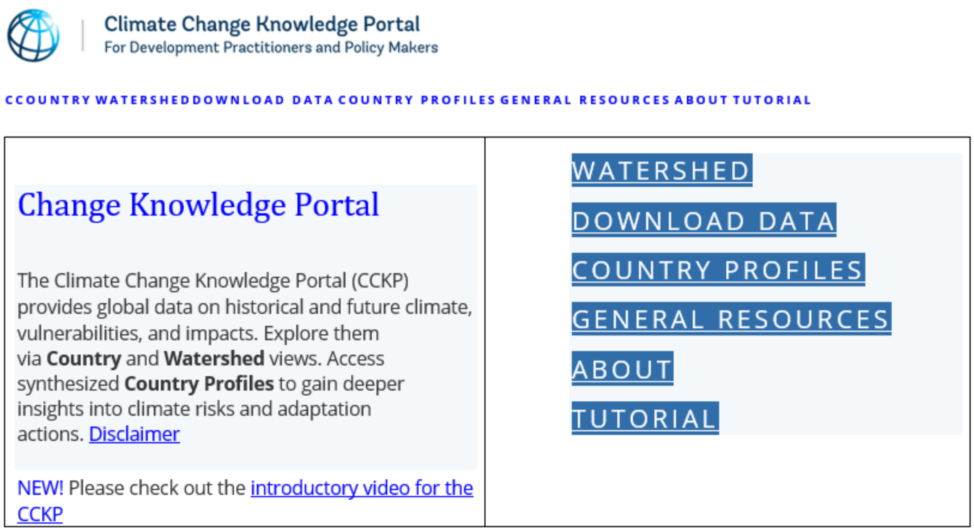

Figure 5: Page for selection of country and period for downloading climate data (Climate Change Data Portal, 2021)

Analysis

Land Cover Change Analysis

Land cover imagery data was as processed to get extract data for analysis. Land cover data analysis was carried out by regression analysis using Microsoft Excel tool kit. The process involves modeling of a land cover type with respect to time (years). Initially linear models will be developed. These will be accepted if their R square is at least 60%. For linear models with R square less than 60%. Second order polynomial models will be developed.

Analysis of Climate Data

Climate data was analyzed by aggregation (Twumasi *et al.*, 2020). Before modeling, rainfall and temperature trends, tables for blocks of several years, for example 10-year, 4-year, etc. blocks were be made. The formation of the tables involved the following steps. To determine rainfall trend for 1915-2020 the data was divided in blacks of 10 years. The average each 10 year was computed and recorded in a table for rainfall versus time in years. For the modelling process, regression analysis was used. First linear regression was used to fit the data using statistical software (SPSS, Microsoft Excel data analysis toolkit or any other) to lines or curves and the equations and corresponding R squared (coefficient of correlations) determined. R squared is a measure of the strength of association between the variables being modeled.

RESULTS AND DISCUSSION

Land Cover

Figure 6., Figure 7, Figure 8, and Figure 9 display classified maps for the years 1990, 2000, 2010 and 2020, and the corresponding land cover classes for respectively. The images varied over the years, implying changes in land use/ land cover, mainly due to influences of anthropogenic activities such as, consistent oil spill, development, and water retention in the area. Land cover variations were verified using the base map tool in ArcMap and other similar studies carried out in the area over the years.

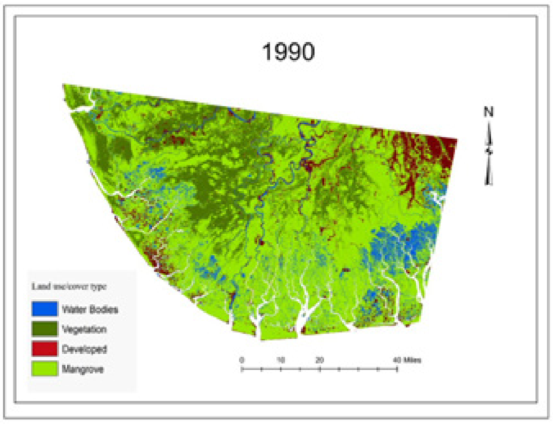

Figure 6: Land cover classes for 1990

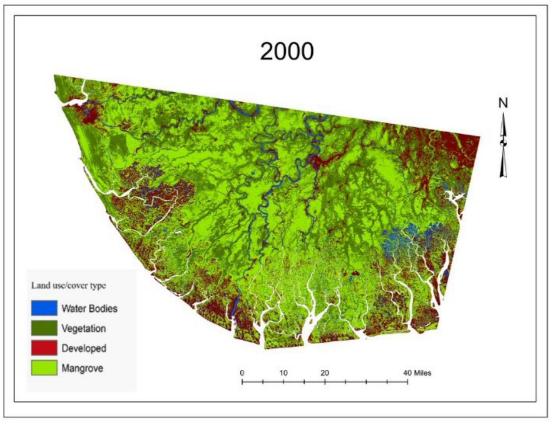

Figure 7: Land cover classes for 2000

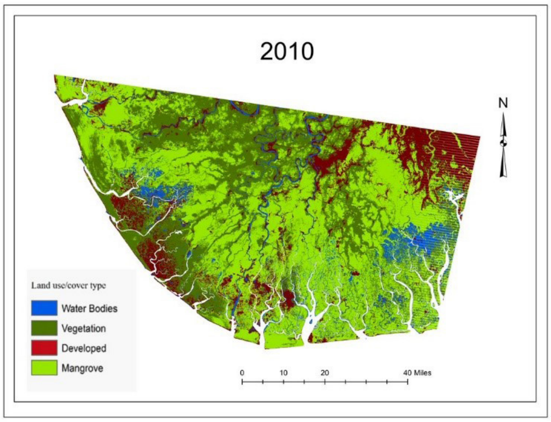

Figure 8: Land cover classes for 2010

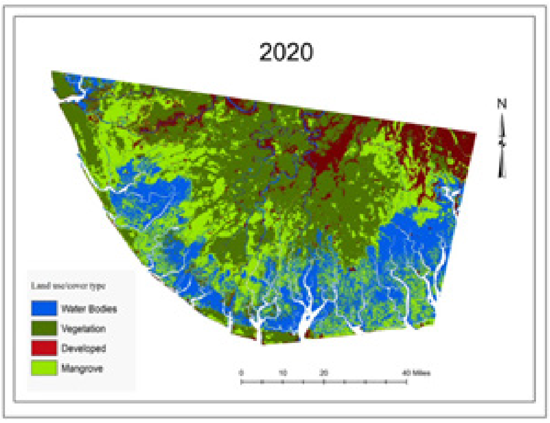

Figure 9: Land cover classes for 2000

The table for the pixel counts for each land cover type for the study are presented in Table 2.
The area for each land cover was calculated using the following formula.
A (area of each land cover) = (number of pixels x pixel size) ($30m^2$) (Radwan *et al.*, 2021).
The areas for the land cover types on the Niger Delta were computed and presented in Tables 2,
To simplify comparisons, the calculated land cover areas in square meters for the different classes of land cover arranged in a single table (Table 3).
Modelling for the given land cover categories versus years was carried out and their corresponding predictions for the year 2040 presented, using Microsoft statistical tool kit.

Table 2: Land cover types for the study area, presented in pixel counts

Land cover type	1990 Number of pixels	2000 Number of pixels	2010 Number of pixels	2020 Number of pixels
Built	997618	2297886	1751114	3403658
Vegetation	7935531	6132800	6047406	10460894
Water	1065646	624511	778376	5414607
Mangrove	2515662	3591285	3975705	9177248

Table 3: Summary of the areas for the different classes of land cover in square meters

Land cover type	1990	2000	2010	2020	Change 1990-2020
Built-in	29928540	68936580	52533420	102109740	72181200
Vegetation	238065930	183984000	181422180	313826820	75760890
Water	31969380	18735330	23351280	162438210	130468830
Mangrove	75469860	107738550	119271150	275317440	199847580

Built-In

Land cover area under built-in was modeled using Microsoft excel spreadsheet by linear curve fitting regression analysis for data displayed in Table 3. The model is presented by Figure 10. The correlational coefficient was found to be about 72.4%. The built-in area is expected to increase to 132000000 square meters in 2040.

To determine whether the relationship between the change in area covered by built-i versus years was statistically significant, the approach by (Namwamba, 2021) was used. Data extracted from the model was included to the original data set of 1990-2020 and the model was used to run a linear regression analysis using Microsoft Excel statistical tool kit. The summary for the analysis is presented in Table 4.

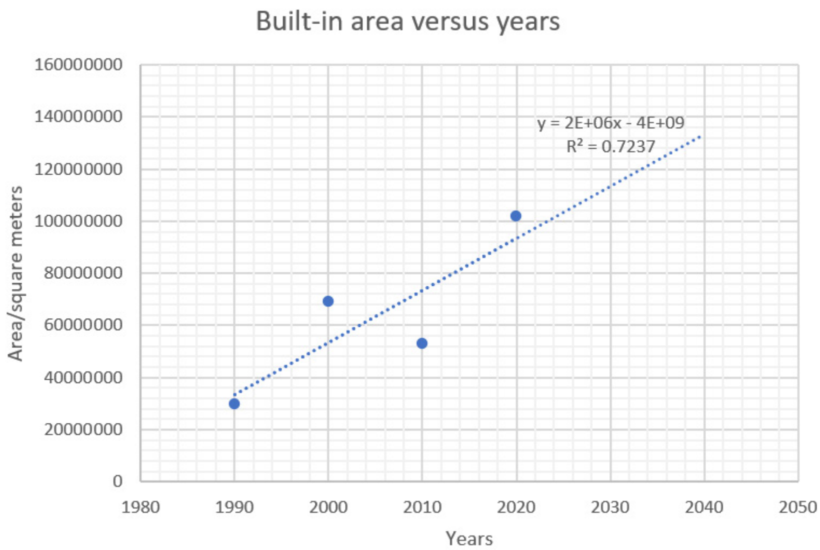

Figure 10: Land cover area under built in (period of 1990-2040)

Table 4: Regression summary for area under built-in versus years

Regression Statistics								
Multiple R	0.951589							
R Square	0.905521							
Adjusted R Square	0.889775							
Standard Error	19821658							
Observations	8							
ANOVA								
	df	**SS**	**MS**	**F**	**Significance F**			
Regression	1	2.26E+16	2.26E+16	57.50619	0.000273			
Residual	6	2.36E+15	3.93E+14					
Total	**7**	**2.5E+16**						
	Coefficients	**Standard Error**	**t Stat**	**P-value**	**Lower 95%**	**Upper 95%**	**Lower 95.0%**	**Upper 95.0%**
Intercept	-6.9E+09	9.25E+08	-7.45428	0.0003	-9.2E+09	-4.6E+09	-9.2E+09	-4.6E+09
Year	3475974	458373.2	7.583283	0.000273	2354375	4597572	2354375	4597572

Since p<0.05, the model is statistically significant.

The increase in built-in area is due to the increase of land being developed to expand businesses and residential housing, etc., yearly as the population in the region rises. Vegetation area versus time in years was modeled from the year 2000 since it adopts a linear trend in 2000. Its model and prediction for 2040 are shown on the Figure 11.

In 2040 the area under is expected to be 420000000 square meters. To test whether the relationship between the change in area covered by vegetation and years is statistically significant the field data and predicted data for the years 2010, 2030 and 2040 were used as input data for linear regression using Microsoft Excel and presented in Table 5.

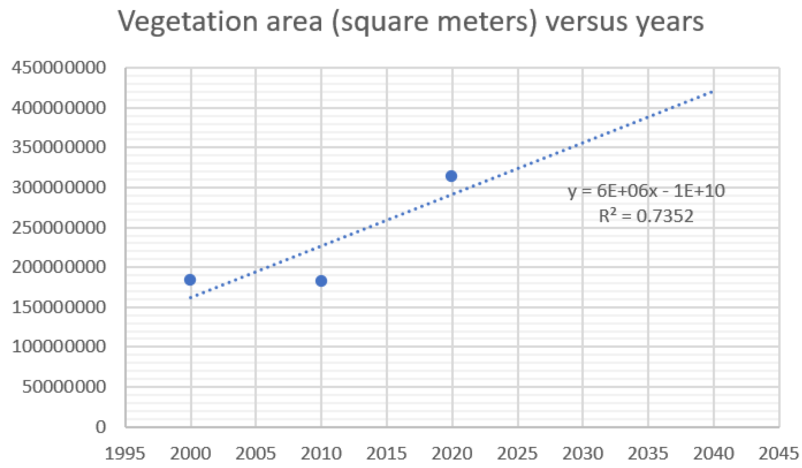

Figure 11: Vegetation area was versus years

Table 5: The area under vegetation versus years

Regression Statistics								
Multiple R	0.965811							
R Square	0.932791							
Adjusted R Square	0.910388							
Standard Error	31884631							
Observations	5							
ANOVA								
	df	**SS**	**MS**	**F**	**Significance F**			
Regression	1	4.23E+16	4.23E+16	41.6369	0.007549569			
Residual	3	3.05E+15	1.02E+15					
Total	**4**	**4.54E+16**						
	Coefficients	**Standard Error**	**t Stat**	**P-value**	**Lower 95%**	**Upper 95%**	**Lower 95.0%**	**Upper 95.0%**
Intercept	-1.3E+10	2.04E+09	-6.30922	0.008046	-19332404174	-6.4E+09	-1.9E+10	-6.4E+09
Year	6506098	1008281	6.452666	0.00755	3297299.407	9714897	3297299	9714897

Since p is less than 0.05,the model is statistically significant

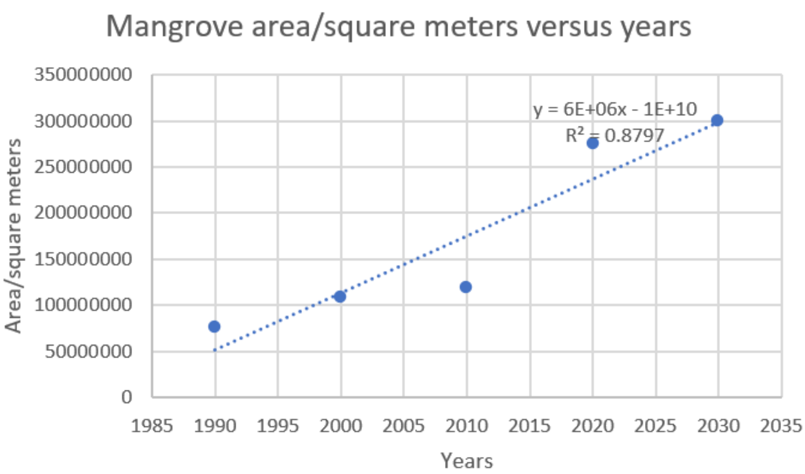

Figure 12: Land cover area with respect to years under mangrove (1990-2050)

The land cover area under mangrove for (1990-2020) was modeled using Microsoft excel spreadsheet by linear curve fitting. The model was extrapolated to predict the coverage by 2040. The predicted land cover area is 360000000 square meters (Figure 12). The correlational coefficient was found to be about 78% (Figure 12).

According to the collected data, between 1990 and 2010 there was a slight increase in land coverage by mangrove forests. However, from 2010 onward, there was a remarkable increase in its land coverage. This could have been a result of the increase of land under commercial crops such as oil palm, raffia palm, etc.

To determine whether the relationship between the changes in area covered with mangrove and the years were statistically significant, linear modeling of the data for 2020 was carried out, and then extrapolated to predict 2050 using Microsoft Excel statistical tool kit. The table for the regression analysis is shown in Table 6.

Table 6: Regression summary for land cover area of mangrove with respect to years (1990-2040)

Regression Statistics								
Multiple R	0.956485							
R Square	0.914864							
Adjusted R Square	0.886485							
Standard Error	41618729							
Observations	5							
ANOVA								
	df	**SS**	**MS**	**F**	**Significance F**			
Regression	1	5.58E+16	5.58E+16	32.23774	0.010825			
Residual	3	5.2E+15	1.73E+15					
Total	**4**	**6.1E+16**						
	Coefficients	**Standard Error**	**t Stat**	**P-value**	**Lower 95%**	**Upper 95%**	**Lower 95.0%**	**Upper 95.0%**
Intercept	-1.2E+10	2.18E+09	-5.59146	0.011298	-1.9E+10	-5.2E+09	-1.9E+10	-5.2E+09
Year	6142431	1081827	5.677829	0.010825	2699573	9585288	2699573	9585288

Sine p<0.05, the model is statistically significant.

Based on predictions of the models, the land coverage and corresponding percentage by 2040 is as given in Table 7.

Each given land cover type was expressed as a percentage of total land using the following formula.

The percentage of each land cover type (each year) = (Area of each type)/(total land cover size) x 100

The formula can be rewritten as follows.

Table 7: Area and percentage cover by each category of land cover by 2040

Land cover category	**Area/ square meters**	**Percentage**
Built-in	132000000	11.558669
Vegetation	450000000	39.4045534
Mangrove	360000000	31.5236427
Water	200000000	17.5131349

(Percentage land cover area by Land cover $C)_Y$ = ((Area under land cover $C)_Y$ / Total land cover area) x100%. Where, Y represents the year for which the computation is being carried out and C, the land cover type. The percentages are presented in Table 8.

There was an increase in percentage coverage by built-in, water while a decrease was realized in land coverage by mangrove and vegetation categories. The increase in percentage coverage by built-in category could be a result development of land to expand businesses and residential area as a response to increase in population. The increase in percentage coverage by water could be a result of increase of impermeable surface caused by soil compaction as the land is developed and changes in rainfall patterns that could be global.

Table 8: Percentages area land coverage by each land clover type

Land cover type	**% cover in 1990**	**Percentage in 2040**
Built-in	7.971724	11.55867
Vegetation	63.41091	39.40455
Water	8.51532	31.52364
Mangrove	20.10205	17.51313

Modeling Rainfall Versus Land Cover Types

Rainfall data for the year range 1993 to 2021 was used to generate corresponding data for 1990-2020. A correlation analysis for percentage land covers by categories, years and rainfall are shown in Table 9.

Rainfall was found to be strongly correlated with % of land coverage by vegetation, and % land coverage by water, respectively.

Table 9: Correlation matrix for percentage land covers by categories, years and rainfall

	Year	**Built-in**	**Vegetation**	**Water**	**Mangrove**	**Rainfall**	**Rainfall**
Year	1						
Built-in	0.240798	1					
Vegetation	-0.94809	-0.45872	1				
Water	0.660499	-0.38543	-0.59861	1			
Mangrove	0.914035	0.579248	-0.91929	0.31321	1		
Rainfall	0.701305	-0.4265	-0.5961	0.988562	0.353684	1	

The corresponding models are presented in Figures 13 and Figure 14, respectively. The model explained only 35.5% of the data. A regression analysis on the data was carried out to determine whether the model was statistically significant. The summary for the analysis is presented in Table 10.

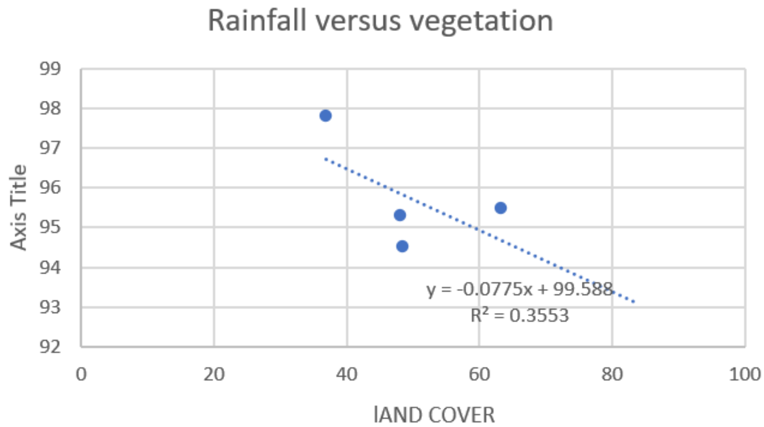

Figure 13: Rainfall versus vegetation

Table 10: Regression summary for rainfall versus vegetation

Regression Statistics								
Multiple R	0.596103							
R Square	0.355339							
Adjusted R Square	0.033009							
Standard Error	1.39386							
Observations	4							
ANOVA								
	df	**SS**	**MS**	**F**	**Significance F**			
Regression	1	2.141807	2.141807	1.102407	0.403897			
Residual	2	3.885693	1.942846					
Total	**3**	**6.0275**						
	Coefficients	**Standard Error**	**t Stat**	**P-value**	**Lower 95%**	**Upper 95%**	**Lower 95.0%**	**Upper 95.0%**
Intercept	99.58838	3.698207	26.92883	0.001376	83.67628	115.5005	83.67628	115.5005
Vegetation	-0.07747	0.073783	-1.04996	0.403897	-0.39493	0.239992	-0.39493	0.239992

Since the probability p>0.05 the variation between rainfall and vegetation was not statistically significant.

Hence the variation between rainfall and vegetation was not statistically significant. The regression summary for the model illustrated in Figure14 is presented in Table 11.

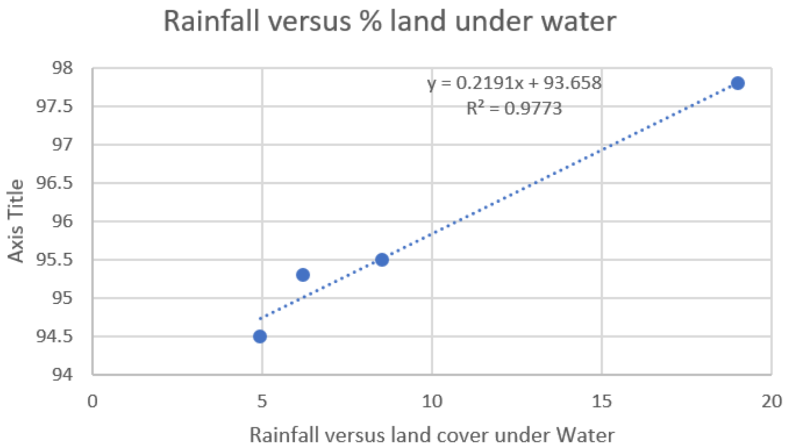

Figure 14: Rainfall versus % area under water

Table 11: Regression summary for the area under rainfall versus % area under water

Regression Statistics								
Multiple R	0.988562							
R Square	0.977255							
Adjusted R Square	0.965882							
Standard Error	0.261819							
Observations	4							
ANOVA								
	df	**SS**	**MS**	**F**	**Significance F**			
Regression	1	5.890402	5.890402	85.92967	0.011438			
Residual	2	0.137098	0.068549					
Total	**3**	**6.0275**						
	Coefficients	**Standard Error**	**t Stat**	**P-value**	**Lower 95%**	**Upper 95%**	**Lower 95.0%**	**Upper 95.0%**
Intercept	93.65765	0.263268	355.7508	7.9E-06	92.5249	94.7904	92.5249	94.7904
Water	0.219052	0.023631	9.269826	0.011438	0.117378	0.320727	0.117378	0.320727

The probability p value is less than 0.05 (0.011).

Hence, the surface model for area cover under water versus rainfall is statistically significant.

Modeling Rainfall Versus Land Cover Types

Rainfall data for the year range 1993 to 2021 was used to generate corresponding data for 1990-2020. A correlation analysis for percentage land covers by categories, years, and rainfall for the data is presented in Table 12.

Table 12: Summary table for the correlation analysis for percentage land covers by categories, years, and rainfall

	Year	**Built-in**	**Vegetation**	**Water**	**Mangrove**	**Rainfall**	**Rainfall**
Year	1						
Built-in	0.240798	1					
Vegetation	-0.94809	-0.45872	1				
Water	0.660499	-0.38543	-0.59861	1			
Mangrove	0.914035	0.579248	-0.91929	0.31321	1		
Rainfall	0.701305	-0.4265	-0.5961	0.988562	0.353684	1	

Rainfall was found to be strongly correlated with percentage of land coverage by vegetation, and percentage land coverage by water, respectively.

Their corresponding models and regression summary tables are presented by Figure 15 and Figure 16, Table 13, and Table 14, respectively. The model explained only 35.5% of the data.

Since $p<0.05$ for the model of the percentage rainfall versus the percentage area under water (Table 14), the model is statistically significant.

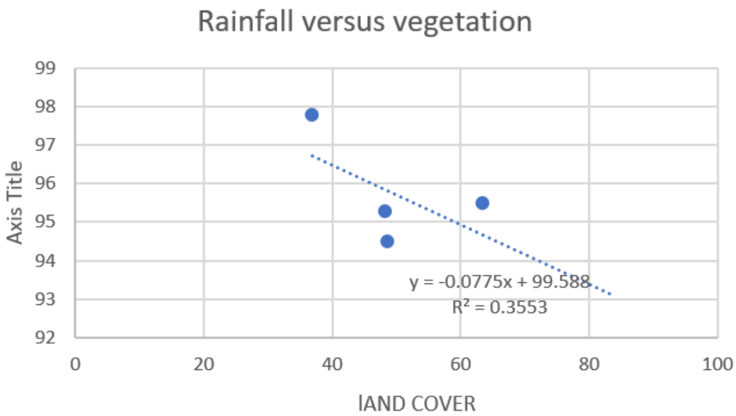

Figure 15: Rainfall versus percentage vegetation cover

Table 13: Regression summary for rainfall versus percentage cover by vegetation

Regression Statistics								
Multiple R	0.596103							
R Square	0.355339							
Adjusted R Square	0.033009							
Standard Error	1.39386							
Observations	4							
ANOVA								
	df	**SS**	**MS**	**F**	**Significance F**			
Regression	1	2.141807	2.141807	1.102407	0.403897			
Residual	2	3.885693	1.942846					
Total	**3**	**6.0275**						
	Coefficients	**Standard Error**	**t Stat**	**P-value**	**Lower 95%**	**Upper 95%**	**Lower 95.0%**	**Upper 95.0%**
Intercept	99.58838	3.698207	26.92883	0.001376	83.67628	115.5005	83.67628	115.5005
Vegetation	-0.07747	0.073783	-1.04996	0.403897	-0.39493	0.239992	-0.39493	0.239992

Since the probability $p>0.05$ the variation between rainfall and vegetation is not statistically significant.

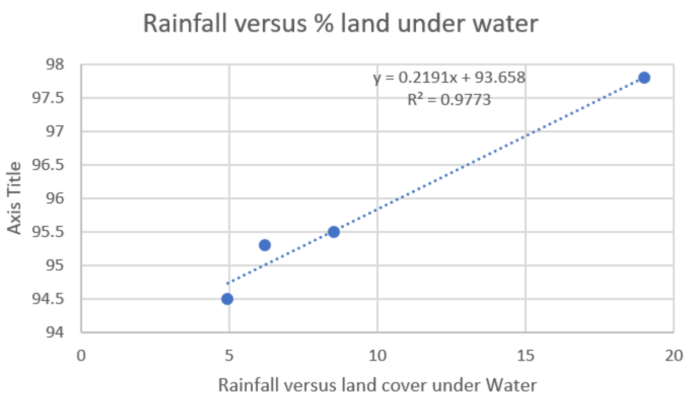

Figure 16: Rainfall versus % area under water

Table 14: Regression summary for the area under rainfall versus percentage area under water

Regression Statistics								
Multiple R	0.988562							
R Square	0.977255							
Adjusted R Square	0.965882							
Standard Error	0.261819							
Observations	4							
ANOVA								
	df	**SS**	**MS**	**F**	**Significance F**			
Regression	1	5.890402	5.890402	85.92967	0.011438			
Residual	2	0.137098	0.068549					
Total	**3**	**6.0275**						
	Coefficients	**Standard Error**	**t Stat**	**P-value**	**Lower 95%**	**Upper 95%**	**Lower 95.0%**	**Upper 95.0%**
Intercept	93.65765	0.263268	355.7508	7.9E-06	92.5249	94.7904	92.5249	94.7904
Water	0.219052	0.023631	9.269826	0.011438	0.117378	0.320727	0.117378	0.320727

The probability p value is less than 0.05 (0.011).

Hence, the surface model for area cover under water versus rainfall is statistically significant.

DISCUSSION

The analysis indicated different variations in the images over the years mainly due to oil spill, development, other anthropogenic activities, and water retention in the area. Increased water stagnation over the years has also led to an increase in coverage of land by water, as shown in the images for 2010 and 2020, and Table 3, respectively. While the land cover by water has increased, the Niger River itself and other surface water bodies have witnessed decreases in water depths (as indicated by the thinning blue lines from between 1990-2020). This has mainly been caused by surface water bodies' siltation and debris due to anthropogenic activities. According to the land cover versus years' models, the percentage coverage by built-in and water increased, while a decrease was realized in land area coverage by mangroves and other vegetation categories. The rise in the built-in category percentage coverage may have resulted from the expansion of commercial and residential spaces due to carter for population and businesses As a result of the changes, the soil is compacted and its ability to hold water and allow water to be transmitted through it decreases. Hence, there is an increase in quantity of water on the ground or surface. Also, due to worldwide changes in rainfall patterns, there may be an increase in the proportion of land covered by water since the water drainage properties of soil have deteriorated. A correlation analysis between rainfall and percentage land coverage for the defined categories yielded results suggesting strong correlations between rainfall and only vegetation and water, respectively. This can be attributed to the decrease in the soil's ability to take in water has over years of its structural manipulation through anthropogenic activities on land. These activities lead to an increase of land area covered by impervious material, and compaction of soil. As the surface of water cover increases because of rainfall and decreased ability of the soil to take in water, the area covered by vegetation decreases. The water covers some of the surfaces that had short vegetation and hence, the vegetation coverage decreases.

CONCLUSIONS

In this study, the land cover changes of specified categories were modeled with respect to time in years for the study area in River Niger Delta. Rainfall over the River Niger Delta region was modeled with respect to the land cover categories and presented. The study also modeled the human population in the River Niger Delta region, and precipitation data of the region versus time in years and forecasted the region's precipitation over the period 1990-2040, respectively.

The results of this study found that the areas of land covered for, built-in, water and mangrove increased, respectively, whereas the area under vegetation decreased. The increase in Built-in was driven by economic growth together with rural-urban migration, mainly. According to the results produced by the analysis, the area under mangroves increased significantly between, 2000-2020, from about 20% to 32%, respectively, which reflects possible conservation efforts by either the Nigerian government, oil companies, area residents or both.

Rainfall was found to have no statistically significant influence on the percentage of area covered by water. This could have been due to the anthropogenic activities that affect soil water permeability.

RECOMMENDATIONS

The following recommendations were made from this study.

(1) More study areas from the Niger-Delta regions should be studied to assess the extent of changes in land cover types, and corresponding environmental degradations.

(2) A qualitative research study in the Niger-Delta region needs to be carried out to unearth socioeconomic impacts of industries, trades, and politics on the regions stake holders, especially the region's local communities.

Recommended Policies

The communities in the Niger Delta region may be particularly exposed to the effects of flooding for half the year and industrial pollutants, thus this study advises the following strategies for their safety and well-being.

1. Stakeholders should be required to adopt (best management practices, or BMPs), by the federal and local governments of Nigeria and the Niger-Delta area, respectively.
2. To reduce excessive siltation and regulate surface erosion, the federal and local governments should, respectively, require stakeholders to rebuild riparian buffers for surface water bodies in the Niger Delta region.
3. The government might impose greater taxes on any businesses whose actions have a harmful impact on the River Niger, with some of the additional revenue going toward.

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