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A Geospatial Assessment of the Impact of Gas Flaring on Vegetation Cover in Delta State, Nigeria

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Abstract: Gas flaring, the deliberate burning of undesirable byproduct gas produced during oil exploration, is something that the Nigerian people have witnessed and are understandably terrified of. Instead of "devastating," the word "dreaded" was chosen to emphasize the point more clearly and forcefully. A lack of understanding regarding the detrimental impacts on the environment, leading to an insufficient regulatory framework, is a key factor in the perpetuation of this practice (removed redundant phrase and rephrased for clarity). Although studies have examined some of the negative environmental impacts of gas flaring, a comprehensive analysis of these effects has not yet begun. To date, there have been no GIS-based studies in Nigeria that quantify the impact of gas flaring on vegetation cover. Both the novel aspects of this study and its gaps in knowledge are highlighted. The primary objective of this research was to address this information vacuum by investigating the potential of geographic information systems (GIS) to mitigate the detrimental impacts of gas flaring on the extensive plant life in Delta State. In order to accomplish this, the study area was covered by three distinct time series of satellite images: CORONA 1967, Landsat 5 TM 1986/87, and Landsat 7 ETM+ 2001/02. extracted unnecessary dates and clarified the situation by assigning specific names to the satellites. The data was divided into four subsets, with each subset selected using the criteria mentioned earlier. Through the use of a GIS-based change detection method, we compared the historical changes in gas flaring and non-gas flaring areas' vegetation and land cover (GIS). "Employed" is now used instead of "received" in the methodology description for better clarity. The study found that gas flaring is a significant factor in the rapid extinction of native plant species in the studied area. Rapid and effective regulatory action is required at the federal, state, and local levels in response to the finding. Policymakers and decision-makers can address this pressing environmental issue with more informed solutions and preventative measures if they incorporate these new findings into strategic planning. After revising the conclusions and suggestions, the call to action is more compelling.

Keywords: gas flaring, GIS, vegetation cover, satellite imagery, change detection, degradation, decision-making, proactive measures

INTRODUCTION

As a precaution, most industrialized nations release the gas when it boils off. In the event of an emergency or equipment malfunction, this ensures that gas can be safely extracted. This is something that Edino et al. (2010) and the World Bank (2003) both acknowledge. However, in less developed, less industrialized nations, the size of the venting and heating system and the distance to gas harvesting and re-infusion are the determining factors (Edino et al., 2010; Worila, 2002). The amount of gas released into Earth's atmosphere in 2004 was 126 BCM. Of that total, Nigeria accounted for over 14%. Nigeria is one of the top twenty countries in the world for gas emissions, right behind Russia. Elvidge et al. (2009) and the World Bank

(2007) both state the following: Gas emissions continue to occur on a worldwide scale for several reasons. These include insufficient funding for initiatives that seek to decrease gas emissions, a lack of an efficient administrative framework, and a lack of communication between the local and international business communities (World Bank, 2002). However, these concerns appear to be well-founded in Nigeria, where the government is weak and degraded, institutions lack authority and accountability, and operations are complex (Edino et al., 2010; Gerner et al., 2004; ICF, 2006; Ishisone, 2004; World Bank, 2002). Gas eruptions have been steadily worsening since oil reserves in Nigeria were discovered in the late 1950s. Multiple studies have connected this incident to global health, social, and economic crises, particularly in Nigeria. The reason behind this is its detrimental impact on the environment and its dedication to causing global damage (Ishisone, 2004; Abdulkareem, 2005; Edino et al., 2010; Oseji 2007; Leahey et al., 2001; Omokaro, 2009; World Bank, 2007). According to some accounts, the soil's physical and chemical characteristics close to eruption sites undergo significant changes during various types of eruptions (Abdulkareem, 2005). In addition, plants located further away from volcanic sites have more chlorophyll than those closer to the eruption sites (Isichei and Sanford, 1976). As a result, governments now have a chance to assist developing nations in reducing this trend by establishing the appropriate administrative, legal, and economic framework to promote gas usage. Welt Bank (2002) and 2004; Zahler et al. (2002).

The Niger Delta is a vital area in the worldwide effort to preserve biodiversity due to the great variety of species that call it home (Ugochukwu and Ertel 2008; World Bank, 1995). The biodiversity of this region is facing serious threats from the rapid environmental degradation caused by oil and gas exploration activities. Additionally, very little research has examined the long-term impacts of gas flaring since its introduction in Nigeria. According to Ishisone, the lack of knowledge about the environmental harm caused by gas flaring and the paucity of research on the topic are the reasons why the Nigerian government has failed to devise an effective strategy to end the practice (2004).

Since the discovery of oil in Nigeria's Niger Delta region, there has been no agreement to assess the impacts of Gas erupting using the Geography Information System (GIS). Furthermore, rather than logical philosophy, most of the studies on the impacts of Gas eruption rely on surveys to support public perceptions (Odjugo and Osemwenkhae, 2009). In this way, a more complicated logical device would be required to fully evaluate the long-term consequences of Gas erupting on plant and land cover in areas near Gas erupting locations.

The geographic information system (GIS) is an appropriate tool for studying the long-term effects of flared gases on Nigerian vegetation and land cover. GIS can store vast amounts of data, monitor long-term change, and recognize intricate interrelationships between ecological features (Eedy, 1995; Smit and Spalding, 1995).

This study attempts to use GIS to examine the effects of gas flaring on vegetation and land cover in Nigeria's Niger Delta region, using Delta State as a case study. Because oil exploration and infrastructure development took place inside the space without enough natural thinking (Twumasi and Merem, 2006), GIS would be a valuable tool for assessing the effects of erupting Gas on the ground cover. It provides a graphical show of the modification of flora and land ensures simple examination through the planning and perceptive capabilities of GIS. This may provide a proof-based evaluation through a spatial translation of satellite images and provide an instrument for constructing a natural information framework data collection (Arimoro et al., 2002; González et al., 2010), assisting in a robust approach strategy on Gas erupting. However, this may lead to an improvement in the Niger Delta's residents' well-being and social prosperity.

Study Area

The Niger Delta consists of nine oil-producing provinces, one of which is Delta State. Strategically located between southern and southern Nigeria, it is a key geopolitical zone. Located between 5°N and 6°30'N and 5°E to 6°45'E, it encompasses 16,842 square kilometers of land. Mangrove swamp occupies over half of that area (Efe, 2006; Nigerian Population Commission [NPC], 2010). Several streams and rivers flow through this region. In the east, the Niger River winds its way through the state, while in the west, the rivers Escravos, Ramos, Benin, and Forcados meander through (Delta State Government, 2004). The far north receives just 190.5 millimeters of rain per year, compared to an average of 266.5 millimeters along the coast. Regardless of the season, development in rural areas is possible due to the weather. Nevertheless, agricultural development occupies a negligible fraction of its total land area. This is due to the fact that a large portion of its landmass is submerged in the Atlantic Ocean, leaving it susceptible to ongoing flooding (Inoni et al., 2006). In Figure 1 we can observe the Delta state. Landforms depicted on the map include gas eruption locations, water bodies, and international boundaries. Approximately 4,112,445 people call Delta home (National Population Commission, 2010), and the majority of that number work in the fishing and farming industries (Federal Office of Statistics, 1995; Ipingbemi, 2009). The riverine and swampy regions of the state are home to a significantly larger portion of this population (Delta government, 2004).

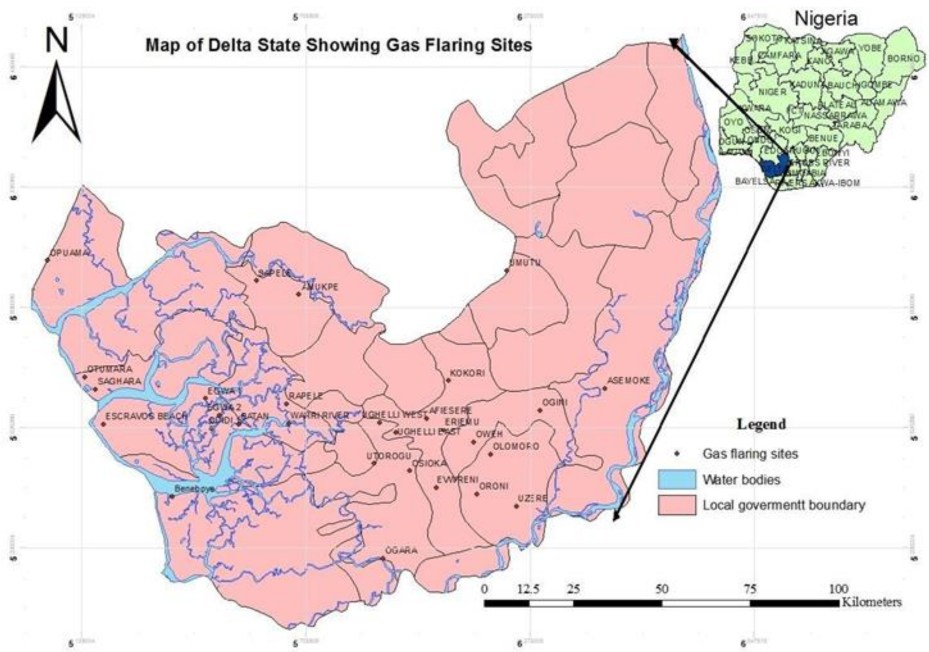


Fig. 1: Map of Delta State showing Gas flaring sites. (NASRDA, 2005)

LITERATURE REVIEW

On page 58 of its 1995 report, the World Bank says that gas flaring is "a wasteful emission of greenhouse gases that contributes to global warming." It is the process of putting associated gases into the air that aren't being used during oil and gas exploration. Hydrocarbons make up this gaseous mixture (World Bank, 1995). The associated gas that is found in oil deposits mixed with oil needs to be separated from the oil before it can be refined. There are three main ways to reach this goal: gas fracking, which involves burning the gas, injecting it back into the ground so that it can be collected later, and collecting the gas for home or business use (Ashton et al., 1999; Edino et al., 2010). Nigeria is the world's seventh-largest gas producer and the largest gas producer in Africa. It also has the largest gas reserves on the continent and is second only to Russia in the world in terms of gas flaring (Nigerian National Petroleum Corporation [NNPC], 2009b; Malumfashi, 2007; World Bank, 2007). Based on the information we have access to, her proven gas reserve is greater than 4 trillion cubic meters, which is equal to 24 billion barrels of oil and about 1.51 x 108 terajoules (TJ) of heat. About half of this is made up of a mix of associated gas (AG) and non-associated gas (NAG) (Sonibare and Akeredolu, 2006). According to a report from the World Bank in 2004, the amount of flared gas in Nigeria was only one-sixth of the total amount of flared gas recorded around the world (World Bank, 2007). The researchers Elvidge et al. (2009) also found that about 15.1 billion cubic meters of gas were burned in Nigeria in 2008. Nigeria has been flaring gas since the late 1950s, when crude oil was first found in the country. This practice is still going on today. In Nigeria's Niger Delta, which is the second-largest delta in the world and the biggest mangrove swamp in Africa, the above-mentioned flaring happens (Odukoya, 2006; Dupont et al., 2000). There are a total of 131 gas flaring sites in this area (National Space Research and Development Agency [NASRDA], 2005).

Several gas flaring reduction projects have been put in place by the federal government of Nigeria in an effort to lessen and eventually eradicate gas flaring. The following are listed:

1. The West African Gas Pipeline (WAGP
2. The Nigeria Liquefied Natural Gas (NLNG) Limited
3. West Niger Delta LNG
4. Escravos gas-to-liquid Projects (EPG

We still haven't ended gas flaring in Nigeria by the originally scheduled date, despite the fact that many programs are trying to do so. One of the primary factors causing this temporary setback is the large amount of natural gas reserves, which includes both AG and NAG. As an illustration, consider the fact that Sonibare and Akeredolu (2006) discovered that the initial LNG plant's gas consumption (NLNG) derived only 30% of its gas from AG. This means AG isn't going to be much use in the fight against gas flaring.

Economic, Social and Environmental Implication of Gas Flaring.

Surrounded by verdant farmland, rural residential areas, and mangrove forests, most gas flaring sites in Nigeria are located on the ground (Abdulkareem, 2005). Another option is to burn the gas straight from flare stacks or flare pits (Ekpoh and Obia 2010). The most typical locations in Delta State for lighting gas flares are shown in Figure 2. Locals there have accused the 159 oil fields in Nigeria's Niger Delta region of causing their region's poor air quality and other environmental problems (Civil Liberties Organization, 2001; Edino et al., 2010).

Figure 2: Gas flaring sites in Delta State, Nigeria. Source

Flaring does not result in total combustion, according to research by Leahey et al. (2001), since it produces innocuous by-products such as water and carbon dioxide. That this is due to flaring is contradicted by this. Additionally, a growing number of carcinogenic byproducts are being produced, which has the potential to harm the biodiversity of the ecosystem. The combustion reactions caused by gas flaring are known to release pollutants into the air. Sulfur dioxide, carbon monoxide, nitrogen oxides, and carbon dioxide are all examples of such pollutants. Human health is severely compromised by these pollutants (Obioh et al., 1994; Sonibare and Akeredolu, 2004; Winter et al., 1999). Acid rain in the Niger Delta of Nigeria is believed to be caused by gas flaring because of the acidic compounds that can be formed when sulfur dioxide and nitrogen oxides react chemically with water (Sonibare and Akeredolu, 2004). Gas farming in the Niger Delta is harmful to crops, according to several studies. These include Abdulkareem (2005), Dung et al. (2008), and Odjugo and Osemwenkhae (2009). Surprisingly, the researchers discovered that fields treated with waste gas had the worst impact on crop growth. The consequences of gas flaring in Nigeria have been the subject of numerous previous studies.

The chlorophyll content and internode length of the leaves of some plant species decrease in areas where gas flares are present (Isichei and Sanford, 1976). Additionally, when compared to the average daily temperature, the surface temperature within 270 meters of the flare site increases by approximately 3.7 degrees Celsius (Oseji, 2007). Heavy metal levels were found to be high in both surface and underground water in the gas flared area of Warri, Delta state, according to recent research by Nwankwo and Ogagarue (2011). The World Health Organization has set safe limits that are lower than these amounts (WHO).

Leahey et al. (2001) found that flaring doesn't completely burn because it produces harmless by-products like water and carbon dioxide. This disproves the theory that flaring is the cause of the event. Also, the ecosystem's biodiversity may suffer due to the high production of cancer-causing byproducts. Scientific evidence shows that combustion reactions set off by flaring gas release air pollutants. Sulfur monoxide, carbon dioxide, nitrogen oxides, and carbon monoxide are all forms of pollution that fall into this category. The health of the general public is severely compromised by these pollutants (Obioh et al., 1994; Sonibare and Akeredolu, 2004; Winter et al., 1999). Due to their acidic compound formation upon chemical reactions with water, nitrogen oxides and sulfur dioxide lend credence to the theory that acid rain in Nigeria's Niger Delta is caused by gas flaring (Sonibare and Akeredolu, 2004). A growing number of scholars have documented the detrimental effects of gas farming on crops in the Niger Delta. Notable examples include Abdulkareem (2005), Dung et al. (2008), and Odjugo and Osemwenkhae (2009). Surprisingly, the results demonstrated that waste gas fields significantly reduced crop growth. Concerning gas flaring in Nigeria, a great deal of study has been conducted. There have been prior investigations of this type. Some plant species' internode lengths and leaf chlorophyll contents decrease in areas where gas flares occur (Isichei and Sanford, 1976). In comparison to the daily mean temperature, the surface temperature within 270 meters of the flare site has also increased by approximately 3.7 degrees Celsius (Oseji, 2007). The gas flared area in Warri, Delta state, had elevated concentrations of heavy metals in both surface and underground water, according to research by Nwankwo and Ogagarue (2011). According to the World Health Organization, those levels were too high to be considered safe (WHO).

MATERIALS AND METHODS

Data set

Dataset used for this research were selected based on the following:

- Landsat data acquired was already geometrically corrected
- Satellite images of cloud cover of less than 10% were acquired
- Apart from the CORONA images, multi spectral Landsat imagery were acquired for

better image analysis

- Only Landsat images that have been terrain corrected (Level 1T) and orthorectified were acquired
- The time period in terms of year and same season were close for acquired images

Table 1: Summary of satellite data acquired for study

Sensor type	ImageDate	ID Scene or Path/Row	Resolution	Spectralbands	Source
CORONA	19/01/1967	DS1038-2074DF (016 – 023)	2.75m	1	USGS
LANDSAT 5 TM	15/01/1986	190/056	30m/120m	7	GLCF
LANDSAT 5 TM	21/12/1987	189/056	30m/120m	7	GLCF
LANDSAT 7 ETM+	17/02/2001	190/056	15m/30m/60m	9	GLCF
LANDSAT 7 ETM+	28/01/2002	189/056	15m/30m/60m	9	GLCF

Other data used for study: 1995 Land use and Land cover maps of Delta State (FORMECU, 1995), Administrative maps/Settlement maps (NASRDA, 2005), Place name data of study area (Office of the Surveyor General of the Federation).

Methodology

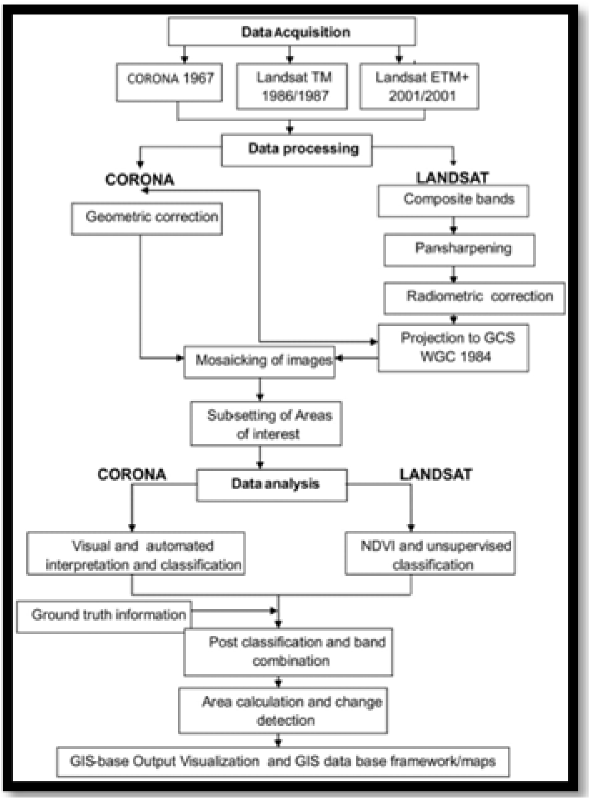


Figure 3: Schematic Diagram of the Research Methodology

Accuracy Assessment:

We verified the correctness of the classification using the Accuracy Assessment command in ERDAS Imagine. Additionally, the land use and cover maps from 1995 were utilized. After dividing each time series into four equal parts, we could determine their Kappa coefficient and total classification accuracy (Table 2)

Table 2: Accuracy assessment for classification result

Subsets	Year	Overall accuracy%	Kappa coefficient
A	1967	78.56	0.72
	1986/87	90.00	0.86
	2001/02	89.78	0.80
B	1967	76.53	0.68
	1986/87	91.96	0.89
	2001/02	92.45	0.85
C	1967	79.97	0.76
	1986/87	90.00	0.83
	2001/02	90.00	0.85
D	1967	82.48	0.77
	1986/87	91.46	0.88
	2001/02	90.98	0.89

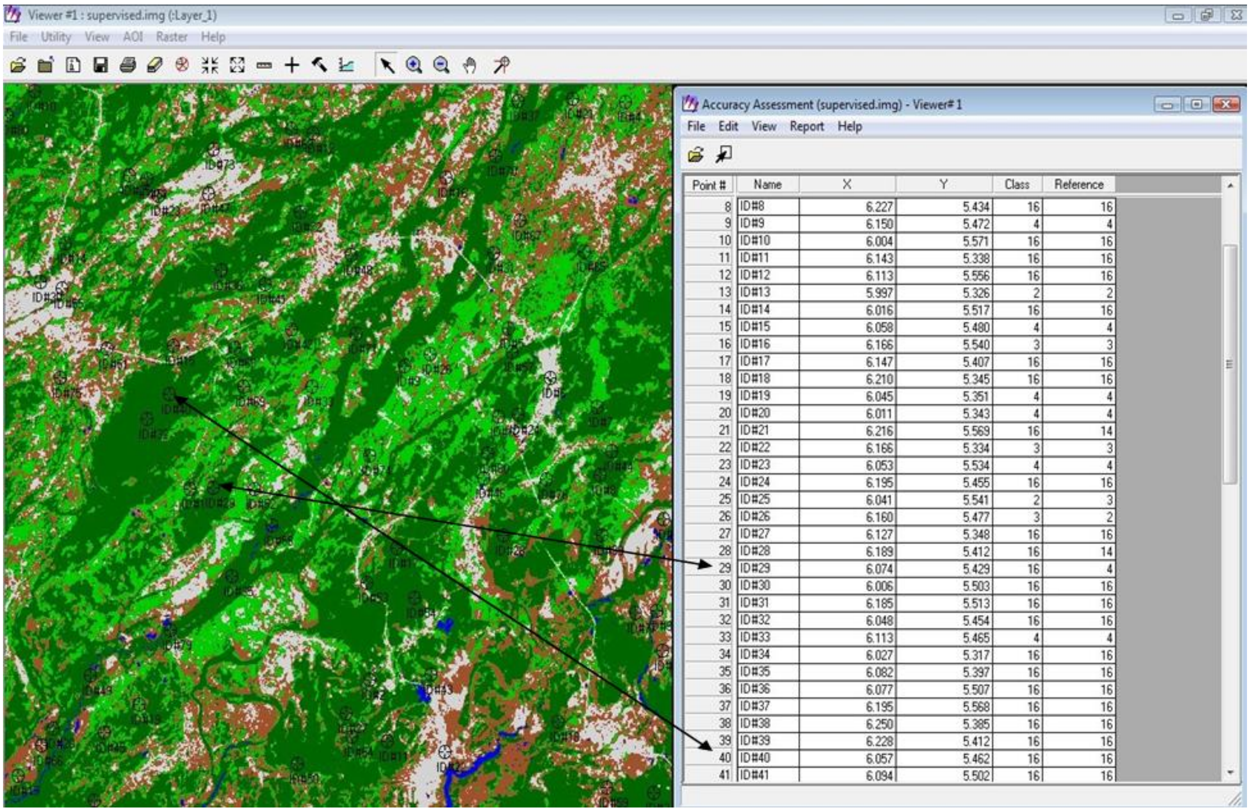


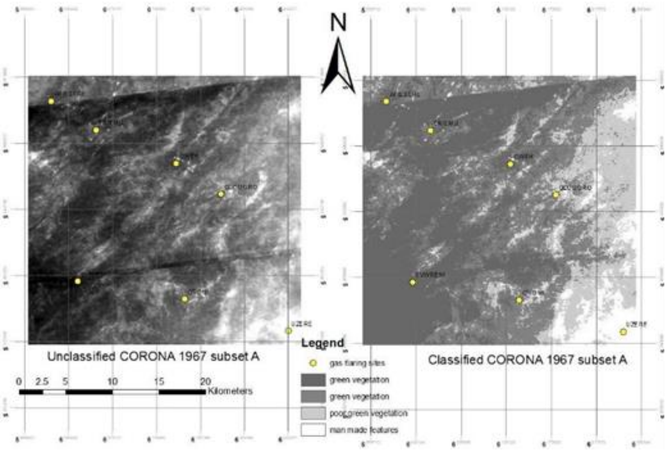
Figure 4: Accuracy assessment cell array for subset A, 1986/87

RESULTS AND DISCUSSIONS

Classification

Land Cover for Subset A

Figures 5–7 display the subset A images, both classified and unclassified. There are seven gas flaring sites in this subset, which covers an estimated 830 km2. Classification results for CORONA subset A showed that over 90% of the land cover was vegetation in 1967, of which 74.64% was green and 18.67% was classed as poor green (see Table 3) based on the different reflectance value of the identified vegetation in the panchromatic band of the CORONA image (Andersen, 2006; Grosse et al., 2005). At first glance, it was impossible to tell which bodies of water they were. Perhaps this is because this area is characterized by a particularly thick growth of a particular kind of vegetation—a fresh water swamp forest (FORMECU).



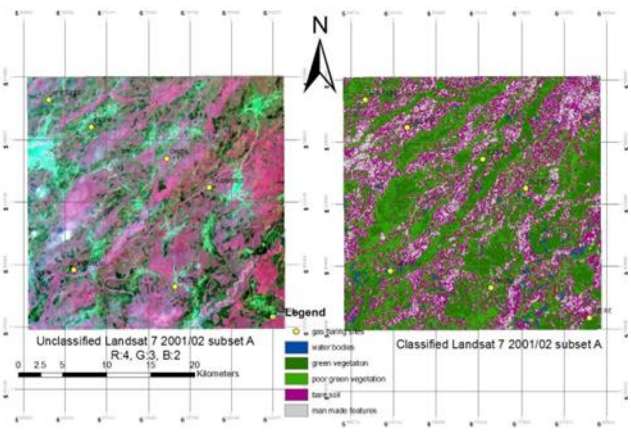
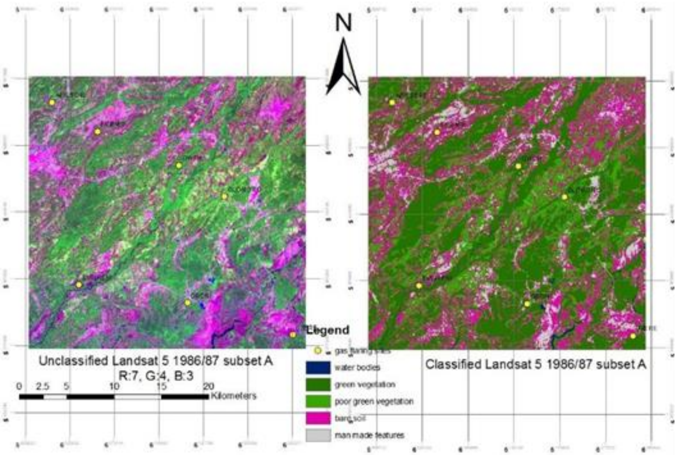


Figure 5: Subset A land cover.1967 Figure 6: Subset A land cover. 1986/87



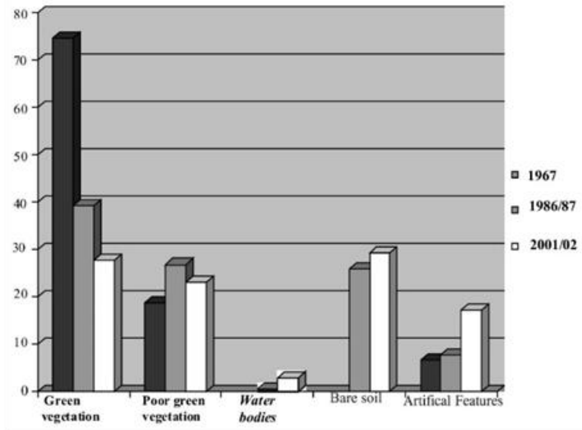


Figure 7: Subset A land cover. 2001/02 Figure 8: Changes in subset A land cover between 1967 and 2001/02

With a visual inspection of the CORONA 1967 image (refer to Figure 5), it became apparent that the percentage of land cover accounted for by man-made features was significantly lower, at 6.69 percent (see Table 3). It was easier to distinguish between vegetated and non-vegetated regions by combining the bands 7, 4, 3, and 4 from Landsat 5 1986/87 with 4, 3, and 2 from Landsat 7 2001/02. As a result of applying Landsat image classification to both subset A images, the percentage of verdant vegetation decreased from 39.27% in 1986/87 to 26.66% in 2001/02. Contrarily, the proportion of poor green vegetation increased from 18.67% in 1967 to 26.80% in 1968/87, before declining to 23.17% in 2001/02. Take a look at Table 3. Possible causes include changes in farming practices or urbanization. The percentage of uncultivated land increased from 26.93 percent in 1986–1987 to 29.15 percent in 2001–2002. The proportion of features created by humans increased from 76.1% in 1986–1987 to 17.22% in 2001–2002. This might be because of the expanding human population. The proportion of water also increased, going from 0.39 percent to 2.91%. The loss of the dense vegetation in the region, particularly the freshwater swamp forest that typically encircles bodies of water, could be to blame (FORMECU). The evolution of subset A is illustrated in Figure 8.

Table 3: Land cover statistics for subset A.

Classes	Area (km²) in 1967	% land cover	Area (km²) in 1986/87	% land cover	Area (km²) in 2001/02	% land cover
green vegetation	625.38	**74.64**	329.77	**39.27**	229.37	**27.66**
poor green vegetation	156.47	**18.67**	225.07	**26.80**	191.31	**23.07**
water bodies	Nil	**Nil**	3.25	**0.39**	24.13	**2.91**
bare soil	Nil	**Nil**	217.75	**25.93**	241.75	**29.15**
man-made features	56.02	**6.69**	63.93	**7.61**	142.81	**17.22**

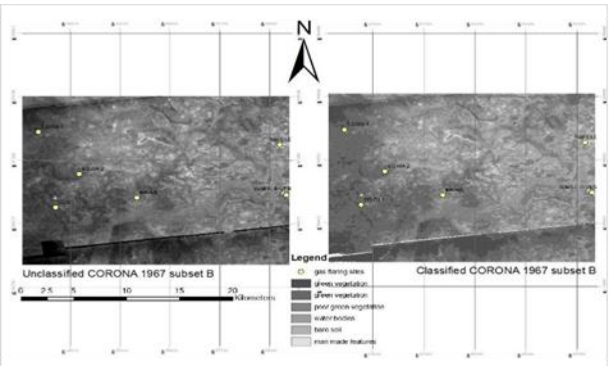
Land Cover for Subset B

Figures 9 to 12 show the unclassified and sorted photos of subgroup B. This subgroup is planned to cover 465km2 and includes six gas flaring hotspots. Subset B's characterization results, like subset A's, revealed a reduction in green vegetation levels from 53.35 percent in 1967 to 36.03 percent in 1986/87 and 23.50 percent in 2001/02. (see Table 4). In contrast to subset A, subset B showed a dramatic increase in the percentage of poor green vegetation, going from 14.46% in 1967 to 18.80% in 1986/87 to 19.81% in 2001/02. This is a significant increase compared to last year's figure of 14.46%.

A decrease was noted in the percentage of bodies of water; it fell from 18.39% in 1967 to 14.46% in 1986/87. The proportion of water bodies has changed very little since then (see Table 4). From 1967 to 2001–02, the percentage of exposed soil surfaces increased from 12.43% to 41.72%. Simultaneously, the proportion of artificial elements decreased from 1.37 percent in 1967 to 0.48% in 2001–02. This demonstrates that many other factors contribute to vegetation degradation, not only urbanization and population growth (see Table 4). Bands 4, 3, and 2 in multispectral images make it easy to distinguish between areas with and without vegetation (see Figures 11 and 12). Figure 10 depicts the evolution of subset B through time.

Table 4: Land cover statistics for subset B.

Classes	Area (km²) in 1967	% land cover	Area (km²) in 1986/87	% land cover	Area (km²) in 2001/02	% land cover
green vegetation	244.00	**53.35**	169.78	**36.03**	109.02	**23.50**
poor green vegetation	66.15	**14.46**	88.61	**18.80**	91.90	**19.81**
water bodies	84.13	**18.39**	68.13	**14.46**	67.22	**14.49**
bare soil	56.87	**12.43**	139.87	**29.69**	193.57	**41.72**
man-made features	6.25	**1.37**	4.79	**1.02**	2.24	**0.48**



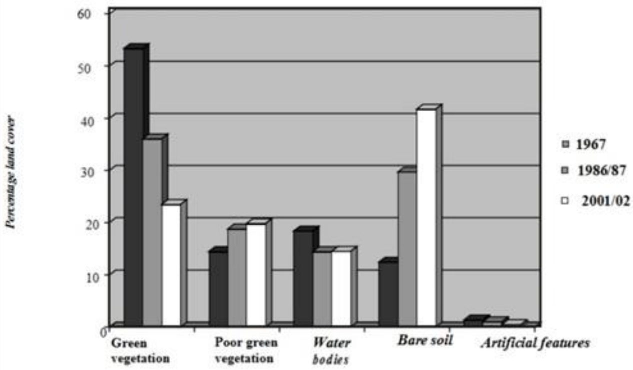
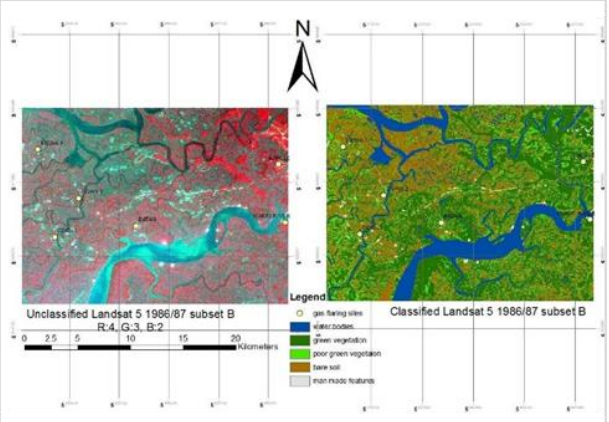


Figure 9: Subset B landcover.1967 Figure 10: Changes in subset B land cover between 1967 and 2001/02



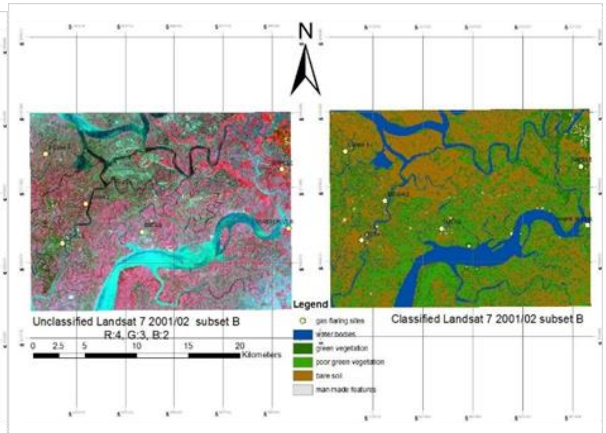


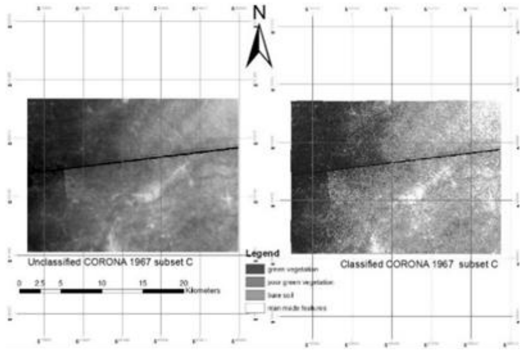
Figure 11: Subset B landcover. 1986/87 **Figure 12: Subset B landcover. 2001/02**

Land Cover for Subset C

There are no gas flaring locations in this area, which covers approximately 466 km2. Figures 13–15 display both the unclassified and classified versions of subset C. The percentage of green vegetation decreased from 49.09 percent in 1967 to 37.85 percent in 1986/87 to 32.27 percent in 2001/02, which is consistent with the results seen in the previous subsets. Peruse Table 5.

Table 5: Land cover statistics for subset C

Classes	Area (km^2) in 1967	% land cover	Area (km^2) in 1986/87	% land cover	Area (km^2) in 2001/02	% land cover
green vegetation	228.75	**49.06**	178.08	**37.85**	149.92	**32.27**
poor green vegetation	138.53	**29.71**	172.76	**36.72**	163.14	**35.12**
bare soil	49.44	**10.61**	65.97	**14.02**	71.26	**15.34**
man made features	49.41	**10.60**	53.70	**11.41**	80.24	**17.27**



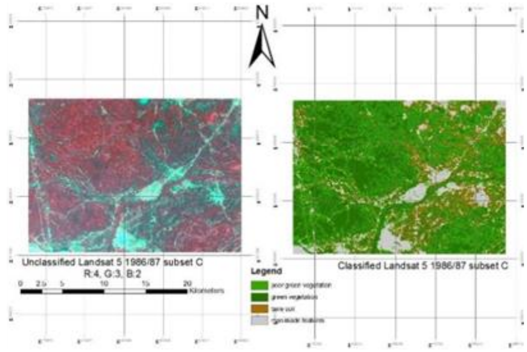
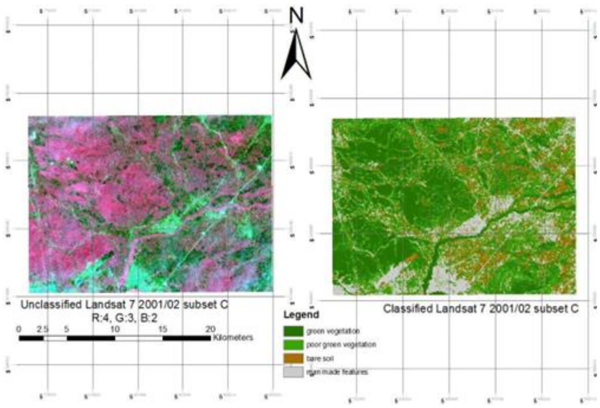


Figure 13: Subset C land cover. 1967 **Figure 14: Subset C land cover. 1986/87**



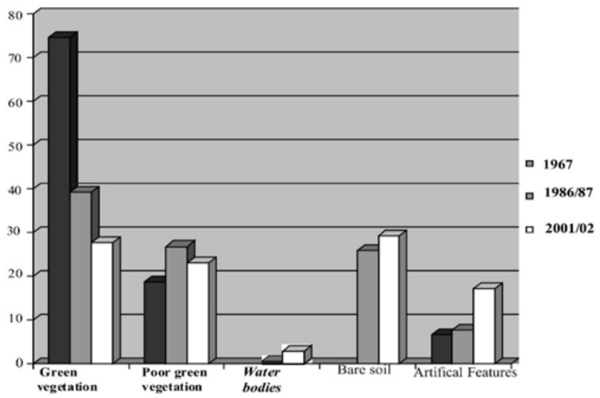
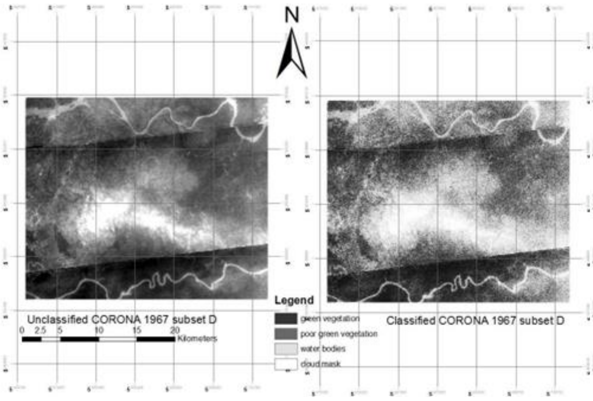


Figure 15: Subset C land cover. 2001/02 **Figure 16: Changes in subset C land cover between 1967 and 2001/02**

Our best guess for subset A is the quantity of insufficient green vegetation between 1967 and 2001/02. Specifically, between 1967 and 1986/87, the percentage of insufficient green vegetation increased from 29.71% to 36.72%, but by 2001/02, it had dropped to 35.12%. This occurred between 1967 and 2001/02. Examine Table 5. The expansion of urban areas and changes in agricultural practices are two of many possible explanations for this finding. The number of artificial features increased in Subset C as it did in Subset A. (see Table 5). Since most people in this area reside in cities, population growth could be the reason behind this observation. The absence of water bodies and the progressive expansion of exposed soil were both revealed by the subset C all-time series of satellite data (see Table 5). The pattern of 4, 3, and 2 bands was consistently employed to distinguish between areas with and without vegetation. The evolution of subset C is illustrated graphically in Figure 16.

Land cover for subset D

Both the unclassified and classified images of subset D are displayed in Figures 17–19. There are no gas flaring sites in this subset, which has a surface area of approximately 825 km2. Additionally, the percentage of verdant vegetation declined over time, falling from 64.74 percent in 1967 to 53.65 percent in 1986/87 and finally to 51.82 percent in 2001/02. The outcome of the classification for this subset proved this. Conversely, the proportion of non-green plants grows over time (see Table 6).



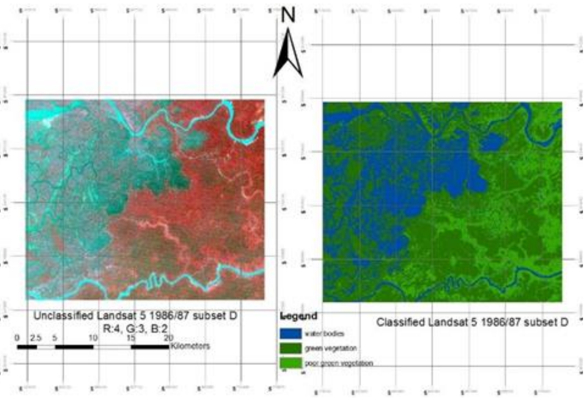
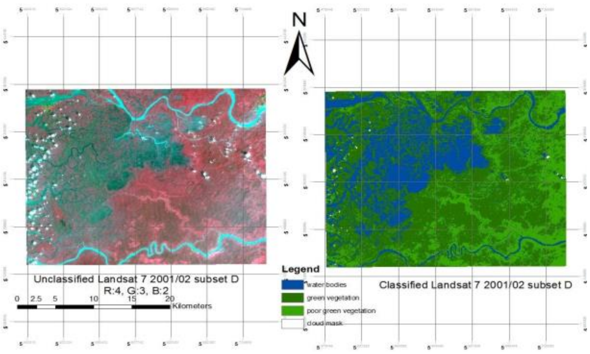


Figure 17: Subset D land cover. 1967 Figure 18: Subset D land cover. 1986/87

Table 6: Land cover statistics for subset D

Classes	Area (km^2) in 1967	% land cover	Area (km^2) in 1986/87	% land cover	Area (km^2) in 2001/02	% land cover
green vegetation	535.91	**64.74**	445.06	**53.65**	424.06	**51.82**
poor green vegetation	121.55	**14.68**	156.78	**18.90**	165.64	**20.04**
water bodies	160.44	**19.38**	227.71	**27.45**	226.40	**27.67**
cloud mask	9.87	**1.19**	Nil	**Nil**	2.20	**0.27**



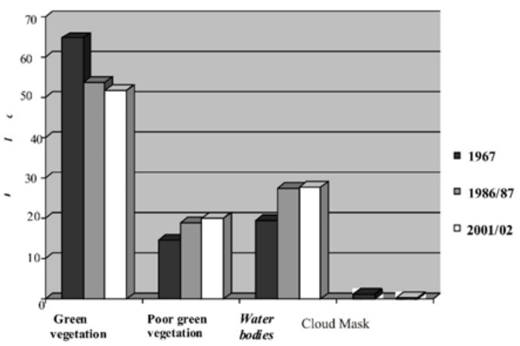


Figure 19: Subset D land cover. 2001/02 Figure 20: Changes in subset D land cover between 1967 and 2001/02

Although the percentage of bodies of water was higher in Landsat images taken in 1986/87 and 2001/02 (27.38% vs. 27.35%), the CORONA images only captured 19.38% of bodies of water in their classification results for this subset. As an example, see Table 6. Already mentioned is the possibility that the type of vegetation that was more abundant in 1967 near the area's bodies of water is responsible for this decline. What we call a "freshwater swamp forest" actually describes this ecosystem. Although the cloud mask percentage is not statistically significant, it may have contributed to the decline in classified bodies of water in 1967. While classifying these land cover types, we did not see any bare soil, artificial features, or spectral characteristics. It was easy to distinguish between the various land cover types in this subset by using the same set of bands (4, 3, and 2). Figure 19 is a graph depicting the evolution of subset D.

Changes in vegetation between 1967 and 2002

The results showing the percentage changes in vegetation over time from 1967 to 2001/02 for the four different subsets are provided in Table 7 to 17. According to Subset A, there was a 47.27 percent decline in green vegetation from 1967 to 1986/87, and a 30.45 percent decline from 1986 to 2001/02. Less densely packed greenery occupied 63.32 percent of subset A's total area (see Table 7). From 1967 to 1986/87, poor green vegetation increased by 43.84%, but from 1986/87 to 2001/02, it decreased by 15%. A total of 22.27 percent more poor green vegetation has grown in this area (see Table 7). As we mentioned earlier, this outcome could have been influenced by urban dwellers or changes in agricultural practices. Subset A's vegetation declined by 46.19 percent over the course of the study. Changes occurred mostly between 1967 and 1986/87. Refer to Table 7.

Table 7: Vegetation change results for subset A

Classes	**Area (km^2) in 1967**	**Area (km^2) in 1986/87**	**Area (km^2) in 2001/02**	**% change 1967 – 1986/87**	**% change 1986 – 2001/02**	**Total % Change**
green vegetation	625.38	329.77	229.37	47.27	30.45	63.32
poor green vegetation	156.47	225.07	191.31	-43.84	15.00	-22.27
Total vegetation	**781.85**	**554.84**	**420.68**	**29.03**	**24.18**	**46.19**

Green vegetation decreased by 55.32 percent over time, while poor green vegetation increased by 38.93 percent, according to subset B's results. The anticipated outcomes are shown by the observed results. There was a 3.71% increase in the amount of poor green vegetation from 1986/87 to 2001/02. Contrast this with subset A, which maintained its percentage throughout the entire time frame (see Table 8). Also, between 1986/87 and 2001/02, the majority of the changes that caused the total loss of vegetation (35.22 percent) occurred. In contrast, subset A encompasses the years 1967–1986–1987. Please refer to Tables 7 and 8.

Table 8: Vegetation change results for subset B

Classes	**Area (km^2) in 1967**	**Area (km^2) in 1986/87**	**Area (km^2) in 2001/02**	**% change 1967 – 1986/87**	**% change 1986 – 2001/02**	**Total % Change**
Green vegetation	244.00	169.78	109.02	30.42	35.79	55.32
poor green vegetation	66.15	88.61	91.90	-33.95	-3.71	-38.93
Total vegetation	**310.15**	**258.39**	**200.92**	**16.69**	**22.24**	**35.22**

From 1967 to 1986/87, the most common year for subset C's loss of green vegetation, followed a pattern similar to that of subset A. Subset C showed a reduction of 34.46%. (see Table 9). From 1986–1987 to 2001–2002, there was a 17.77 percent increase in the amount of low-green vegetation. On the other hand, a decline of 5.57% occurred during the same time frame. The outcomes in this subset are identical to those in subset A. Take a look at Table 9. Based on the information provided, it appears that certain factors impact both subsets (A and C). The outcomes might be impacted by these variables. Compared to subsets A and B, the total loss of vegetation in subset C was 14.76 percent, according to the analysis. The years 1986–1987 and 2001–2002 saw the bulk of this decline.

Table 9: Vegetation change results for subset C

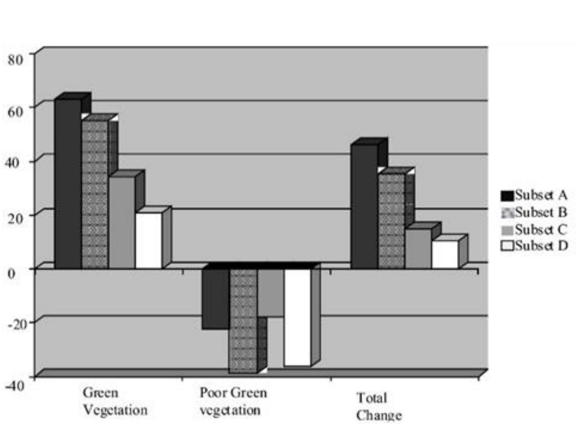
Classes	Area (km^2) in1967	Area (km^2) in 1986/87	Area (km^2) in 2001/02	% change 1967 – 1986/87	% change 1986 – 2001/02	Total % Change
green vegetation	228.75	178.08	149.92	22.15	15.81	34.46
poor green vegetation	138.53	172.76	163.14	-24.71	5.57	-17.77
Total vegetation	**367.28**	**350.84**	**313.06**	**4.48**	**10.77**	**14.76**

The amount of verdant vegetation also decreased gradually in subset D. To be more specific, there was a decline of 20.87 percent, from 16.69 percent in 1967 to 4.71 percent between 1986/87 and 2001/02, in the percentage of variation (see Table 10). Both subsets D and B shared many commonalities. Over time, the proportion of less vibrant plants rose to 36.27 percent (see Table 10). The overall loss of vegetation was 10.31%, significantly lower than the losses observed in subsets A and B.

Table 10: Vegetation change results for subset D

Classes	Area (km^2) in1967	Area (km^2) in 1986/87	Area (km^2) in 2001/02	% change 1967 – 1986/87	% change 1986 – 2001/02	Total % Change
green vegetation	535.91	445.03	424.06	16.69	4.71	20.87
poor green vegetation	121.55	156.78	165.64	-28.98	-5.65	-36.27
Total vegetation	**657.46**	**601.81**	**589.70**	**8.46**	**2.01**	**10.31**

From 1986–1987 to 2001–2002, there was a discernible decline in the quantity of poor green vegetation in subsets A and C. Across all subsets, this pattern stood out: lower quality green vegetation and less overall green vegetation. Not only that, but the intriguing discovery that subsets D and S, which lack gas flaring sites, have a substantially lower percentage change warrants your attention. You can see the percentage changes in vegetation across all subsets in Figure 21, which is a graph.



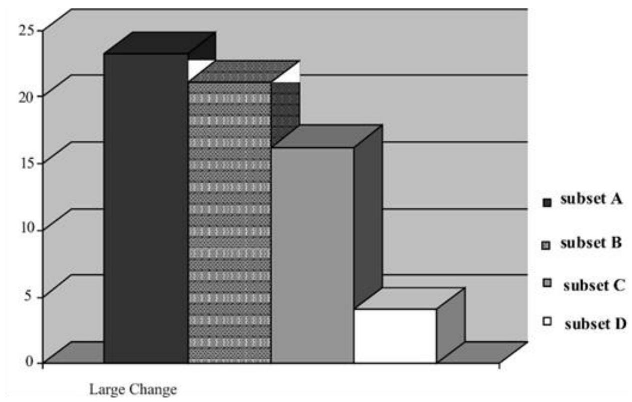
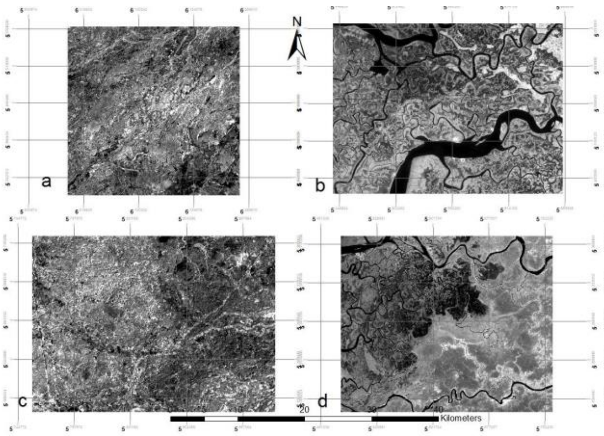


Figure 21: Percentage changes in vegetation Figure 22: Percentage changes in egetation over time for subsets A to D index over time for subsets A to D

NDVI of Landsat images

Images of the normalized difference vegetation index (NDVI) for each subset (A to D) of the two separate time series of Landsat images can be found in Figures 23 and 24, respectively. Data from the vegetation index from 1986–1987 to 2001–02 are displayed in Table 11. With the area measured in square kilometers, it also provides the percentage change. According to the study's findings, the disputed modifications do not significantly impact the analysis and dynamics of land cover. Things that are changing very little are therefore not given much attention.



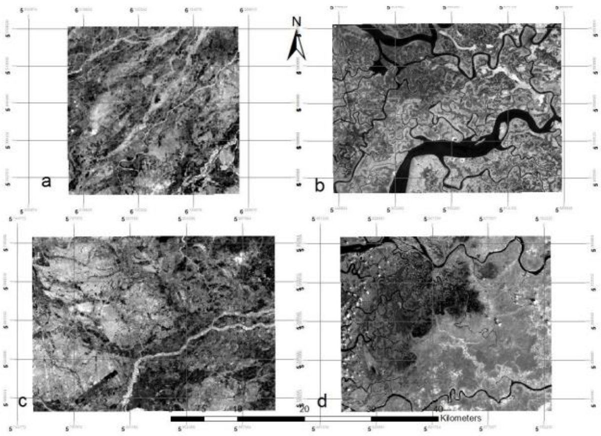


Figure 23: NDVI images of 1986/87 Figure 24: NDVI images of 2001/02 (a: Subset A b: Subset B c: Subset C d: Subset D) (a: Subset A, b: Subset B, c: Subset C, d: Subset D)

Subset A, which comprises seven gas flaring sites, experienced the most significant change in vegetation index, measuring 23.21%, due to the increased urban population. Subset D, consisting of a single small urban area devoid of gas flaring sites, exhibited a significantly lower level of vegetation index variation, clocking in at 4.11 percent. Subsets B and C's vegetation index showed very large percentage changes. There was a 21.13% change in Subset B and a 16.23% change in Subset C. (see Table 11). Figure 22 and Figure 25 both provide visual representations of the alterations.

Changes in NDVI images

Table 11: NDVI change results for subsets A – D

	Subset A		**Subset B**		**Subset C**		**Subset D**	
Classes	**Area**	**%**	**Area**	**%**	**Area**	**%**	**Area**	**%**
	km²	**Change**	**km²**	**Change**	**km²**	**Change**	**km²**	**Change**
	(1986/87		**(1986/87**		**(1986/87**		**(1986/87**	
	-		**-**		**-**		**-**	
	2001/02)		**2001/02)**		**2001/02)**		**2001/02)**	
no change	245.50	**29.60**	134.97	**21.19**	165.77	**36.79**	376.32	**45.96**
small change	391.34	**47.19**	230.51	**49.75**	218.03	**46.98**	408.89	**49.93**
large change	192.52	**23.21**	97.89	**21.13**	80.34	**16.23**	33.64	**4.11**

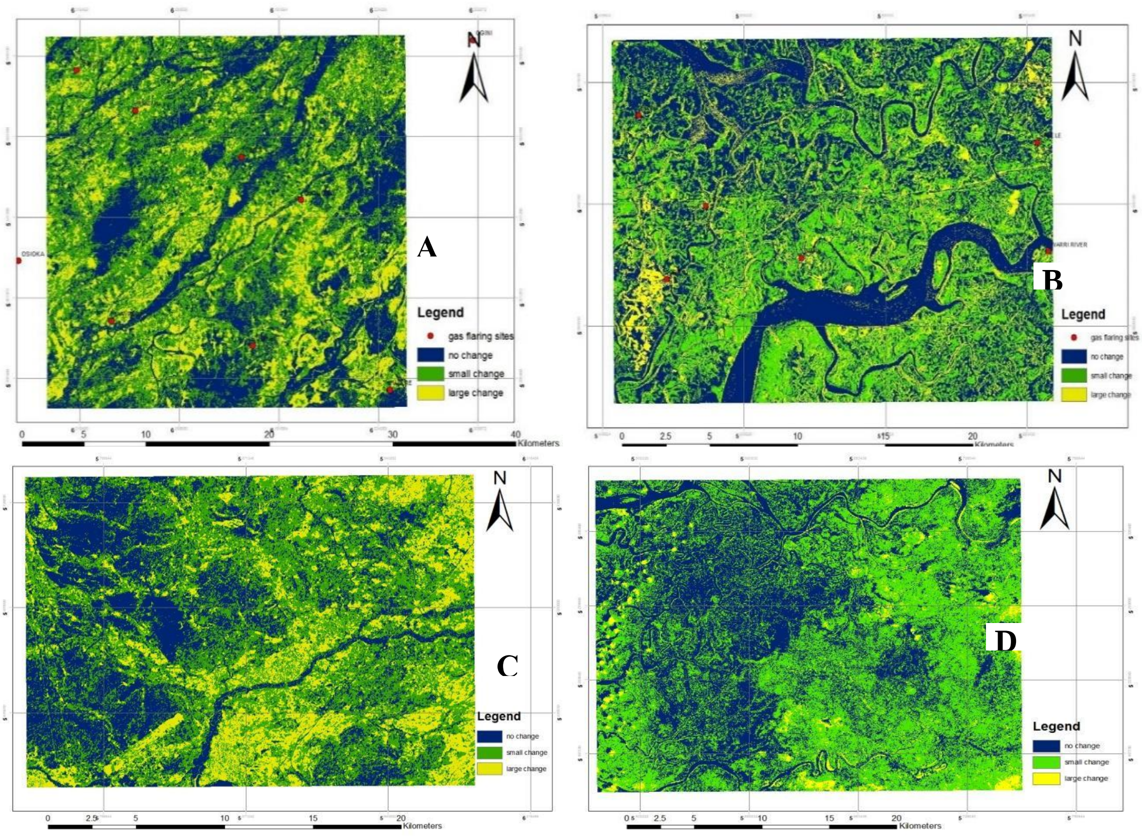


Figure 25: Difference NDVI images of 1986/87 from 2001/02 of the four subsets (A – D) showing area of changes

Discussions

Here, the researcher will discuss the findings obtained through applying research procedures. The researcher will discuss the ramifications of such outcomes and different elements that might have affected outcomes yet excluded from research techniques.

Changes in green vegetation

From the study results, most land cover types experienced significant changes over time in each of the subgroups examined. One noteworthy similarity among subsets was a progressive decrease in green vegetation, demonstrating the massive loss of the Niger Delta's important forest and the district's vulnerability to unfavorable climate changes, as suggested by some scientists (Akinro et al., 2008; Uyigue and Agho 2007).

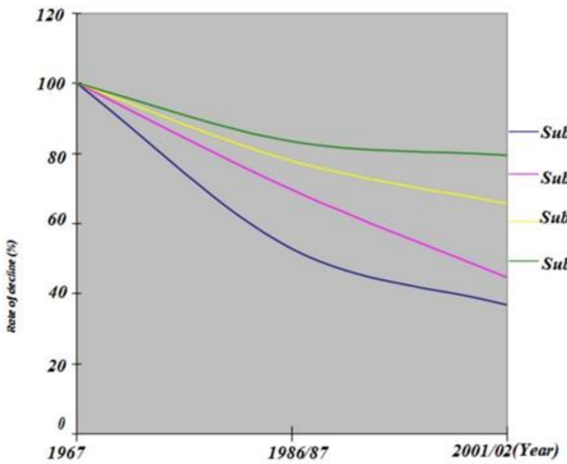


Figure 26: Rate of decline in green vegetation for all subsets

The performance decline could have occurred for a number of different reasons. Subsets A and B, which had gas flaring sites, had percentage changes of 63.32 and 55.32 percent, respectively; subset D, which did not, had percentage changes of 20.87 percent; for details, see Table 7-10 and Figure 36. These kinds of discoveries prove that gas flaring is one of the main reasons why the vast natural forests that formerly covered the Niger Delta region are disappearing. Looking at how the various subsets fared after modifying natural vegetation and man-made features lends credence to these assertions. Despite subset B having fewer man-made features, data analysis revealed that the amount of green vegetation consistently decreased in subset A. This indicates that green vegetation is relatively unaffected by urbanization and other man-made variables. Another important component influencing the general state of verdant vegetation is gas flaring, which impacts both categories. Isichei and Sanford (1976) found that gas flares caused plants to have significantly less chlorophyll. This finding supports their claim.

Factors influencing the degree of gas flaring impacts on green vegetation

The differences in percentage change of decline in green vegetation between time series of subset A and subset B could be influenced by several factors. Two major factors are: the year of commissioning of gas flaring sites (the length of gas flaring at site) and the volume of gas flared from these sites. Most of the gas flaring sites in subset A were commissioned as early as 1965 while that of subset B were commissioned after 1971 (see Table 12). This could influence the change in green vegetation as land cover types in subset A have been subjected to the effects of gas flaring earlier than land cover types in subset B.

Table 12: Name of gas flaring sites and year commissioned in subset A and B

Subset A	Year commissioned	Location
Olomoro	1965	Land
Uzere	1965	Land
Afiesere	1968	Land
Eriemu	1969	Land
Evwreni	1969	Land
Oroni	1970	Land
Oweh	Nil	Land
Subset B	**Year commissioned**	**Location**
Egwa 1	1971	Swamp
Batan	1971	Swamp
Odidi 1	1971	Swamp
Warri river	1971	Swamp
Rapele	1972	Swamp
Egwa 2	1974	Swamp

The quantity of flared gas is an additional critical component that influences the severity of the effects, in addition to the previously mentioned factors. From 1965 to 2002, the amount of gas flared each year is depicted in Figure 27. Tables 1 and 2 show that the amount of flared gas has grown significantly from 2.73 billion cubic meters in 1965 to 24.84 billion cubic meters in 2002. One million cubic meters is equal to one million cubic meters. Figure 28 shows that between 1965 and 1987, 1988 and 2002, flared volumes increased by 357.50 BCM. The mass is 317.02 bcm. This may explain why subset B had a more pronounced decline in greenery from 1986/87 to 2001/02, even when the intervening twenty years are ignored. Examine Table 8. This is true despite the fact that the period between 1986–1987 and 2001–2002 spanned only fifteen years. This may teach us that the flared gas might change the result in unexpected ways.

It is still too soon to conclude that the quantity of flared gas did not play a significant role, even though subset A's results did not align with subset B's pattern of vegetation loss (refer to Tables 7 and 8). Subset A factors, including population growth, farming, and the early start-up of gas flaring sites, may also contribute to changes in green vegetation, which is another explanation for this. In addition, studies conducted by Abdulkareem in 2005 demonstrated that ground-level pollution increases in direct correlation with flared gas volumes. This demonstrates that the quantity of flared gas determines the effect of gas flaring. Using the amount of gas flared from each installation separately would have been more appropriate for the purpose of analysis. Regrettably, due to data accessibility issues, the quantity of flared gas from various locations could not be shared for research purposes. Still, evidence from studies, government statistics on flaring gas, and other sources suggests that the area of flaring significantly affects the severity of the effects. However, in order to offer solid proof for this assertion, additional research is required.

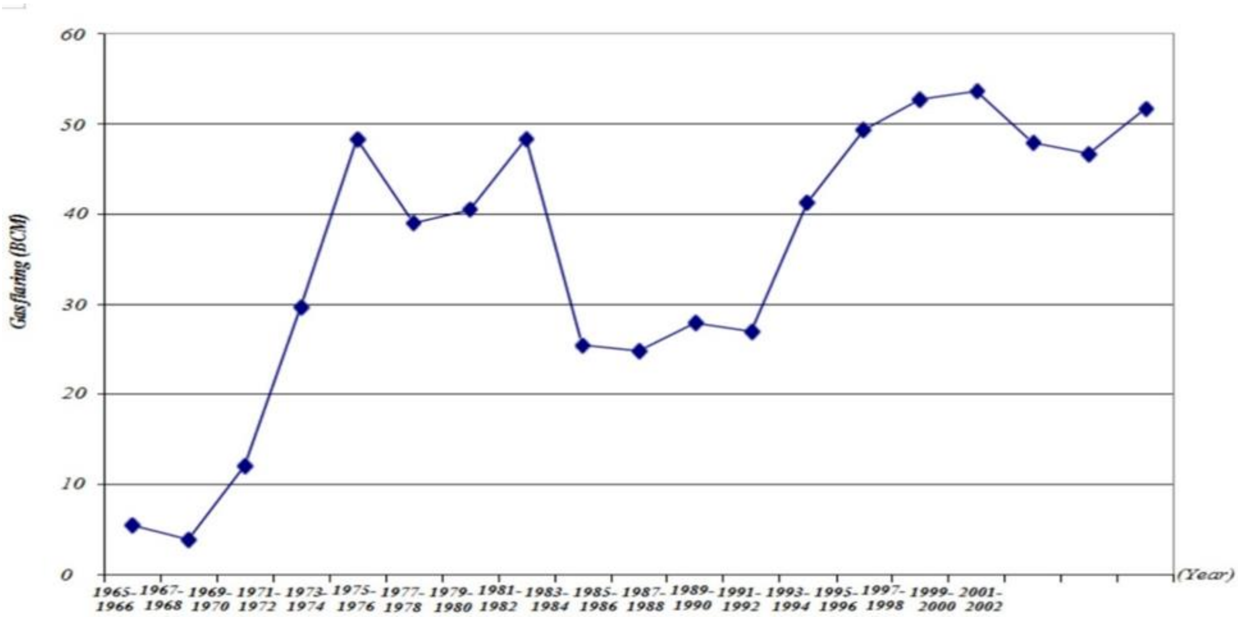
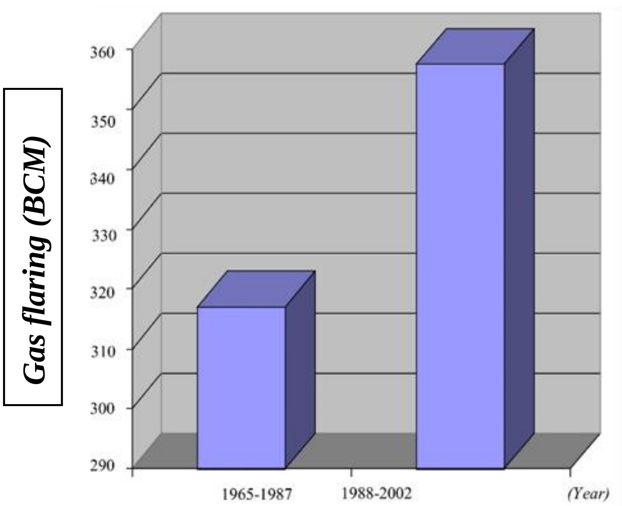


Figure 27: Increases and decreases of gas flaring volumes from 1965 – 2002



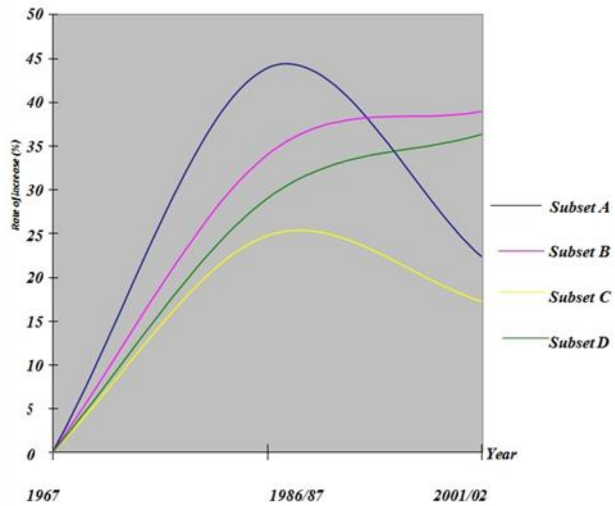


Figure 28: Increases in the amount of Figure 29: Rate of increase in poor gas flaring volumes over time green vegetation for all subsets

Poor green vegetation changes.

Poor green vegetation expanded after some time, with increments more significant in subgroups B and D, unlike the reduction in green vegetation observed in all subsets. The example of changes seen in helpless green plants is vividly depicted in Figure 29. Poor green vegetation indicates optional or helpless developing vegetation, as mentioned in part 3. Auxiliary vegetation is defined as regrowth after exacerbating the typical vegetation, which has few species in its overhangs and shows little floristic differentiation (Chokkalingam and Jong, 2001). A progression of optional vegetation recovers due to the decrease of green vegetation, which is the normal timberland of the Niger Delta locale. This may be seen in results between 1967 and 1986/87, where a synchronized drop in green vegetation coincided with an increase in helpless green vegetation (see Table 7 - 8 and Figures 26 - 29).

These findings are similar to those of Uyigue and Agho (2007), who discovered that there are more bushes and grass in some parts of the Niger Delta, indicating a lack of regular woodland. In this way, results obtained between 1967 and 1986/87 could very well indicate that Gas flaring contributes to the spread of poor green vegetation, considering how a drop in green vegetation leads to the development of alternative vegetation. However, unlike the steady rate fall in green vegetation, the poor green vegetation results exhibited both increases and decreases. Between 1986/87 and 2001/02, there was a gradual expansion in helpless green vegetation for subsets B and D (see Table 8 and 10 and Figure 29), but a decline for subgroup An and C (see Table 8 and 8 and Figure 29). (See Table 7 and 9 and Figure 29). The rapid expansion in artificial elements of roughly 123 per cent for subset An and a half for subset C between 1986/87 and 2001/02 (see Tables 10 and 12) is common to both subsets (An and C), coinciding with a decrease in helpless green vegetation. This indicates that gas flaring is not the primary cause of changes in poor green vegetation. Other anthropogenic influences, such as urbanization and agriculture, may be reliable.

Furthermore, given that the two subsets represent provincial regions, the steady expansion in poor green vegetation between 1986/87 and 2001/02 for subsets B and D could be attributed to distinct elements, similar to the increase in farmlands (farmlands are more in-country regions than metropolitan regions). Reasons can also be inferred from the fact that subgroup B, which had Gas flaring destinations, had a lower rate increment of 3.71 per cent than subset D, indicating that Gas flaring may be affecting crop development. Given the differences in the rate of increments seen in poor green vegetation between periods, this hypothesis requires additional investigation.

In summary, rate changes for all-out vegetation in subsets An and B (46.19 percent and 35.22 percent, respectively) were essentially not the same as rate changes in subsets C and D (14.76 percent and 10.31 percent, respectively) (see figure 21), further entangling Gas flaring as a legitimate goal for vegetation changes. The level of massive alterations in the vegetation list was higher in subsets with Gas flaring locations (subset A: 23.21 percent and subset B: 21.13 percent) than in subsets without Gas flaring locales (subset C: 17.31 percent and subset D: 4.11 percent), according to NDVI results (see Table 11). These findings support the theory that Gas flaring causes vegetation alterations, presented by several analysts (Odjugo and Osemwenkhae 2009; Uyigue and Agho 2007). The method that Gasses flaring is believed to generate vaporous contaminations such CO_2, CO, NO, NO_2, and SO_2 (Sonibare and Akeredolu 2004), and cancer-causing outcomes like anthracene and benzo(a)pyrene could be attributed to the changes in vegetation as a result of Gas flaring (Sonibare and Akeredolu 2004). (Leahey et al., 2001). It has also been blamed for the increased temperature in the entire Niger Delta district by Akinro et al. (2008). Furthermore, it has been discovered to raise surface and soil temperatures (Odjugo, and Osemwenkhae, 2009; Oseji, 2007). According to the findings, the offer increase in bare soil was more significant in subgroups with Gas flaring locations (see Table 10 and 11). This supports the findings of Isichei and Sanford (1976), who suggested that Gas flaring causes soil to dry out due to increased soil temperatures. These discoveries have severe implications for the residents of the area and the climate in general. Wood fuel used for community energy generation by the people of the area would currently not be readily available, monetary yields would be reduced, and ranch property would be rendered useless for crop production, resulting in financial trouble. Aside from the effects on residents, the Niger Delta's biodiversity, which includes a variety of land-based and sea-based vegetation endemic to this region, is under jeopardy (Ugochukwu and Ertel 2008).

Other variables influencing vegetation change

Although research reveals that gas flaring has a significant impact on vegetation changes, other factors, such as different types of oil and gas exploration exercises, may have contributed to the vegetation changes observed in each of the four subsets. Below are the elements that have been recorded:

• **Urbanization and agrarian practices:** Urbanization and population growth are usually linked.

Aside from expanding regular segment development, Delta State, as Nigeria's largest oil-producing state (Inoni et al., 2006), has attracted people from all across the country, resulting in population growth and, as a result, increased urbanization. According to estimates, Delta State's metropolitan population grew by more than 75 per cent between 1962 and the mid-1980s (Achi, 2006). Because of the rapid urbanization, vegetation has changed for wood fuel, accommodation, transit, modern, and agriculture uses. Furthermore, the lack of adequate environmental assurance rules has resulted in immature farming methods like deforestation and shrubbery consumption (Nwajiuba, 2008). The rate of decrease in green vegetation was higher in subset A (63.32 per cent) when compared to subset B (55.32 per cent) (subsets with Gas flaring destinations) and higher in subset C (34.46 per cent) when compared to subset D (20.87 per cent) (subsets without Gas flaring locales), according to research findings (see Table 7 - 10 and Figure 26). As previously stated, metropolitan advancements are a feature common to both subsets An and C, although it is absent from subsets B and D. These findings suggest that urbanization plays only a modest role in the loss of green vegetation. Additional proof can be found in the deterioration of helpless green vegetation in subsets An and C when the two subsets' artificial elements were rapidly expanding (see Table 10 and 12). This decline in helpless green vegetation occurred at a faster rate in subset A (15%) than in subset C (5.57%). (See Table 7 and 9). The fact that subset A had the most significant increase in the level of artificial highlights of roughly 123 per cent compared to subset C's increase of around half could explain such a conclusion. These findings support Madu's (2009) findings that the more the population density and metropolitan population increase, the more significant the negative ecological impact.

• **Oil spillage:** The oil spill is one of the key factors contributing to the change in vegetation cover in Delta state. It usually occurs due to inadvertent or deliberate damage to pipelines or oil offices (UNDP, 2006). As a result, oil spills into surrounding vegetation/farmlands, streams, and waterways, used as a means of livelihood and drinking water for neighboring residents. The United Nations Development Program (UNDP) estimates that 6,817 oil slicks occurred between 1976 and 2001, resulting in an estimated loss of 3,000,000 barrels (UNDP, 2006). This amounts to 262 occurrences every year, spilling over 115,000 barrels of oil, with roughly 6% ashore, 25% on the swamp, and 69 per cent in a seaward climate (UNDP, 2006; Sterner, 2010). The degradation of oil pipelines, hopeless upkeep of frameworks, functional activities, human error, and injury are the primary drivers of oil slicks in the Niger Delta (Amnesty International, 2009). Oil spills have far-reaching consequences. They range from soil ripeness loss, water contamination, the extinction of sea-going species, and a decline like human well-being to vegetation degradation (Amnesty International, 2009; Sterner, 2010). According to research conducted by Osuji et al. in 2004, oil leakage is responsible for a drop in the number and species variety of plant cover in the Agbada west plain of the Niger Delta area.

Table 13 shows a few records of oil spills in the Niger Delta, including two significant slicks (the Funiwa oil well victory in 1980 and the Delta State 28-year-old trunk oil pipeline leakage at Jones Creek in 1998), which resulted in the obliteration of the world's most famous mangrove timberland (UNDP, 2006). The impact of an oil spill can be felt across vast areas. The Jones spring oil spill, for example, was felt across more than 34 networks (Gabriel, 2004). Although oil spillage incidents in Delta State away from Ughelli are not included in any of our subsets (A - D), the fact that their effects can be felt across large areas makes oil spillage a significant factor that may have influenced vegetation change.

Table 13: Some oil spills records in the Niger Delta

State	Date	Episode	Quantity in barrels
Akwa Ibom	Jan,1998	Idoho oil spill	40,000
Bayelsa	Feb,1995	Ogoda-Brass Pipeline Oil spillage	24,000
Bayelsa	May,2000	Etima oil spill	11,000
Delta	*July,1979*	*Forcadosterminal oil spillage*	*570,000*
Delta	*July,1984*	*Ughelii oil spill*	*Unknown*
Delta	*March,1998*	*Jones Creek*	*21,548*
Delta	*Oct, 1998*	*Jesse oil spill*	*10,000*
Delta	*August,2005*	*Ughelli oil spill*	*10,000*
Edo	Nov,1982	System2cWarri-KadunapipelinerupturеatAbudu	18,000
Ondo	August,2004	Ewan oil spill	Unknown
Rivers	July,1970	Bomu field blow out	Unknown
Rivers	1972	Safram (now ELF) Obagi21oilfield blowout	Unknown
Rivers	Jan,1980	Funiwa No. 5well blowout	400,000
Rivers	May,1980	Oyakama oil spillage	10,000
Rivers	August,1983	Oshika oil spill	10,000
Rivers	1997	Ebubu oil spill	3,000
Rivers	Dec,2003	Aghada oil spill	Unknown

• **Anti socio-economic activities:** Pipeline vandalism, oil robbery, illegal refining, and bunkering all hurt the climate. These anti-financial activities are prompted by financial problems, inextricably linked to poverty (Uyigue and Agho 2007). According to the UNDP, poverty should be measured regarding access to health care, water, education, business, and other necessities (UNDP, 2006). Delta State's poverty rate was 19.8% in 1980, but it increased to 45.35 per cent in 2000. (National Bureau of Statistics, 2005). This means that the increasing population of people are losing access to necessities due to the abolition of their traditional working model. For the sake of adaptation and endurance, the residents of the area, notably the youth, are now participating in the aforementioned financial activities, which have resulted in more climate obliteration (Odoemene, 2011). Pipeline vandalism, oil theft, and illegal bunkering are all linked to oil spills and fires, causing environmental damage, contamination, and revenue loss for the Nigerian government (Uyigue and Agho 2007). The NNPC's annual factual report shows that pipeline vandalism has increased rapidly over the years, from 500 instances in 1999 to more than 2000 cases in 2008. (NNPC, 2008). Although no narrative proof of the natural impact of illegal refining has been written yet, news stories and aerial images have demonstrated the apparent effects on the surrounding vegetation (Nossiter, 2010; Purefoy, 2010).

• **Mining exercises:** While Gas flaring and oil spills are the most commonly cited causes of vegetation depletion, other oil and gas exploration activities such as effluent release and penetrating digging (drilling) create substantial ecological impact. If not adequately treated, effluent outflows, also known as formation water, contain oil, heavy metals, and possibly damaging synthetics, and have been reported to cause contamination and ecological corruption when released into the environment (Obire and Amusan 2003). Unfortunately, since the 1950s, when raw petroleum extraction began in Nigeria, arrangement water has been dumped into the environment without proper treatment by most international oil companies (Amnesty International, 2009). Drilling activities generate a large amount of waste and mud, routinely disposed of carelessly (Amnesty International, 2009). More debris is delivered as dug ruins due to digging, which includes the evacuation of silt, soil, and vegetation (Ohimain et al., 2008). This haphazard disposal of drilling trash and dig crown jewels can also twist and change the geology and hydrology of the site (Ohimain, 2003; Ohimain et al., 2008). Ruins that have been dug can prompt the adjustment of soil conditions, prompting fermentation which can harm vegetation. Likewise, the immediate removal of dig ruins on mangroves can prompt their deficiency of oxygen(asphyxiation), thus prompting the passing of vegetation cover (Ohimain, 2003). Boring and excavating have been ongoing since the raw petroleum was discovered in Nigeria, much like the gushing. Although its impact on local hydrology is currently being studied (Ohimain et al., 2008), the number of mangrove trees may have been obliterated for an extended period due to lack of oxygen or fermentation-related effects could be significant.

• **Corrosive downpour/ Acid rain:** Acid rain is caused by ozone-depleting chemicals such as carbon dioxide, nitrogen oxides and sulfur dioxide, which react with water particles in the atmosphere to produce acids. Corrosive rain can have severe consequences for biodiversity and artificial items with metallic surfaces (Akinro et al., 2008). Its sharpness lowers the pH of the soil, prompting the emptying of soil supplements (Singh et al., 2008). It is impossible to talk about corrosive rains in the Niger Delta without mentioning gas flaring. This is because multiple examinations and investigations have identified Gas flaring as one of the major causes of corrosive rain in the area (Ekpoh and Obia 2010; Leahey et al., 2001; Sonibare and Akeredolu, 2004). As previously mentioned, Gas flaring releases ozone-depleting compounds such as CH4, NO2, CO2, and SO2 into the atmosphere (Dung et al., 2008; Obioh et al., 1994), with the World Bank estimates that Nigeria's gas flares emit roughly 10% of global CO2 (World Bank, 2002). When combined with Gas flaring, unrefined or adjacent agrarian practices, vehicle exhaust, current emanations, and forest fires, an exceptional amount of CO2 is produced, contributing to the development of corrosive rain (Ekpoh and Obia 2010). Horticulture is the most notable patron, accounting for 40% of CO2 emissions, while Gas flaring accounts for 30%. (Nwajiuba, 2008).

CONCLUSION

This research has uncovered GIS's capabilities in assessing the impact of changing environmental conditions throughout time. It looked at the CORONA data's high spatial resolution in identifying land cover types since the 1960s to fully assess the number of changes that have occurred over time as a result of gas flaring. The CORONA data focused on regions with dense vegetation and less exposed land however when compared to Landsat data from the exact review location, huge differences were observed. This resulted from studies that revealed a rapid decline in Delta State's natural forest. According to a previous study by Onojeghuo and Blackburn (2011), Delta State, among other Niger Delta states, had the worst misfortune in terms of vegetation cover, with a massive shortage of 469,731has, accounting for 8% of the district. The findings also revealed that Gas flaring is a significant factor contributing to the state's rich forest's decline. According to the findings, numerous variables such as the season of dispatching of Gas flaring locations and the volume of Gas ejected can determine the magnitude of gas flaring effects. The analysis also revealed that due to Gas flaring and other anthropogenic variables, the review region's natural mangrove and tropical rainforest quickly devolved into determined savannah.

REFERENCES

1. Abdulkareem, A. S. (2005). Evaluation of ground-level concentration of pollutant due to gas flaring by computer simulation: A case study of Niger-Delta area of Nigeria. *Leonardo Electronic Journal of Practices and Technologies*.6:29-42.
2. Aghalino, S. O. (2009). Gas flaring, environmental pollution and abatement measures in Nigeria,1969 –2001. *Journal of Sustainable Development in Africa*.11(4):219–238.
3. Akinro, A. O., Opeyemi, D.A. and Ologunagba, I.B. (2008). Climate change and environmental degradation in the Niger Delta region of Nigeria: Its vulnerability, impacts and possible mitigations.*ResearchJournalofAppliedSciences*.3(3):167–173.
4. Amnesty International, (2009). Nigeria: Petroleum, pollution and poverty in the Niger Delta.AFR44/017/2009.
5. Andersen, G. L. (2006). How to detect desert trees using CORON Aimages: Discovering historical ecological data. *Journal of Arid Environments*.65:491–511.
6. Arimoro, A. O., Fagbeja, M. A. and Eedy, W. (2002). The need and use of Geographic Information Systems for Environmental Impact Assessment in Africa: with an example from ten years' experience in Nigeria. *African Journal of Environmental Assessment and Management*.4(2):16-27.
7. Ashton, N.J., Arnott, S., and Douglas, O. (1999). The human ecosystems of the Niger Delta—anera hand book. Environmental Rights Action, Lagos.
8. Chokkalingam U. And Jong, W. D. (2001).Secondary forest: a working definition and typology. *InternationalForestryReview*.3 (1):19–26.
9. Civil Liberties Organization(2001).*Blood Trail*. Lagos: Unilag Press.
10. Delta State Government (2004). Facts Behind the Figures, 1999–2004. Available at http://www.deltastate.gov.ng/FBF/(visitedlaston18/06/11).
11. Dung, J. E., Bombom, S. L. and Agusomu, D. T. (2008). The effects of gas flaring on crops in the NigerDelta, Nigeria. *GeoJournal*.73:297–305.
12. Dupont, M. L., Jahns, S., Marret, F. and Ning, S. (2000). Vegetation change in equatorial West Africa: Time-slices for the last 150ka. *Palaeogeography*, *Palaeoclimatology Palaeoecology*. 155:95–122.
13. Edino, M. O., Nsofor, G. N. and Bombom, S. L. (2010). Perceptions and attitudes towards gas flaring in the Niger Delta, Nigeria. *Environmentalist*.30:67–75.
14. Eedy, W. (1995). "The use of GIS in environmental assessment". *Impact Assessment*. 13: 199- 206.
15. Efe, S. I. (2006). Quality of rain water harvesting for rural communities of Delta State, Nigeria. *Environmentalist.* 26:175-181.
16. Ekpoh, I. J. and Obia, A. E. (2010). The role of gas flaring in the rapid corrosion of zinc roofs in the NigerDelta Region of Nigeria. *Environmentalist*.30:347–352.
17. Elvidge, D. C., Ziskin, D., Baugh K. E., Tuttle, T.B., Ghosh, T., Pack, W. D., Erwin, H. E. and Zhizhin,
18. M. A. (2009). Fifteen-Year Record of Global Natural Gas Flaring Derived from Satellite Data. *Energies*.2:595-622.
19. Federal Office of Statistics. (1995).Annual Abstract of Statistics. Federal Office of Statistics, Lagos. Forestry Management, Evaluation, and Co-Ordinating Unit

[*Nigeria*](FORMECU).(1995).

20. Gabriel, A. O.I.(2004).Women in the Niger Delta: Environmental issues and challenges in the third millennium. *Journal of Sustainable Development in Africa*. Available at http://www.jsdafrica.com/Jsda/Fall2004/women%20in%20the%20niger%20delta.pdf(visitedlaston05/08/11).
21. Gerner, F., Svensson, B. and Djumena, S. (2004). Gas flaring and venting: A regulatory frame work and incentives for gas utilization. *Public Policy for thePrivateSector*.279
22. Gerth J. and Labaton, L.(2004).Shell with held reservesdatainNigeria.NewYorkTimes,19Mar
23. González, A., Gilmer, A., Foley, R., Sweeney, J. and Fry, J. (2010). Applying geographic information systems to support strategic environmental assessment: Opportunities and Limitations in the contex to fIrish land-use plans. *Environmental Impact Assessment Review*.14p.
24. Grosse, G., Schirrmeister, L, Kunitsky, V. V. and Hubberten, H. W. (2005). The use ofCORONA images in Remote Sensing of periglacial geomorphology: An illustration from the NE Siberian coast. *Permafrost andPeriglacialProcesses*.16:163– 172.
25. ICF (2006). *Nigeria: Guidebook for Carbon Credit Development for Flare Reduction Projects.*International.June2006.
26. Inoni, E. O.,Omotor, G. D., and Adun, N. F.(2006).The effect of oil spillage on crop yield and farm income in Delta State, Nigeria. *Journal of Central European Agriculture*.7(1):41– 48.
27. Ipingbemi, O. (2009). Socio-economic implications and environmental effects of oil spillage in some communities in the Niger delta. *Journal of Integrative Environmental Sciences*. 6(1):7-23.
28. Ishisone, M.(2004).Gas Flaring in the Niger Delta: the Potential Benefits of its Reduction on the Local Economy and Environment. Available at http://socrates.berkely.edu/es196/projects/2004final/ishisone.pdf (visitedlaston27/05/11).
29. Isichei, O. A. and Sanford, W. W.(1976).The Effects of waste gas flares on the surrounding vegetation in south eastern Nigeria. *Journal of Applied Ecology*.13(1):177-187.
30. Leahey, D. M., Preston, K. and Strosher, M.(2001).Theoretical and observational assessments of flare efficiencies. *Journal for Air Waste Management Association*. 51 (12): 1610–1616.
31. Madu,I.A.(2009).The impacts of anthropogenic factors on the environment in Nigeria. *Journal ofEnvironmental Management*.30:1422–1426.
32. Malumfashi, G. I. (2007). Phase-out of gas flaring in Nigeria by 2008: The prospect of a multi- win project(Review of the Regulatory, Environmental and Socio-Economic Issues).*Nig Gas Flaring Petroleum Training Journal(PTJ)*1.4No.2.
33. National Bureau of Statistics/Federal Office of Statistics(2005).Report of Nigeria Living Standard Survey2003/2005,Abuja.
34. National Space Research and Development Agency *[Nigeria]* (NASRDA) 2005.
35. Nduka, J. K. C.,Orisakwe, O. E.,Ezenweke, L. O., Ezenwa, T. E., Chendo, M. N. and Ezeabasili, N.G. (2008). Acid rain phenomenon in Niger Delta region of Nigeria: Economic, biodiversity, and public health concern. *The Scientific World Journal*. 8:811–

818.

36. Nigerian National Petroleum Corporation(NNPC).(2008). *Annual Statistical Bulletin*. Corporate Planning and Development Division(CPDD). January–December 2008.
37. Nigerian National Petroleum Corporation(NNPC).(2009).*Annual Statistical Bulletin*. Corporate Planning and Development Division (CPDD). January–December2009.
38. Nigerian Population Commission (2010). Available at http://www.population.gov.ng/index.php (visitedlaston21/02/11).
39. Nossiter, A. (2010). Far From Gulf, a Spills courage 5 Decades Old. *New York Times*.16th June 2010. Available at http://agriculturedefensecoalition.org/sites/default/files/pdfs/10X_2010.pdf(visited laston08/08/11).
40. Nwajiuba, C. U. (2008). Adapting to climate change: Challenges and opportunities. In Doppler, Wand Bauer,S(eds). *Farming & Rural Systems Economics*.Pp1–6.
41. Nwankwo, C. N., Ogagarue, D.O. (2011). Effects of gas flaring on surface and ground waters in Delta State Nigeria. Journal of Geology and Mining research 3 (5), 131-136
42. Obioh, I. B.,Oluwole,A.F.,Akeredolu,F.A.(1994).Non-CO2 gaseous emissions from upstream oil and gas operations in Nigeria. *Environmental Monitoring and Assessment*.31:67–72.
43. Obire, O and Amusan, F.O.(2003).The Environmental impact of oil field formation water on a fresh water stream in Nigeria. *Journal of Applied Sciences & Environmental Management*. 7(1):61–66.
44. Odjugo,P. A. and Osemwenkhae, E.J.(2009).Natural gas flaring affects micro climate and reduces maize (Zea mays) yield. *International Journal of Agriculture and Biology*. 11(4):408–412.
45. Odoemene,A.(2011).Social consequences of environmental change in the Niger Delta of Nigeria. *Journal of Sustainable Development.* 4(2):123–135.
46. Odukoya, O. A.(2006).Oil and sustainable development in Nigeria: A case study of the Niger Delta. *J. Hum. Ecol*.20(4):249-258.
47. Ohimain, E. I. (2003). Environmental impacts of oil mining activities in the Niger Delta.
48. Man groveeco system. *8th International Congress on Mine Water & the Environment, Johannesburg, South Africa*.8:503–517.
49. Ohimain, E. I., Imoobe, T. O. and Bawo, D. D. S. (2008). Changes in water physicochemical properties following the dredging of an oil well access canal in the Niger Delta. *World Journal of Agricultural Sciences*. 4(6):752–758.
50. Omokaro, O. (2009).Oil and gas extraction in the Niger Delta Region of Nigeria:The social and environmental challenges. *Freiberg Online Geology*.24:13–20.
51. Onojeghuo, O. A. and Blackburn, G. A. (2011). Forest transition in an ecologically important region: Patterns and causes for landscape dynamics in the Niger Delta. *Ecological Indicators*.(11):1437– 1446.
52. Oseji,O. J. (2007).Thermal gradient in the vicinity of Kwale/Okpaigas plant, Delta state, Nigeria: Preliminary observations. *Environmentalist*.27:311–314.
53. Osuji, L. C., Adesiyan, S.O. and Obute G.C.(2004).Post-impact assessment of oil pollution in Agbada west plain of Niger Delta, Nigeria: field reconnaissance and total extractable hydrocarbon content. *Chemistry and Biodiversity*.1:1569–1578.

54. Purefoy, C.(2010). Death and oil in Niger Delta's illegal refineries. *CNN World News*. 3rd August 2010. Available at http://articles.cnn.com/2010-08-03/world/=PM:WORLD(visitedlaston08/08/11).

55. Singh A. and Agrawal M. (2008). Acid rain and its ecological consequences. *Journal on Environmental Biology*. 29(1):15-24.

56. Smit, B. and Spalding, H. (1995). Methods for cumulative effects assessment. *Environ. Impact Assess. Review*.15:81-106.

57. Sonibare, J. A. and Akeredolu, F. A. (2004). A theoretical prediction of non-methane gaseous emissions from natural gas combustion. *Energy Policy*.32:1653–1665.

58. Sonibare, J. A. and Akeredolu, F. A. (2006). Natural gas domestic market development for the total elimination of routine flares in Nigeria's upstream petroleum operations. *Energy Policy*34:743– 753.

59. Steiner, R. (2010). Double standard: Shell practices in Nigeria compared with international standards to prevent and control pipeline oil spills and the Deep-water Horizon oil spill. *Report for Friends of the Earth Netherlands.*

60. Twumasi, A. Y. and Merem, C. E. (2006). GIS and remote sensing applications in the assessment of change within a coastal environment in the Niger Delta region of Nigeria. *Int. J. Environ. Res. Public Health*.3(1):98-106.

61. Ugochukwu, C. N. C. and Ertel, J. (2008). Negative impacts of oil exploration on biodiversity management in the Niger Delta area of Nigeria. *Impact Assessment and ProjectAppraisal*.26(2):139–147.

62. Uyigue, E. & Agho, M. (2009). Community adaptation to climate change and other environmental changes in the Niger Delta region of Southern Nigeria: *Community Research and Development Centre (CREDC). IOP Conference Series: Earth and Environmental Science*.6:1–30.

63. Winter, F., Wartha, C., Hofbauer, H. (1999). NO, and NO2 formation during the combustion of wood, straw, malt waste, and peat. *Bio resource Technology*.70:39–49.

64. World Bank (1995). *Defining environmental development strategy for the Niger Delta, Volume 1.*

65. Industry and Energy Operations Division, Central Africa Department, World Bank. May1995.

66. World Bank (2002). –*Reporton Consultations with Stakeholders.”* World Bank–GGFR Report 1.

67. Global Gas Flaring Reduction Public-Private Partnership. Washington, D. C.

68. World Bank (2003).–*Kyoto Mechanism For Flaring Reduction.* “World Bank Group Report2.

69. Global Gas Flaring Reduction Public-Private Partnership. Washington, D.C.

70. World Bank (2007). *A Twelve-Year Record of National and Global Gas Flaring Volumes Estimated Using Satellite Data* Final Report. Available at http://siteresources.worldbank.org/INTGGFR/Resources/DMSP_flares_20070530_b-sm.pdf (visitedlaston23/01/11).