NIPES

Journal of Science and Technology Research

Journal homepage: www.nipesjournals.org.ng

Normalized Difference Vegetation Index (NDVI) Assessment of Vegetation Around Oben Gas Flow Station, Edo State, Nigeria

Amaechi Chika Floyd[1], Ajokpauwu Elo Ruth[1]

[1]Department of Environmental Management and Toxicology, Faculty of Life Sciences, University of Benin, Benin City, 1154, Nigeria

Article Info

***Keywords*:**
Gas Flaring, Vegetation, NDVI, GIS,

Received 17 February 2022
Revised 08 March 2022
Accepted 09 March 2022
Available online 13 March 2022

https://doi.org/10.37933/nipes/4.1.2022.25

https://nipesjournals.org.ng

Abstract

The burning of associated gas from crude oil is known as gas flaring and it is a frequent practice in Nigeria. One of the main reasons for its continued usage is the lack of an effective regulatory framework, which may be due to a lack of environmental knowledge of its consequences. This study seeks to determine the effects of gas flaring on vegetation using Oben gas flow station as a case study. The study assessed vegetation health with the use of GIS at marked distances of analyzed years. Several studies have been undertaken to highlight the environmental impact of gas flaring, but none have yet been undertaken to quantify the long-term cumulative effect on vegetation. In addition, little attempt has been made in Nigeria to assess the impact of gas flaring using GIS. This study employed the use a GIS-based change detection methodology (Normalized Difference Vegetation Index) to analyze vegetation changes over time in the study area. Three separate time series of satellite imagery of research area (Landsat 4 TM and Landsat 7 ETM 1987, 2002, 2019) were gathered to achieve this. The findings indicate that gas flaring is a substantial contributor to the study areas change in natural vegetation, where in the year 1987 vegetation was normal, the average mean was 0.62; In 2002 vegetation was very poor and affected, average mean decreased to 0.18 but slightly increased in 2019 to an average of 0.26. This study recommends that government should provide adequate funding for scientific research on gas flaring, to fully assess its impact on vegetation, biodiversity and the entire ecosystem, and develop ways of mitigation.

1. Introduction

It is an undeniable fact that exploration and exploitation of petroleum resources has huge economic gains for countries with crude oil reserves. It provides a strong base for wealth creation as well as building a sustained economy. Contrary to the economic gains, there are negative consequences associated with crude oil extraction where it is not well managed [1]. Gas flaring is one of the major environmental issues in the crude oil industry in recent times. When you drill for oil, you also get gas. In ideal situations this associated gas would be sold to consumers, or it would be used to generate power and then resold as electricity. But this requires costly investment into pipelines, power plants, and other infrastructure. Therefore, in practice, some oil producers opt to sell the oil and burn the gas [2].

Gas flaring is the burning of natural gas that is associated with crude oil when it is pumped up from the ground. Nigeria is currently the second largest gas-flaring country in the world after Russia based on recent statistics [3] [4]. According to the [5], Nigeria has proven natural gas reserves of about 163 trillion standard cubic feet, which in energy terms is substantially larger than its oil resources. Over 50% of the produced gas (mainly associated gas) was flared, as at 2001. [6] suggests that there are three main reasons why most of the associated gas produced during oil extraction is flared. Firstly, domestic demand for natural gas is not large enough to utilize all the associated gas, if recovered; secondly, the high cost of recovery of associated gas compared to non-associated gas and lastly, the inadequacy of gas infrastructure for distribution of gas to potential consumers. The threat to humans, animals and plant life posed by pollution due to gas flaring cannot be over-emphasized. The impact is of global and local concern. Flaring is a means of safely disposing of waste gases through the use of combustion [7]. It also considered as burnt of associated gas produced by oil explorers which increase carbon emission. The said emission is one of the fundamental and key problem worldwide and it significantly attract attention globally especially on the issue of global warming. So many factors could lead to increase in carbon that has tremendous effect on our society today. Researchers assert that, gas flaring is one of the major contributor that led to carbon emission. The said gas flaring is released as a result of crude oil production [8]. Today crude oil, is a major player on global energy market [8]. To meet up the persistent increase in demand, oil producing states increase their production among which Nigeria is not in isolation.

Studies has correlated gas flaring and vegetation impact, government and industry on the other hand have not been able to significantly reduce gas flaring due for varying reasons. Since the discovery of crude oil in the Niger Delta region of Nigeria, studies to assess the impacts of gas flaring on vegetation using Geography Information System (GIS) in Nigeria is insufficient. Furthermore, majority of the studies on the impacts of gas flaring on vegetation are based on public perceptions by use of questionnaires rather than scientific methodology [9]. Therefore, a more sophisticated scientific tool would be required to fully assess the impacts gas flaring has on the vegetation and land cover in areas of gas flaring sites over time. The Geographic Information System (GIS) with the aid of the Normalized Difference Vegetative Index (NDVI) is a useful tool that may help with a variety of tasks, calculating the long-term effects of gas flaring on Nigerian vegetation and land cover. The Geographic Information System (GIS) has the ability to store enormous data sets, evaluate change over time, and spot complicated patterns environmental characteristics and their interrelationships. GIS is also extremely useful in assessing the effects of gas flaring on vegetation, this is because it provides a graphical representation of the change in vegetation for easy examination thanks to its mapping and analytical capabilities, geographical interpretation of satellite photos, giving an evidence-based assessment as well as a tool for developing environmental protection. As a result, sound policy development on gas flaring will be aided [10]. This study therefore seeks to determine the temporal severity on of gas flaring on vegetation using Oben gas flow station as a case study.

2. Methodology

2.1 The Study Area

Oben is situated in Orhionmwon, Edo, Nigeria, its geographical coordinates are 5° 59' 0" North, 5° 55' 0" East and its original name (with diacritics) is Oben. The seplat gas flow station is known as OML 4 in warri and edo state. OML 4 covers an area of 267km^2. The Oben field is located in OML 4 and is the main producing field on the block. Facilities on the block include a 60,000bopd capacity flow station, a 465 MMscfd capacity non-associated gas processing plant and an associated gas compressor station with five 10 MMscfdassociated gas (‘AG’) compressors.

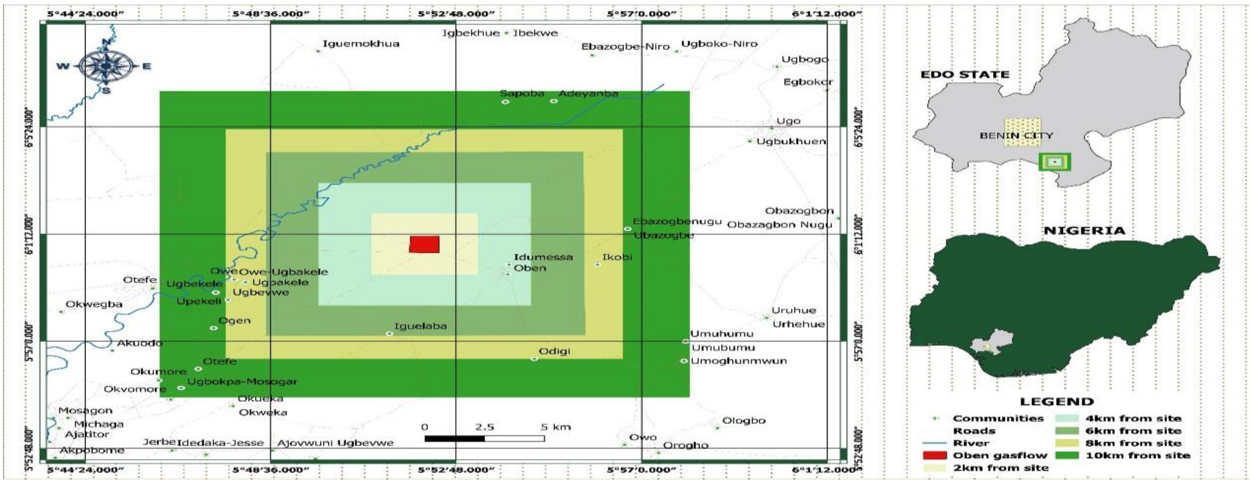

Figure 1: Study Area

Oil exports from the Oben flow station are routed via the Oben Amukpe pipeline to the Amukpe facilities and onwards to either the Forcados terminal or Warri refinery. Production operations and facilities are supported by the Oben Field Logistics Base. The Oben field in particular is central to the Company's future gas expansion plans and is strategically located as an important gas hub with access to Nigeria's main gas demand centres. The licence was renewed in 2018 for a further 20 years and is next due for renewal on 21 October 2038.

2.2 Research Design

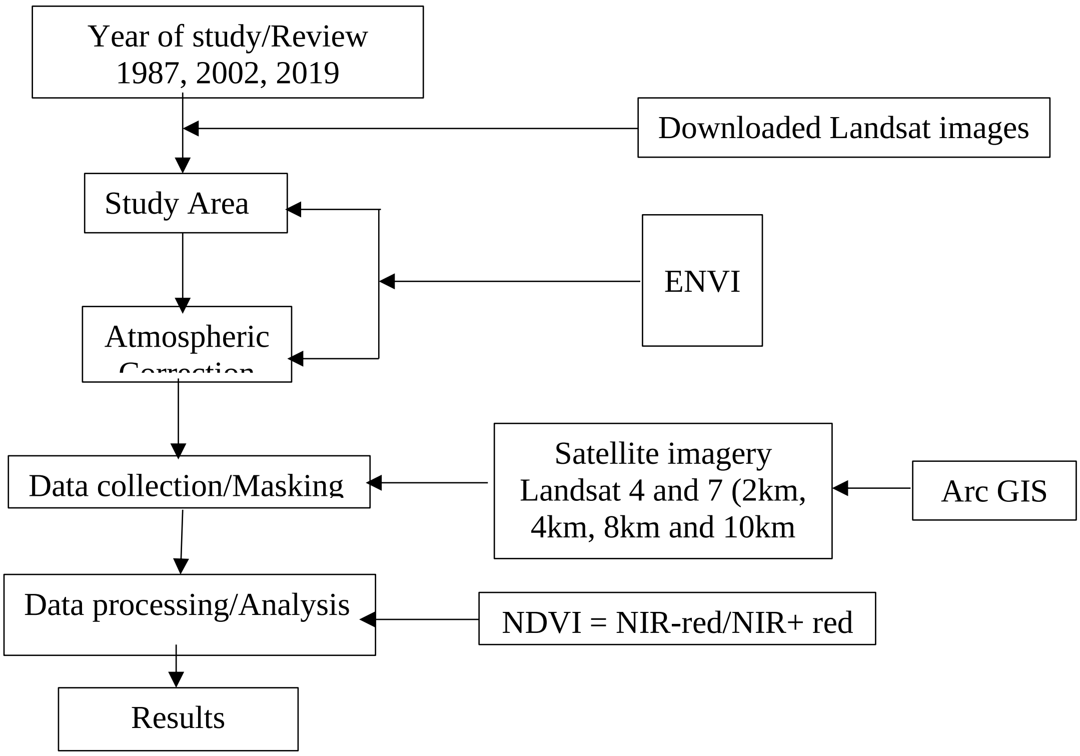

Figure 2: Schematic illustration of the research design

Data was gathered for the years 1987, 2002 and 2019. In order to ascertain the effect of gas flaring on the surrounding vegetation of Oben gas flow, a radius of 10km was mapped out from the gas flare stack and NDVI values were generated for vegetation within 2km, 4km, 6km, 8km and 10km away from the gas flaring site. These was achieved using ARCGIS 10.3 software. Satellite images of cloud cover less than 10% were acquired.

2.3 Data Type and Source

This study relied primarily on secondary data analysis derived from the application of NDVI technology, with the use of Landsat Research Design. Secondary data is one of the two data type, the other been primary data. These two data types are very important in research; however for the purpose of this study, the researcher will be adopting the secondary data type.

2.4 Method of Data Collection

Images from Landsat 4 and Landsat 7 were downloaded from the United States Geological Survey (USGS) website (http://edcsns17.cr.usgs.gov/NewEarthExplorer/) for the study area. The data for this study was collected before the Oben gas flow station site got licensed and after it was licensed for operations. To collect good quality Landsat imagery, images with cloud cover less than 10% were downloaded. Attempts were made to collect data of same day and same season but due to cloud cover the above data were collected which have less than 10% restriction. Data was collected yearly at an average of 20 years interval.

2.5 Method of Analysis

Table 1: Description of landsat data used

Satellite Sensor	Scene Date	Product ID	Path/row
Landsat 4 TM	21-12-1987	LT04_L1TP_189056_19871221_20170210_01_T1	189/56
Landsat 7ETM+	28-1-2002	LE07_L1TP_189056_20020128_20170201_01_T1	189/56
Landsat 7 ETM+	29-12-2019	LE07_L1TP_189056_20191229_20200124_01_T1	189/56

This process involves arranging and organizing the data for analysis. ArcGIS 10.3 and ENVI 5.3 were used for data processing and analysis. Below are the steps undertaken in data processing;

1. **Projection to GCS WGS 1984:** All data were projected to Geographic Coordinate System (GCS) World Geodetic System (WGS) 1984.
2. **Radiometric and atmospheric correction:** Satellite data of a geographic location involves different radiometric values because of variation in illumination conditions, solar angle and changes in sensor calibration atmospheric effects [11]. It is important to perform radiometric and atmospheric correction to remove these radiometric effects before image processing and post classification stages. These changes reduces the sensor noise and effects of atmospheric factors caused by atmosphere effects like haze, clouds or particles that exist in the atmosphere. This include process of converting the digital number (DN) from sensor into unit’s absolute reflectance [12]. Radiometric correction involves conversion of DNs to radiance, dark-object-subtraction, converted radiance to Top of Atmospheric (TOA) reflectance and finally application of atmospheric correction. This process was carried out as described by [13] using the ENVI FLAASH tool.

3. Masking of study area: In order to ascertain the effect of gas flaring on the surrounding vegetation of Oben gas flow, a square with a radius of 10km was mapped out from the center of the gas flow and NDVI values was generated for vegetation within 2km, 4km, 6km, 8km and 10km away from the gas flaring site. These were achieved using ARCGIS 10.3 software.

2.6 Image processing

Normalized Difference Vegetation Index (NDVI): NDVI is an indicator usually used to assess the spatial distribution of vegetation and their photosynthetic activity [14]. [15] first used it, in 1973 to monitor and distinguish vegetated areas from other land cover types [16]. The mathematical algorithm is based on bands 3 [Red (R)] and band 4 [Near Infra-Red (NIR)] measurements with the formula below:

NDVI = (Band 4 - Band 3) / (Band 4 + Band 3)

NDVI images were generated from the 3 Landsat images using the above formula in ENVI 5.3

NDVI Equation = (NIR - R) / (NIR + R).

Table 2: Table showing the NDVI classification

Class/Feature	NDVI Range
Water	**-1 ≤ - 0.014**
Built-up	**0.015 - 0.09**
Barren land	**0.10 - 0.20**
Shrub and Grassland	**0.21 - 0.30**
Sparse Vegetation	**0.31 - 0.40**
Dense Vegetation	**0.41 - ≤ 1**

Figure 3: NDVI Vegetation Classes

3.Results and Discussion

3.1 Figure 4 depicts satellite imagery from the year 1987 at marked distances.

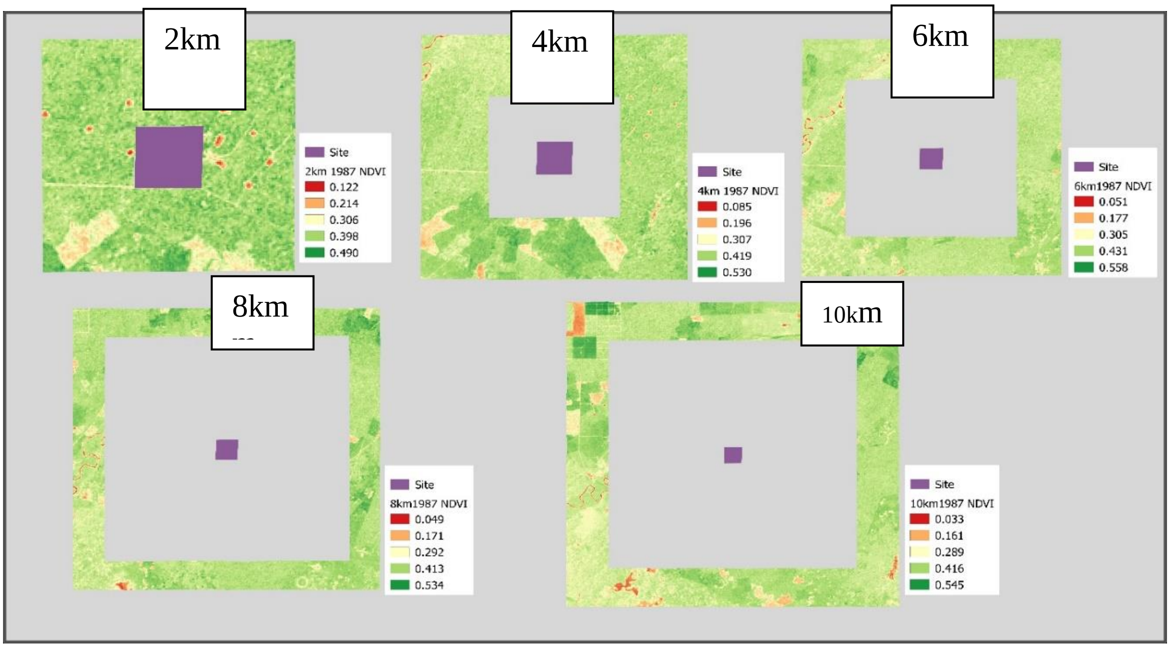

Figure 4:1987 Satellite imagery of vegetation at marked distances.

Figure 5 depicts satellite imagery from the year 2002 at marked distances

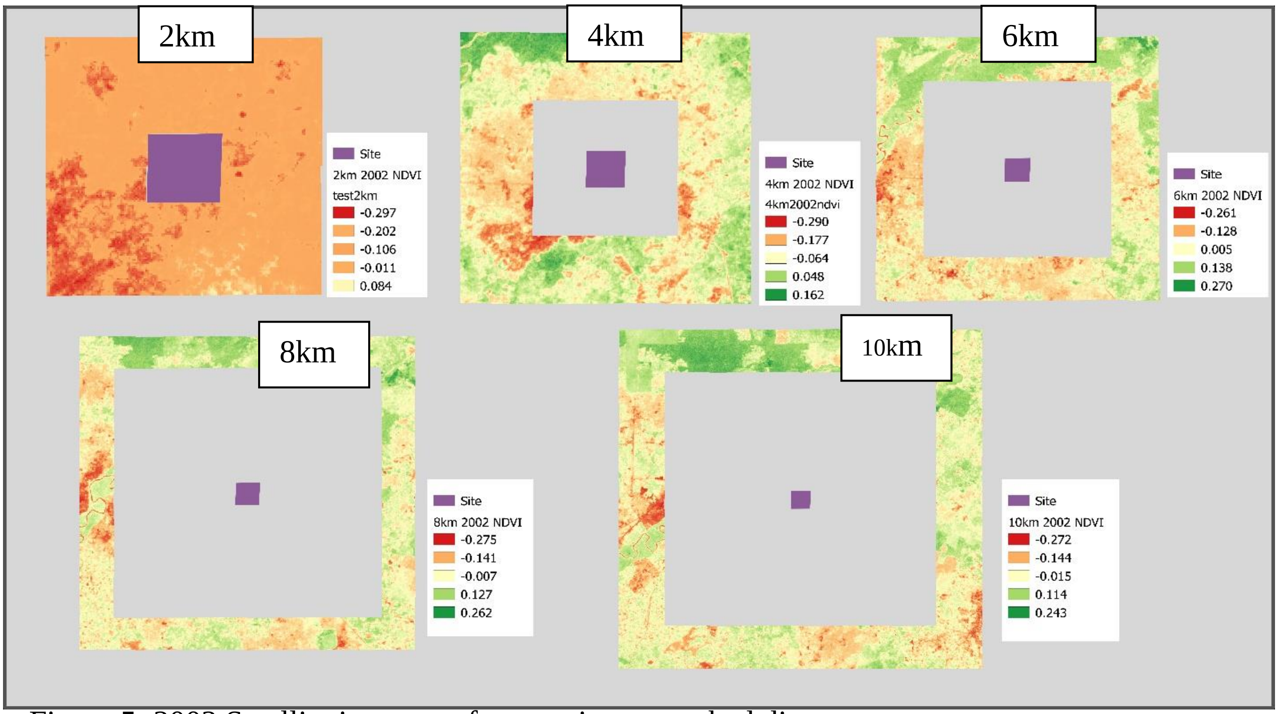

Figure 5: 2002 Satellite imagery of vegetation at marked distances.

Figure 6 depicts satellite imagery from the year 2019 at marked distances

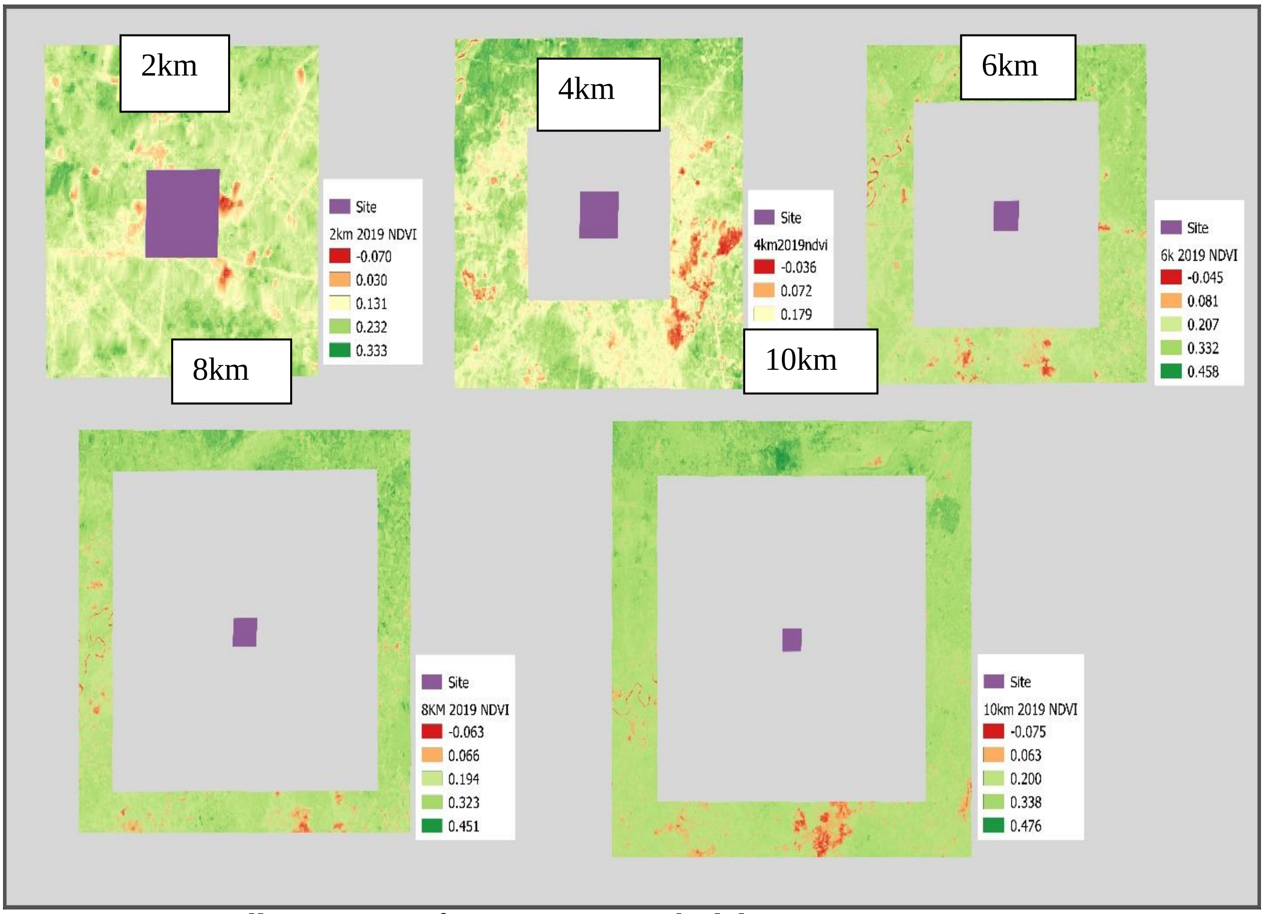

Figure 6: 2019 Satellite imagery of vegetation at marked distances.

Table 3: A Table showing NDVI values at marked distances for analyzed years

Year	**Distance**	**Max (NDVI)**	**Mean (NDVI)**	**Min (NDVI)**	**SD (NDVI)**
	2km	0.33	0.28	-0.07	0.04
2019	4km	0.39	0.33	-0.04	0.06
	6km	0.46	0.36	-0.04	0.06
	8km	0.45	0.37	-0.06	0.06
	10km	0.50	0.37	-0.08	0.07
2002					
	2km	0.08	0.02	-0.3	0.07
	4km	0.16	0.08	-0.29	0.07
	6km	0.27	0.17	-0.26	0.08
	8km	0.26	0.18	-0.28	0.08
	10km	0.25	0.18	-0.27	0.08
1987					
	2km	0.49	0.39	0.12	0.04
	4km	0.53	0.39	0.08	0.04
	6km	0.56	0.39	0.05	0.04
	8km	0.53	0.38	0.05	0.04
	10km	0.66	0.39	0.03	0.06

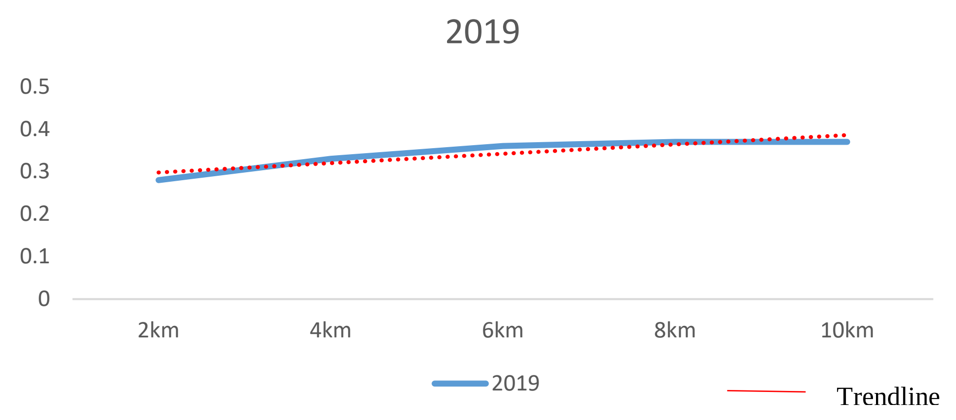

Figure 7: A graph showing mean NDVI trend line for 1987

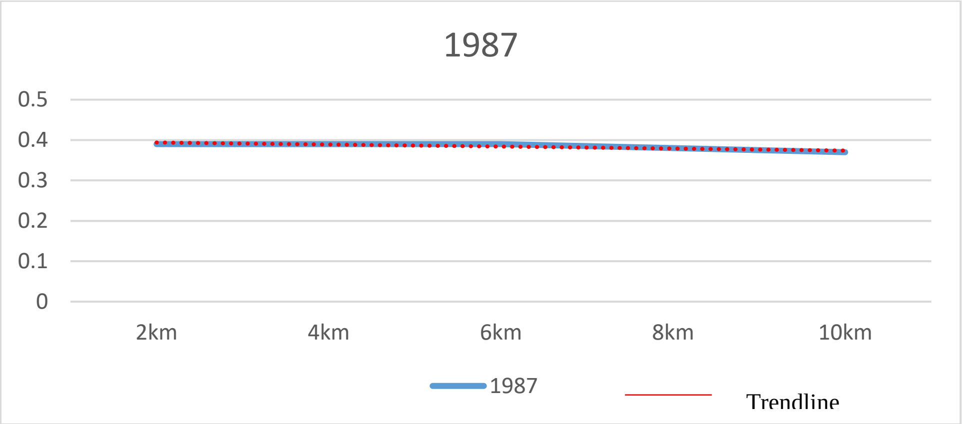

Figure 8: A graph showing mean NDVI trend line for 2002

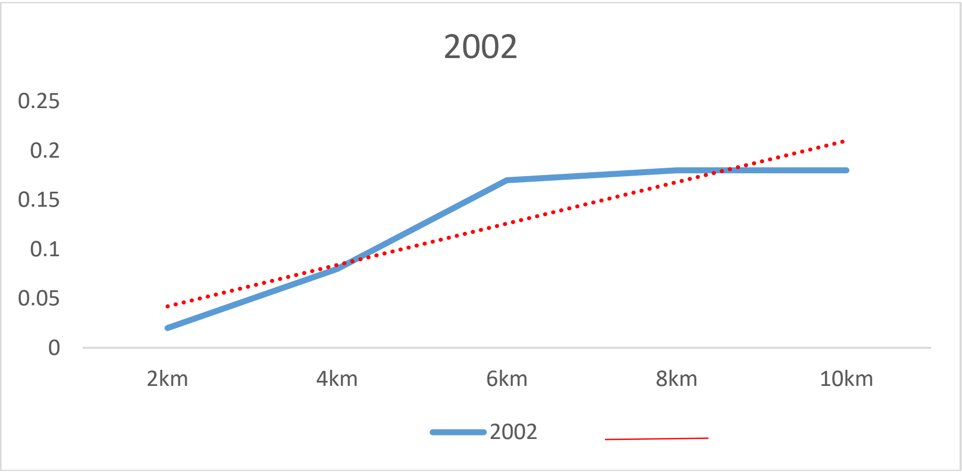

Figure 9: A graph showing mean NDVI trend line for 2019

The NDVI analysis result for vegetation around Oben gas flow show changes in vegetation index across the analyzed years (1987, 2002, and 2019). According to the Figure 4, the vegetation health around the gas stack in 1987 had the highest maximum value and highest mean value. After fifteen years of operation, the NDVI maximum value decrease rapidly from 0.66 to 0.27 and increased to 0.5 in 2019. This was also evident in the mean values. The decrease in the temporal assessment from 1987 to 2002 might be attributed to effect of gas flaring on the vegetation around the gas stack. The NDVI spatial assessment across the analyzed years from 2km to 10km from the gas stack shows gradual increase from the gas stack. This also proves that there is a detrimental effect of gas flaring on vegetation around the gas stack. According to [17], retardation of vegetation and crop around gas stacks can be attributed to atmospheric contaminates like oxides of nitrogen, carbon and sulphur, particulate matter, hydrocarbon and ash. The study also suggested that the effect of heating and soil contamination plays a major role in the reduction of vegetation health around the gas stack. In correlation to [17] with the result of this study, there is a spatial gradient in the effect of gas flares on the vegetation around the gas stack. [18] reported that the major contributing factor of acid rain in the Niger Delta region of Nigeria is gas flaring and this have a detrimental effect on vegetation and soil fertility. In 2002, there was a massive decline in the NDVI values across all analyzed distances followed by an increase in 2019. This result can be attributed to the increase in average temperature from 27.02^0c in 1991 to 28.3^0c in 1997 and then back to 27.4^0c in 2002 as reported by [19]. According to [20] there is a correlation between temperature and vegetation health as vegetation will decline under rainfall and increasing temperature. Nigeria remains Africa’s largest gas energy producer, possessed the second highest gas flaring rate in the world in 2011, and dropped to the seventh highest rate between 2013 and 2015 [21]. The decrease in production from 2013 can also attributed to the slight increase in NDVI maximum and mean values in 2019. About 1.4 billion cubic feet of gas is flared into Niger Delta atmosphere daily. The sanction of flaring associated gas has increased from US$0.07 fine per 1000 cubic feet of gas flared in 1998 to US$3.50 in 2008 [22]. This increase in punishment fee has reduced the volume of gas flared which has directly impacted vegetation health. This research has shown that gas flaring has serious effect on vegetation over time, from Table 2, we can observe from the spatio-temporal assessment, 1987 at 2km the NDVI max was 0.49 and 0.66 at 10km, vegetation health was very poor in 2002 but increased slightly in 2019 but even with the increase, NDVI max at 10km was 0.50, so to get NDVI value of 1987 at 2km in 2019, we had to move farther away from the gas stack. This might be attributed to decrease in chlorophyll content of vegetation in area of gas flare [22]. The decrease in chlorophyll in plants near flares is as a result of heat. Heat is known to decrease chlorophyll [23], gas flares affect the accumulation of chlorophyll, photo chlorophyll and the rate of conversion of the latter to chlorophyll in leaves. Deformations by lesions and color variegation are often expressed symptoms of reduced chlorophyll accumulations in plants.

4. Conclusion

This research has explored the capabilities of GIS in environmental assessment of changes through time. It investigated the high spatial resolution of the Landsat data in identifying vegetation cover types as early as 1987, to fully estimate amount of changes that have occurred over time as a result of gas flaring. The NDVI data clearly showed the study area had rich vegetation before the flaring of gas by the flow station. But during this research data of same study area, vast changes were observed overtime. This lead to result from research revealing a rapid decline in the vegetation. Results further demonstrated that gas flaring is a major factor responsible for such decline in the rich vegetation of the study area. Variations in percentage decline of green vegetation from results suggested that other factors like time of commissioning of gas flaring sites and volume of gas flared can determine the magnitude of gas flaring impacts. Although there was a considerable increase in the NDVI value between 2002 and 2019 due to reduction in gas flared and climatic conditions. Furthermore, it can be confirmed from the results of the study that gas flaring significantly contributed to the loss of the rich natural forest of the study area, it is highly recommended that the Nigerian Government should:

- Set up laws or polices coercing multi-national oil companies to divulge information on its oil and gas exploration activities to the general public especially to stakeholders and local indigenes directly affected by their activities.
- Provide adequate funding to scientific research on gas flaring, to fully assess it impacts on vegetation, biodiversity and the entire ecosystem, and develop ways of mitigation.
- Train its workers especially those saddle with the responsibility of policy implementation on environmental management systems.
- Associated gas utilization as it will contribute significantly to the economy of Nigeria in general [24].
- From this study, it shows that NDVI average value at 2km for 1987 was 0.39 but at 10km for 2002 was 0.18. This study further recommends that human settlement should be beyond 10km from the gas flare stack and further research should be done to determine the recommended safe human settlement distance from the gas stack.

With the implementation of the above recommendations, more detailed research studies would be carried out which could assist in formulating more appropriate policies and developmental strategies for the region [25].

References

[1] Amorin, R. and Broni-Bediako, E. (2013). Major challenges in Ghana's oil and gas discovery: Is Ghana ready? ARPN Journal of Science and Technology, **3**(1): 21 - 25.

[2] World Bank Group (2004). Global Gas Flaring Reduction: A Public - Private Partnership. Volume 2. World Bank: Washington DC, USA. 116p.

[3] IRIN (2015). Nigeria: Gas flares still a burning issue in the Niger Delta. Available online at http://www.irinnews.org/report/95034/nigeria-gas-flares-still-a-burning-issue-in-the-niger-delta. Accessed March 20th, 2021.

[4] Ndubuisi, F. and Olaode, F. (2015). Nigeria Yet to Endorse New Global Initiative to End Gas Flaring by 2030. Available online at http://www.thisdaylive.com/articles/nigeria-yet-to-endorse-new-global-initiative-to-end-gas-flaring-by-2030/207198/. Accessed February 28th, 2021.

[5] National Energy Policy. (2003). Energy Commission of Nigeria. The Presidency; Federal Republic of Nigeria

[6] Ibitoye, F. I. (2014). Ending natural gas flaring in Nigeria's oil fields. Journal of Sustainable Development, **7**(3): 13 - 22.

[7] Boxall, P. C., Chan, W. H. and McMillan, M. L. (2005). The impact of oil and natural gas facilities on rural residential property values: A spatial hedonic analysis. Resource and Energy Economics, **27**(3): 248 - 269.

[8] Akpomuvie, O. and Orhioghene, B. (2011). Tragedy of commons: analysis of oil spillage, gas flaring and sustainable development of the Niger Delta of Nigeria. Journal of Sustainable Development, **2**: 200 - 210.

[9] Odjugo, P. A. and Osemwenkhae, E. J. (2009). Natural gas flaring affects microclimate and reduces maize (zea mays) yield. Internationl Journal of Agriculture and Biology, **11**(4): 408 – 412.

[10] Twumasi, Y. A., and Merem, E. C. (2006). GIS and remote sensing applications in the assessment of change within a coastal environment in the Niger Delta region of Nigeria. International journal of environmental research and public health, **3**(1): 98-106.

[11] Lu, D., Mausel, P., Brondizio, E. and Moran, E. (2004). Change detection techniques, International Journal of Remote Sensing, **25**(12): 2365 - 2401.

[12] Lillesland, M. T., Kiefer, W. R. and Dupman, W. J. (2008). Remote Sensing and Image Interpretation, 5th Edition. John Wiley and Sons: New York, USA. 723p.
[13] Abdelrahman, A. E. (2018). Comparison of two soil quality indices using two methods based on geographic information system, The Egyptian Journal of Remote Sensing and Space Science, **12**: 2411 - 2452.
[14] Basith, A., Matori, A. N. and Harahap, I. S. H. (2010). Past Landslides at Post Slim: Evaluation of its Causative Factors Using Geospatial and Remote Sensing Data. Conference Report No. 14B234. International Conference on Sustainable Building and Infrastructure: Kuala Lumpur, Malaysia. 305p.
[15] Rouse, J.W., Haas, R.H., Schell, J.A and Deering , D.W. (1973). Monitoring Vegetation Systems in the Great Plains with ERTS (Earth Resources Technology satellite). Proceedings of 3rd Earth Resources Technology Satellite Symposium, Greenbelt, 10- 14 December, SP-351, 309-317
[16] Lyon, J. G., Yuan, D., Lunetta, R. S., and Elvidge, C. D. (1998). A change detection experiment using vegetation indices. Photogrammetric engineering and remote sensing, **64**(2); 143 - 150.
[17] Dung, E. J., Bombom, L. S., and Agusomu, T. D. (2008). The effects of gas flaring on crops in the Niger Delta, Nigeria. GeoJournal, **73**(4): 297-305.
[18] Seiyaboh, E.T and Izah, S.C.(2017). A Review of Impacts of Gas Flaring on Vegetation and Water Resources in the Niger Delta Region: International Journal of Economy, Energy and Environment. **2**(2 4): 48-55
[19] Amaechi, C. F., and Biose, E. (2016). Gas flaring: Carbon dioxide contribution to global warming. Journal of Applied Sciences and Environmental Management, **20**(2): 309-317.
[20] Adepoju K.A., Adelabu S.A and Fashae O.A. (2019). Vegetation Response to Recent Trends in Climate and Landuse Dynamics in Typical Humid and Dry Region under Global Change. Advances in Meteorology. http/doi.org/10.1155/2019/4946127
[21] Royar, K. T. (2012). Money Talks: Why Nigeria's Petroleum Industry Bill will Fail to End Gas Flaring. Naval War College Newport Ri Joint Military Operation Dept.
[22] Isichei, A. O. and Sanford, W. W. (1976). The effects of waste gas flares on the surrounding vegetation in South-Eastern Nigeria. The Journal of Applied Ecology, **13**(1): 177 - 187.
[23] Lawanson, A. O., lmevbore, A. M. A. and Fanimokun, V. O. (2013). The Effects of Waste-Gas Flares on the Surrounding Cassava Plantations in the Niger Delta Regions of Nigeria. Available online at http://www.istrc.org/images/Documents/Symposiums/Sixth/6th_symposium_proceedings_0041_section_3_239.pdf. Accessed February 21st, 2021.
[24] Amaechi, C. F., & Emejulu, M. J. (2021). Cost–Benefit Analysis of Associated Gas Flaring in the Niger–Delta Area of Nigeria. Journal of Applied Sciences and Environmental Management, **25**(3): 363-369.
[25] Ishisone, M. (2004). Gas flaring in the Niger Delta: The potential benefits of its reduction on the local economy and environment. Available online at http://socrates.berkeley.edu/*es196/ projects/2004final/Ishone.pdf. Accessed February 24th, 2021.