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Assessment of Forest Loss and Degradation in Ndokwa-West, Delta State

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Abstract

This study examined the extent of forest loss and degradation between 1972 and 2018 in Ndokwa-west LGA, Delta state, Nigeria. Landsat multispectral images of 1972, 1987, 2002, 2004, 2014 and 2018 were employed for the study. Image classifications were done using ArcGIS 10.5 and four major classes were identified, namely: forest, settlement, bareground and waterbodies. NDVI values of the images were also calculated using ArcGIS 10.5, while additional NDVI data of the study area were obtained from FORTH Remote Sensing Lab. Data were analysed using charts, time series graphs and multiple regression analysis to determine the extent of change in forest canopy cover and forest health. The protective function of the forests was also observed while examining the change in land surface temperature through the years under study. Results showed that much of the forest cover were lost; about 904km^2 of forest between 1972 and 2018, mainly from changes to settlements and bare ground. Time series graph showed a decline in the NDVI from 1972 to 2018; an indication of decline in forest health. Significant relationship between forest loss and Land Surface Temperature (LST) with R^2= 0.729 was established and the declining NDVI values of the study area was seen to correspond with increasing LST values through the study years. This is an indication of a loss in the protective function of the forests in the study area. NDVI *and LST results revealed that the forest zone experienced fragmentation, decline in forest health and protective function within the study period. The study recommended forest conservation and management across the zone and advocated that both the government, stakeholders and individuals contributes to actualizing the target and in turn reduces environmental change impacts in the region.*

Keywords: degradation, environmental change, fragmentation, modification, Niger Delta

Introduction

The issue of forest loss and degradation has been a reoccurring discourse among environmentalists (Onwubuya et al 2015). This has led to a lot of research and efforts towards the management and controlled exploitation in order to conserve forest species. In spite of these efforts, forest loss is much exacerbated and little or no conservation initiatives are upheld in many zones in the tropics. This has become a global problem as there was a net decrease in global forest area at the rate of 5.5 million hectares a year from 2010 to 2015 (Keenan et al., 2015). The largest net loss of forest occurs in South America and Africa and reports show that about 4.0 million hectares per year were lost between 2000 and 2010 (Eludoyin et al., 2019). Up to 70 percent of global forests are at risk of further degradation (Hansen et al. 2013; Hadad et al. 2015). Unintended consequences of forest vegetation and loss include biodiversity loss, reduced ecosystem services and increased carbon emissions (Foley et al. 2005).

Forest loss and degradation is known to contribute to global warming which occurs from increased atmospheric concentrations of greenhouse gases (GHG) leading to net increase in the global mean temperature as the forests are primary terrestrial sinks of carbon (Houghton, 2005). Thus, forest loss disrupts the global carbon cycle and increases the concentration of atmospheric carbon dioxide. In the tropics, forest loss is responsible for the emission of roughly two billion tonnes of carbon (as CO_2) to the atmosphere per year (Houghton, 2005). The consequent greenhouse effect resulting from the increasing atmospheric carbon has been identified to be one of the major causes of climate change. On the other hand, forests protect the surfaces of earth and reduce the impact of radiation on the biosphere; hence dictating the surface temperature of a given locality. In situations where such cover is lost, direct impacts of radiation are experienced and generally cause debilitating impacts on the environment. Forests provides regulatory functions to ecosystems and generally helps to reduce adverse environmental change impacts in the environment, notwithstanding, they are lost at increasing scales across the globe.

Globally, forest cover is reducing at astronomical scales as a result of a host of anthropogenic activities. Its greatest toll and impact are however seen in tropical landscapes where land use changes arising from agriculture and urbanization (built up areas) are growing in scale (Igu et al. 2020; 2021). In Africa the greatest losses in forest cover area observed between 2010 and 2015 were observed in Nigeria (410 K ha y^{-1}), Tanazania (372 K ha y^{-1}), Zimbabwe (312 K ha y^{-1}) and Democratic Republic of Congo (311 K ha y^{-1}) (Keenan et al 2015; Eludoyin et al 2019). In Nigeria forests are being exploited for various purposes, which often render them permanently degraded. The resources are sometimes permanently lost due to unsustainable exploitation and change in forest landuse. Natural forests have reduced drastically and its impacts on climate change are increasing (Aigbe, 2012). The level of deterioration of forest resources is a factor of uncoordinated land use policy and other forms of land-use such as agriculture, grazing, industrialization, urbanization and water management. This often leads to the formation of bare surfaces, areas prone to flooding and general environmental degradation. Also increasing air temperature, rise in sea level, salt water intrusion, flooding and coastal erosion have all been identified as effects of forest loss (Aigbe, 2012).

Following the losses in forest cover, there is need to manage the ecosystems well and to a great extent engage in sustainable forest use across the remaining forest landscapes. To achieve that, adhering to Food and Agriculture Organization (FAO 2010) of the United Nations requirements of sustainable forest management is seen as an ideal pattern. This will then ensure that the 'extent of forest resources, biological diversity, forest health and vitality, productive functions of forest resources, protective functions of forest resources, socio-economic functions and a legal, policy and institutional framework' of forest ecosystems are managed and utilized adequately. In line with the guidelines on forest exploitation and on the foregoing observations of forest loss in Africa and Nigeria in particular, this research focused on examining the dynamics surrounding forest cover loss and probable forest degradation in Ndokwa West LGA, Nigeria. Insights from the study is needed to make valuable recommendations and policies aimed at conserving forests in the zone and in Nigeria where forest cover loss is becoming an ecosystem concern.

Materials and Methods

Study Area

Ndokwa-west is one among twenty-five Local Government Areas in Delta state (Fig. 1). It lies at approximately 5º 39′N and 6º 00′N of latitude and between 6º 08′E and 6º 29′E of longitude. It is estimated to have a total landmass of 1,426Km². The study area lies within the Niger Delta basin and it is underlain by the continental sands of the Benin formation. The area is characterized with low elevation of between 3 to 175 metres above sea level and has a flat topography. The landscape of Ndokwa-west is drained by River Ase, River Adofi and Okumeshi River which serves as sources of fish and water to the inhabitants of the area. These streams are all tributaries of the River Niger, as they are all known to drain into it. The characteristics of the climate of the study area can be best described as tropical. The summers are much rainier than the winters, with average temperature being 27.6°C and annual precipitation at 1169 mm (Delta State Economic Atlas, 2008). The area lies within the sub-equatorial zone, characterized by the equatorial forest vegetation, comprising of three levels of vegetation right from the forest bed. Some economic trees like rubber (*Havea brasilliensis*), iroko (*Milicia excelsa*), mahogany (*Swientinia spp*.), and palm trees (*Elaesis guineensis*) occur naturally in the midst of undergrowths and grasses. It is believed that much of the original forest has given way to the short trees and undergrowths due to human activities, but closer to river banks or levees, the forests may still be found in their natural states (Delta State Economic Atlas, 2008). According to the 2006 census, Ndokwa-west LGA has an estimated population of 150,024 people (NPC, 2006). With a growth rate of 2.61percent the projected population figure for 2018 is 204,379 persons (Human Population Calculator, 2019).

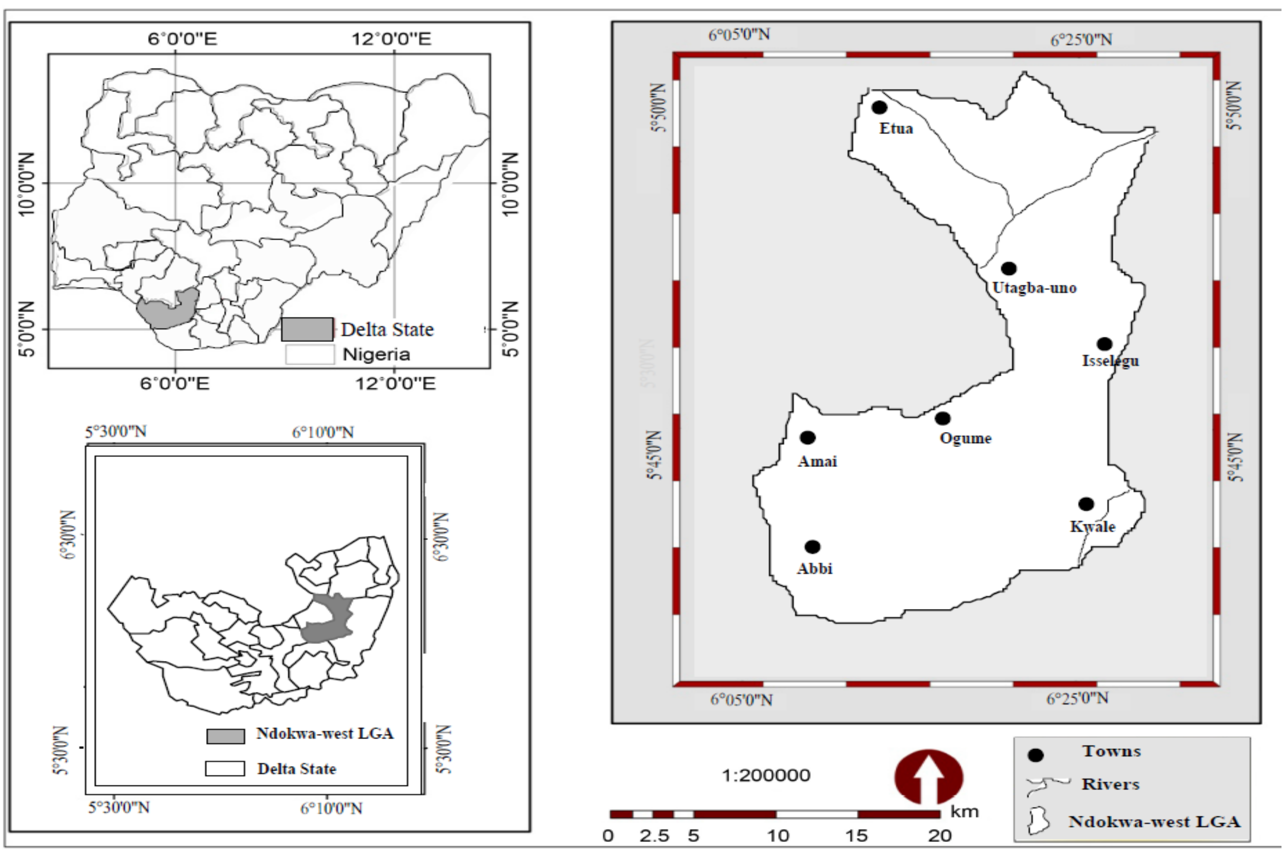

Fig. 1: Ndokwa-west LGA and the map of Delta state and Nigeria inset

Methodology

Data Collection

The data used for this research were mostly obtained from secondary sources. Landsat Multispectral imageries of the study area were downloaded from USGS.com, for 1972, 1987, 1990, 2002, 2004, 2014 and 2018, representing the time series being reviewed. The imageries collected were the most suitable for our research, as they were devoid of cloud cover interference which could compromise the data results. The imageries were loaded into ArcGIS 10.5 in order for it to lie in its geographic location, as Landsat imageries have auto georeferencing properties when it is uploaded into ArcGIS. The multispectral imageries were all clipped to the shape file of the study area in order to produce the multispectral image of the study area from the entire area downloaded. The shape file of the study area was obtained from the georeferencing of local government area map of the study area.

Additional data were obtained from the data base of the United States based Google Earth Engine (GEE), the remote sensing lab of the Foundation for Research and Technology (FORTH), as well as the Delta state Ministry of Lands and Surveys. The data collected was useful in analyzing the various indicators for examining the extent of forest loss and degradation in the study area. The indicators focused on were: forest canopy cover, forest health and forest protective function.

Forest Canopy Cover

The use of Forest Canopy Cover as an indicator to investigate forest degradation was done using data obtained from the Multispectral Imageries of the study area. The landuse/landcover (LULC) classification of the principal components of the imageries enabled us to observe the variations in land use types, through the years under study. This is in order to see how the changes in other landcover types have affected the forest cover area. This is necessary in order to determine the extent of fragmentation of the forests, since fragmentation is an indicator of forest degradation. The classification scheme deployed in this research is a modification of Anderson (1967) as shown in Table 1.

Table 1. LULC Classification scheme

SN	Landuse/Landcover Classes
1	Water bodies
2	Settlement
3	Forest land
4	Bare ground

Forest Health

The health of a forest is mostly determined by how well its vegetation absorbs most of the visible light that hits it, while reflecting a large portion of the near – infrared light. Unhealthy or sparse vegetation reflects more visible light and less near – infrared light (Rouse et al., 1974 and Pettorelli, 2013). The health of a forest is usually calculated using the Normalised Difference Vegetation Index (NDVI). This is the most common Vegetation Index (VI) and is mathematically represented as:

NDVI = NIR – RED / NIR + RED …………… (1)

Where RED and NIR stand for the spectral reflectance measurement acquired in the red (visible) and near infra-red regions, respectively.

The NDVI value of a forest ranges from -1 to +1. Thus high NDVI values indicate dense and undisturbed forest vegetation, which absorbs most of the visible light that hits it; this is described as a healthy forest. Conversely, lower NDVI values indicate sparse vegetation and less absorption of visible light, or unhealthy vegetation.

Decline in forest protective function

The decline in forest protective function was examined while studying the land surface temperature (LST) of the study area over the study period. The LST data for the study period were obtained from the FORTH Remote Sensing Lab. This was used to establish the trend in the study area over the study period. Comparison between the LST values and the NDVI values were used to establish if the changes in vegetation cover affects the land surface temperature. The NDVI was used in this analysis because it is an index of forest degradation and its decline also leads to a loss in protective function. It is important to note that the land surface temperature is different from atmospheric temperature or temperature of the surrounding air.

Results and discussion

Estimating loss in forest cover area

Four major categories were identified: forests, bare earth, human settlements and water bodies (Fig 2-5) in different proportions. The study area experienced changes in land use within the study period (Table 2).

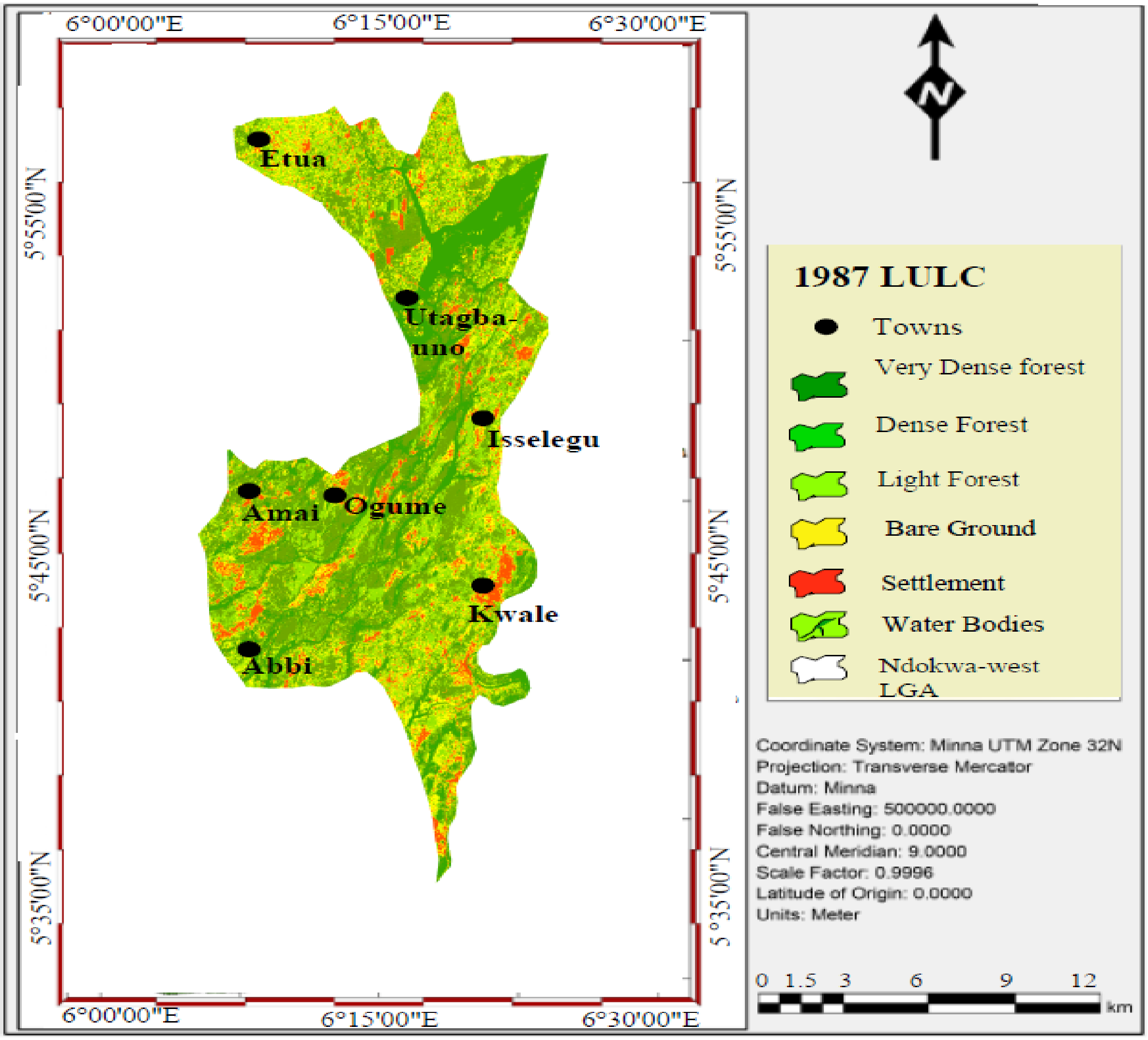

Fig. 2: LULC Ndokwa-west: 1987

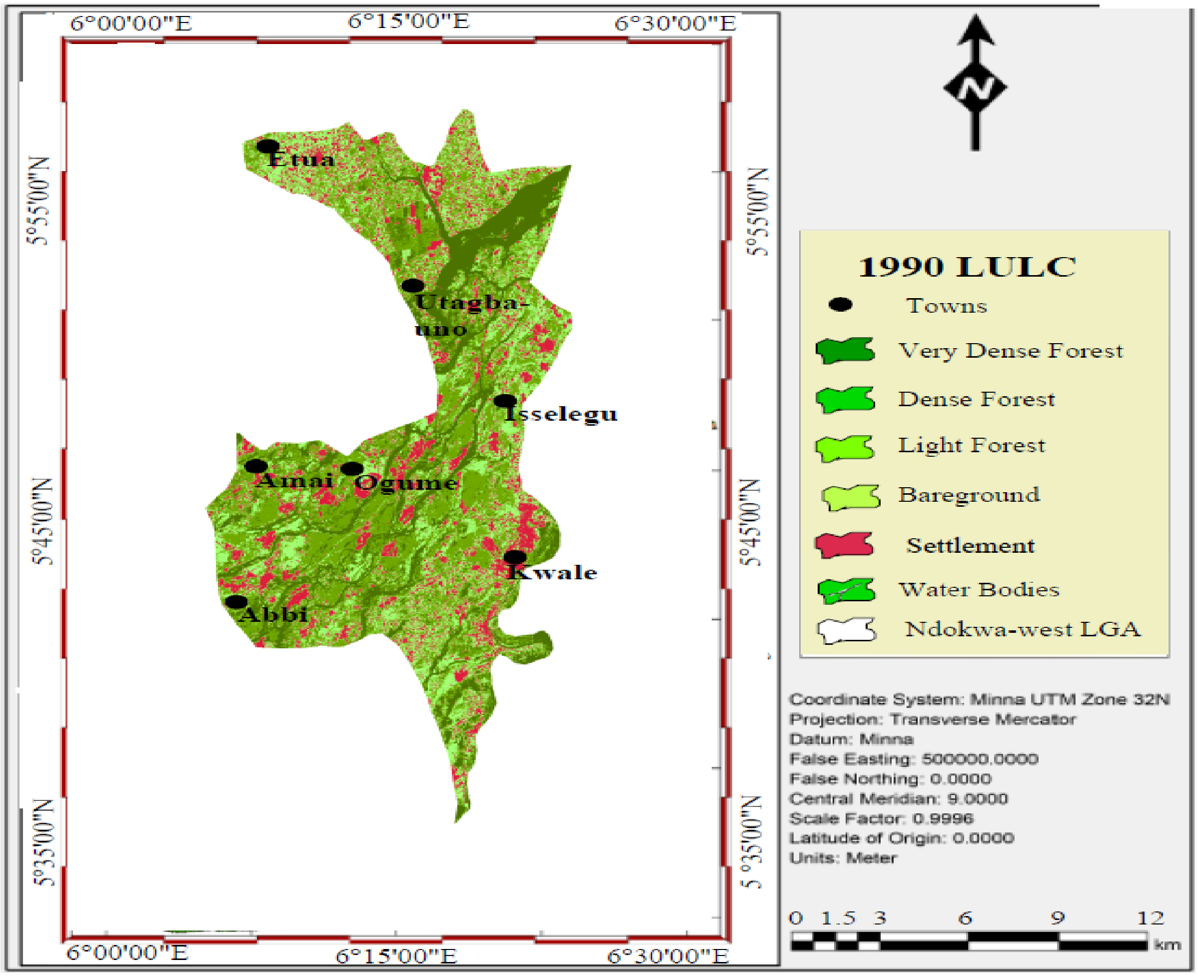

Fig. 3: LULC Ndokwa-west: 1990

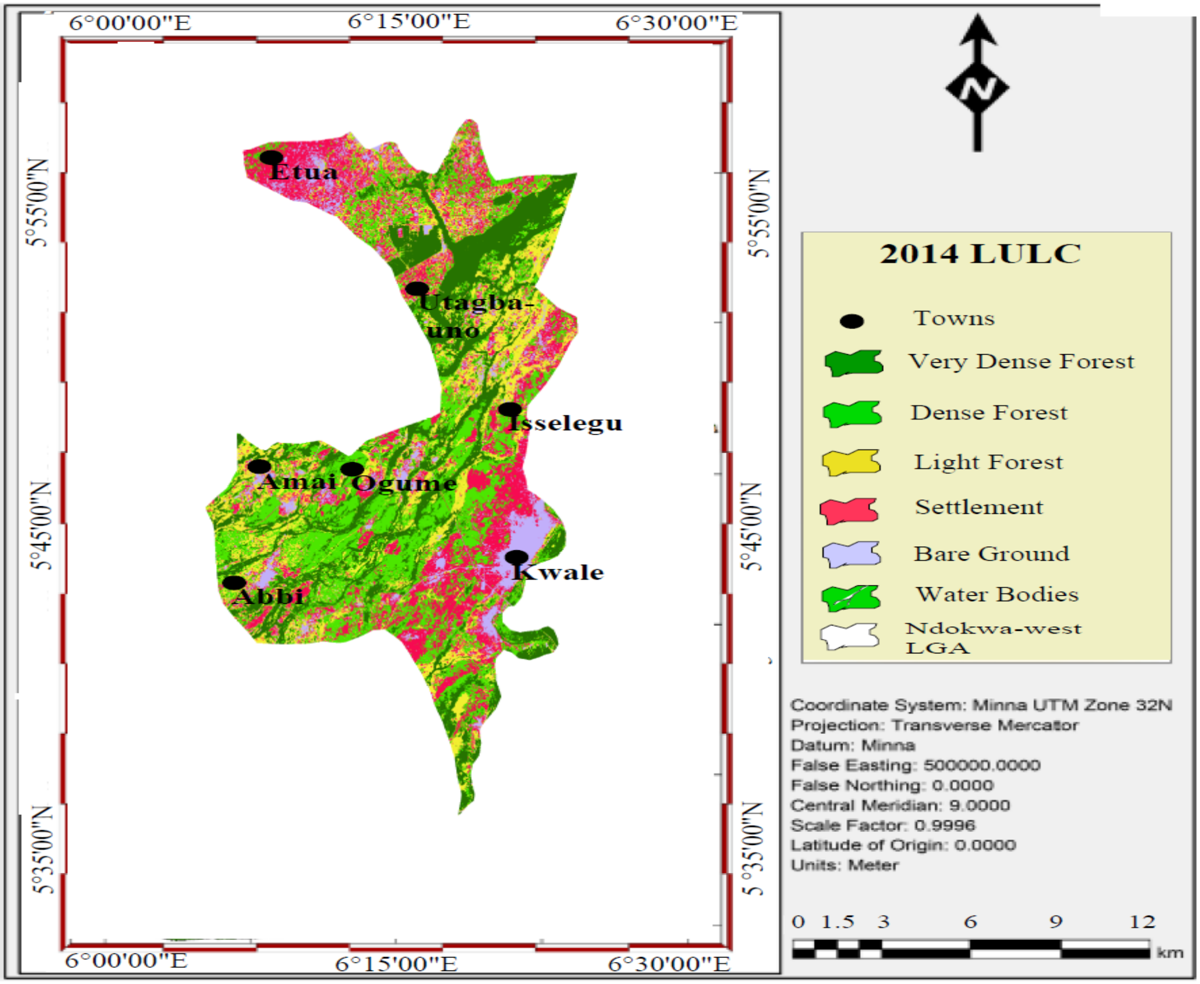

Fig. 4: LULC Ndokwa-west: 2014

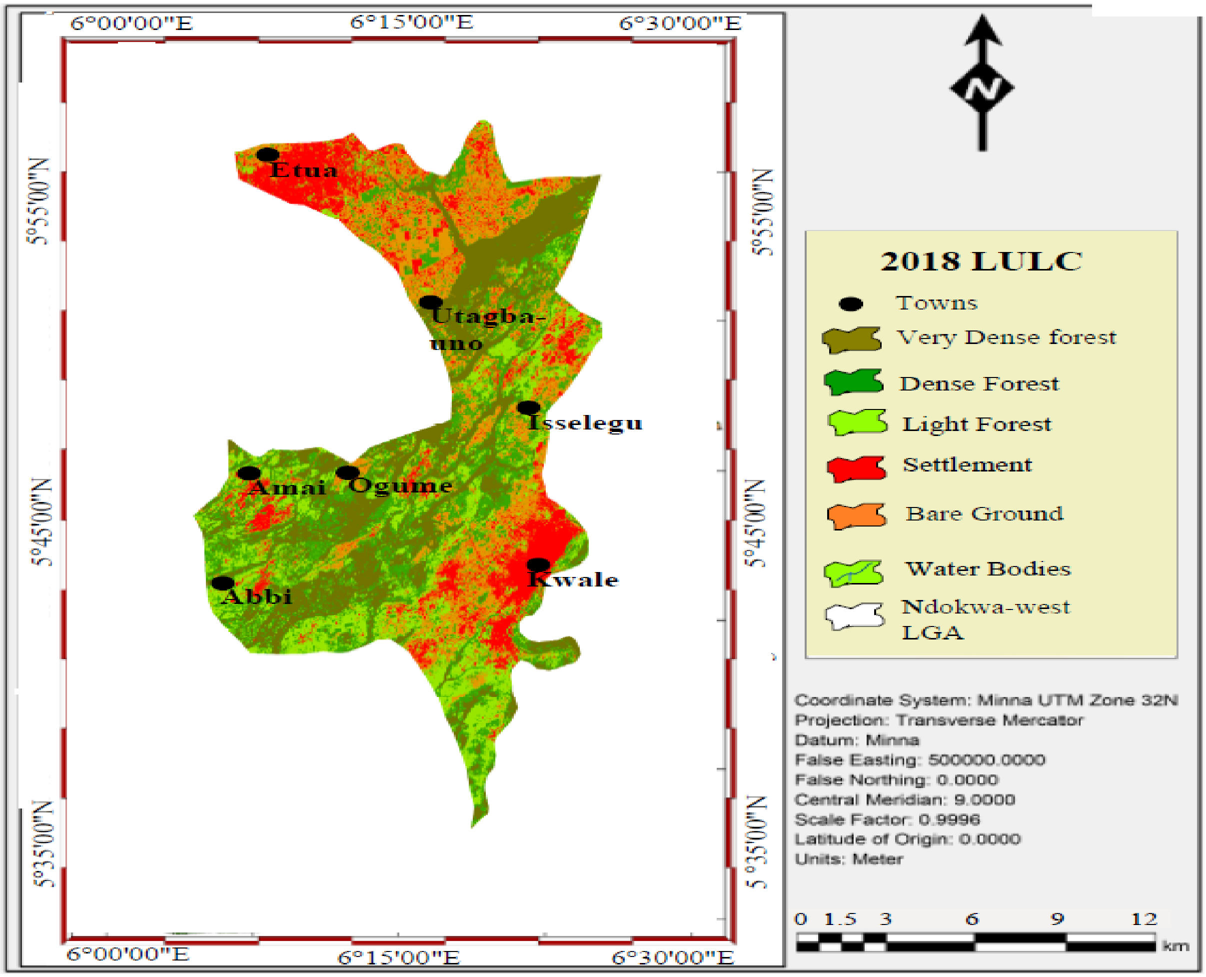

Fig. 5: LULC Ndokwa-west 2018

Table 2 Dynamics in LULC over the study years.

S/No	LULC (In Pixel sizes)	1972	1987	1990	2002	2004	2014	2018
1	Water bodies	_	2189	630	_	_	1360	1120
2	Settlements	8	31818	159983	205921	205963	632644	761250
3	Forest	275438	914282	857918	793566	793223	367466	212515
4	Bare earth	_	153456	83844	102258	102559	100275	126860
	Total in Pixels	275446	1101745	1101745	1101745	1101745	1101745	1101745

Principal Factors affecting forest loss

A multiple regression analysis was carried out using the landcover values derived from table 1. This was to determine if there is relationship between the rate of change of forest landcover type and the other landcover types. The results of the multiple regressions are presented in table 3.

Table 3 Multiple Regression results for forest against other landcover types

Summary Output

Regression Statistics	
Multiple R	0.999999846
R Square	0.999999691
Adjusted R Square	0.999999228
Standard Error	256.2606399
Observations	6

ANOVA

	df	*SS*	*MS*	*F*
Regression	3	4.25164E+11	1.42E+11	2158100
Residual	2	131339.0311	65669.52	
Total	5	4.25164E+11		

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	1103033.99	691.3310191	1595.522	3.93E-07
Settlement	-1.000356616	0.000402155	-2487.49	1.62E-07
Bareground	-1.011122092	0.006868149	-147.219	4.61E-05
Water bodies	-0.805304819	0.20009669	-4.02458	0.056553

Forest Health

The data for forest health was obtained from the calculation of the Non-Differential Vegetation Index using ArcGIS 10.5 and the multispectral images, as well as the additional data obtained from Google Earth Engine. The results of the NDVI for the study area are shown in tables 4 and 5.

Table 4. NDVI Tables (Google Earth Engine)

S/ No	Scene_id	View_id	Date	Cloud	Min	Max	AVERAGE (NDVI VALUES)
1	LT05_L1GS_189056_19840627_20170220_01_T2	L5TM/LT05_L1GS_189056_19840627_20170220_01_T2	6/27/1984		-0.1216	0.7487	0.4855
2	LM05_L1GS_189056_19850427_20180406_01_T2	L5MSS/LM05_L1GS_189056_19850427_20180406_01_T2	4/27/1985		0.0016	0.2545	0.0995
3	LT05_L1TP_189056_19861124_20170215_01_T1	L5TM/LT05_L1TP_189056_19861124_20170215_01_T1	11/24/1986		0.0803	0.6647	0.3606
4	LT04_L1TP_189056_19871221_20170210_01_T1	L4TM/LT04_L1TP_189056_19871221_20170210_01_T1	12/21/1987		0.0787	0.5502	0.4175
5	LT04_L1TP_189056_19880106_20170210_01_T1	L4TM/LT04_L1TP_189056_19880106_20170210_01_T1	1/6/1988		0.0954	0.4207	0.3064
6	LT04_L1TP_189056_19891210_20170201_01_T1	L4TM/LT04_L1TP_189056_19891210_20170201_01_T1	12/10/1989		0.0144	0.662	0.5008
7	LT04_L1GS_189056_19900924_20170128_01_T2	L4TM/LT04_L1GS_189056_19900924_20170128_01_T2	9/24/1990		-0.1624	0.7685	0.2541
8	LT05_L1TP_189056_19911224_20170124_01_T1	L5TM/LT05_L1TP_189056_19911224_20170124_01_T1	12/24/1991		0.1001	0.4965	0.3666
9	LT04_L1TP_189056_19920117_20170124_01_T1	L4TM/LT04_L1TP_189056_19920117_20170124_01_T1	1/17/1992		0.0695	0.3125	0.2102
10	LT05_L1GS_189056_19990213_20161220_01_T2	L5TM/LT05_L1GS_189056_19990213_20161220_01_T2	2/13/1999		0.047	0.4753	0.2495
11	CBERS_4_AWFI_20170110_110_093_L4	CBERS4AWFI/CBERS_4_AWFI_20170110_110_093_L4	1/10/2017		0	0.3687	0.2327
12	S2A_tile_20181219_31NHG_0	S2/31/N/HG/2018/12/19/0	12/19/2018	0	0.1284	0.5829	0.3032

Table 5. NDVI calculated using ARCGIS 10.5

STUDY YEAR	1972	1987	1990	2002	2004	2014	2018
NDVI	0.974	0.4818	0.4312	0.3816	0.3726	0.3552	0.3043

Forest Protective Function

The forest protective function of the study area was observed using information from the changes in land surface temperature during the study period. The data for land surface temperature of the study area was obtained from the FORTH Remote Sensing Lab data base. The values observed are presented in table 6.

Table 6. Land Surface Temperature (LST) data (source: FORTH Remote Sensing Lab)

YEAR	**1972**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**
LST (ºC)	--	--	--	--	27	36	41	27	20
YEAR	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
LST (ºC)	27	20	--	--	--	--	--	33	35
YEAR	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
LST (ºC)	37	37	38	34	36	33	35	41	42
YEAR	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
LST (ºC)	43	40	42	38	33	32	36	32	37

A simple regression analysis was carried out to determine if there is a relationship between increasing land surface temperature in the study area and the temporal change in forest health. The result is presented in table 7.

Table 7 Results of simple regression analysis between LST and NDVI values

Multiple R	0.854079454
R Square	0.729451714
Adjusted R Square	0.661814642
Standard Error	2.645833877
Observations	6

ANOVA

	Df	SS	MS	F	Significance F
Regression	1	75.49825239	75.49825239	10.7847915	0.03038568
Residual	4	28.00174761	7.000436903		
Total	5	103.5			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	56.9290	7.5168	7.5736	0.0016	36.0591	77.7990	36.0591	77.7989
Percentage NDVI Values	-0.6300	0.1918	-3.2840	0.0304	-1.1626	-0.0974	-1.1626	-0.0973

In order to determine the extent of loss of vegetation cover, the static landcover distribution for each study year is derived from the previously downloaded landsat multispectral images. The values were obtained from the attribute tables of all the imageries classified and the figures observed represent the static area of each landcover category for each study year. The extent of loss of forest cover was estimated from the difference in the forest landcover value of 1987 (benchmark year) and that of 2018 (current year). This amounted to a loss of 701767 pixel areas or about 908km^2 of forest cover in the study area during the study period.

The results of our multiple regression analysis to determine the principal factors affecting forest loss show that 99.99 percent of our data is explained by the analysis (R^2= 0.9999). The P values for settlement and bare earth landcover types were observed to be less than our alpha value of 0.05. This means that there is a significant relationship between the change in size of these two landcover types and the change in size of forest cover. With a P-value greater than 0.05, water bodies are observed to have no significant relationship with the change in forest landcover. Thus the increase in size of the settlement and bareground land types results in the change (decrease) in size of the forest landcover area.

Fig. 6 shows a component bargraph for the values of each landcover type for all the study years. Settlements and bare earth increased over the study period while forest cover area decreased throughout the study years.

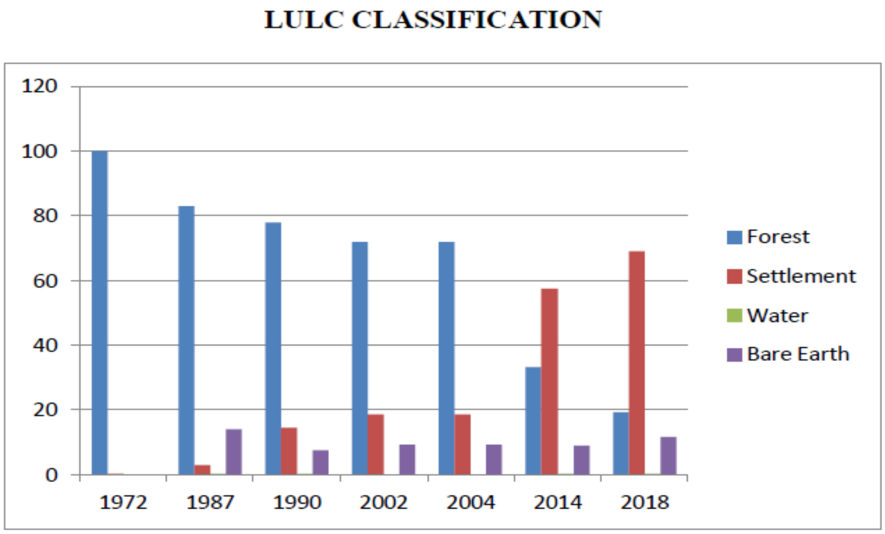

Fig 6. Land use and cover dynamics over the study period

Generally, there was a decrease in NDVI values from 1972 to 2018 (Fig 7). Fluctuations experienced during the period were mainly from forest regeneration experienced in the zone. The value obtained for 2018 was 0.3032, which is less than 0.94 that was recorded for 1972. Equally, there was a gradual decrease in forest health between 1972 and 2018 in the study area; seen as a negative trend during the study period (Fig 8).

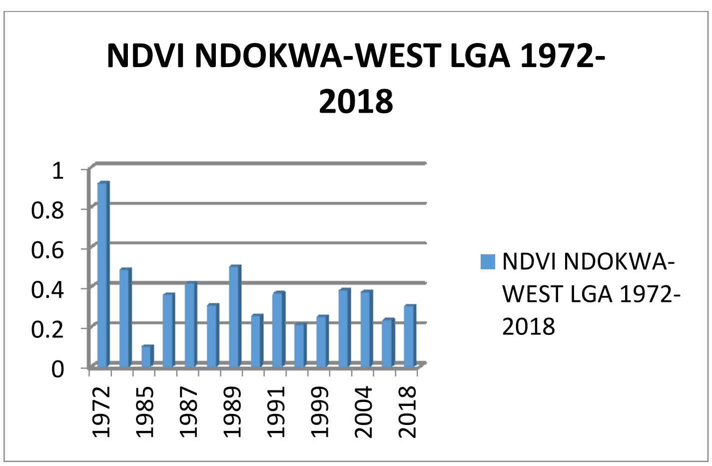

Fig 7. Bar chart showing the NDVI values for the study period

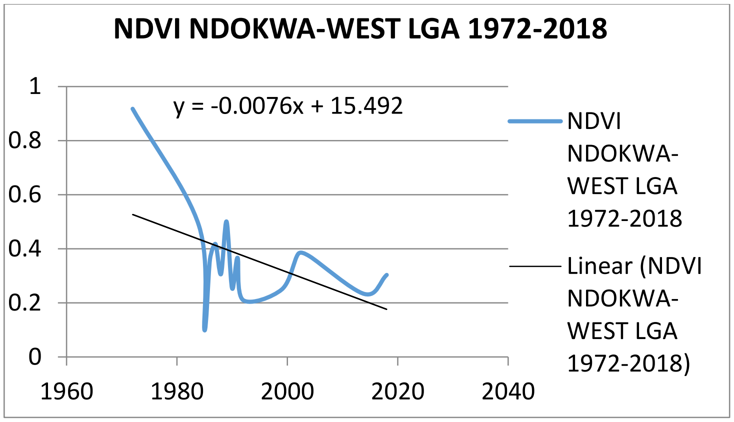

Fig 8.Trend graph for forest health in the study area

The results of the multiple regression analysis confirmed the existing relationship between the NDVI values (forest health values) and LST in the study area. R square value of 0.7295 furthermore showed that as much as 72.95 percent of the data was explained by the analysis.

Land surface temperature values of the study area increased steadily from 1972 to 2018 (Fig 9).

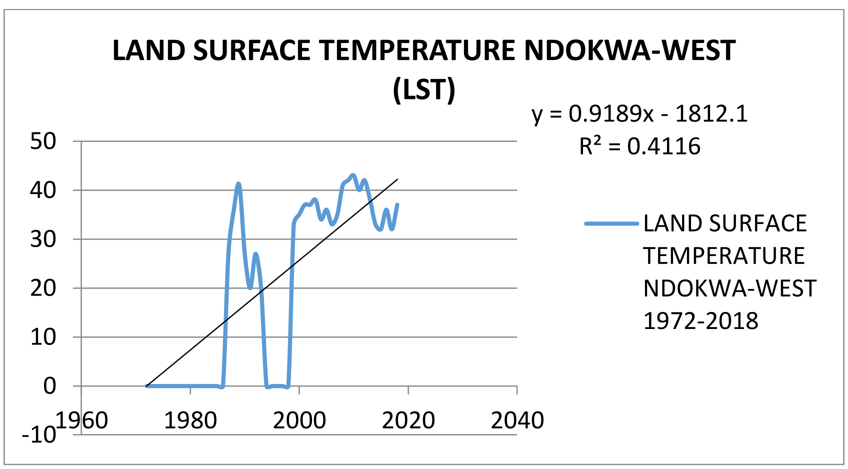

Fig: 9. Trend Series graph for LST between 1972 and 2018

Results from the classification of the images obtained through the study years showed how the changes in the various landcover types gradually led to a steady decline in the size of the forest cover in the study area. Settlement landuse contributed to much of the forest cover loss and fragmentation in the study area. The results of the NDVI values of the study area also showed that forest health declined through the years. A decline in forest health is an indication of forest degradation. There was a significant relationship between NDVI and LST values in the study area.

The declining forest cover, as well as the NDVI values of the study area corresponded with increasing LST values through the study years. This is an indication of a loss in the protective function of the forests in the study area, as more solar radiation directly hits the land surface. On the other hand, the declining protective function also showed an evidence of forest degradation in the study area since the forests no longer served as buffer against the solar radiation. Generally, the area experienced forest degradation and the forest health and protective functions were as a result reduced. Forest loss and degradation in the area were mainly as a result of conversion of forest areas to other land uses. Such anomalies are expected and inevitable in an area with increasing population and attendant pressures such as the Niger Delta region and much of tropical landscapes (Igu, 2017). Though such trends are expected to continue over the coming years especially as many households depend on the forests as sources of livelihood as well, wholistic and feasible forest management initiatives are needed to ensure that the entire forest cover are not lost completely. Actualizing forest conservation and management in the region has been challenging, especially because much of the individuals in the zone are poor and lack alternative sources of livelihood. Addressing their welfare concerns will no doubt be the starting point to achieving forest management in the zone. Furthermore, managing already established forest reserves and establishing protected areas at community levels will equally promote the forest stock of the zone and needs to be maximally harnessed.

Associated effects of forest loss and degradation such as increased surface temperature are quite pronounced in the zone. This will likely increase if the trend of forest loss continues in the zone and may present a worrisome scenarios for the region as climate change impacts becomes more adverse. Efforts to reduce such impacts such as promoting afforestation and reforestation schemes should be given attention and promoted. Though such tasks (tree planting) are normally borne by the government (at municipal, state or national levels), engaging stakeholders, communities and individuals to achieve such strides are to be explored for greater achievements.

Conclusion

Forest loss was experienced in the study area within the epochs under review. This trend of loss was mainly due to the conversion of the forests to other land uses, especially built up areas. Such modifications of the landscape contributed to the increased surface temperature of the zone and degradation of the ecosystem. Engaging in forest management initiatives are much advocated for the zone in order to reduce and manage associated impacts of environmental change in the region.

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