

Detection of Impacts of Gas Flaring in the Environment: Application of Landsat Earth Observation Data

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Abstract

The study focused on detection of the impacts of gas flaring at 5 gas flaring sites in the Niger Delta using satellites data. 6 Landsat 5 Thematic Mapper (TM) data, and 13 Landsat 7 Enhanced Thematic Mapper Plus (ETM+) data spanned from 17/01/1986 to 08/03/2013 with < 5% cloud contamination was used. The atmospherically corrected reflectance was used for the calculation of Normalized Differential Vegetation Index (NDVI) and classification of land cover (LC) types. The Planck equation was inverted using thermal band calibration constants to derive Land Surface Temperature (LST). The transect plot of the reflectance bands (1-4) and NDVI, and 4 cardinal plot analyses for NDVI and LST were adopted to explore the results. Mean and standard deviation of NDVI obtained for the 5 sites are as follows: Eleme I (1.917×10^{-5} , 2.069×10^{-4}), Eleme II (1.501×10^{-5} , 1.340×10^{-4}), Bonny LNG (2.129×10^{-5} , 8.290×10^{-5}), Umurolo (5.806×10^{-5} , 7.499×10^{-5}) and Onne (2.285×10^{-6} , 7.952×10^{-5}). The results show that LSTs and NDVIs exhibited opposite spatial distribution patterns at the 5 flaring sites investigated. This suggests that vegetation cover, health, growth, etc., within the area has been negatively affected. Regarding these results, we draw a conclusion that Landsat 5 TM and Landsat 7 ETM+ have the capacity for detection of the impacts of gas flaring in the Niger Delta.

Keywords: Detection, Impacts, Earth Observation (EO) data, Landsat 5, Landsat 7, Normalized Differential Vegetation Index (NDVI)

Introduction

The main aim of flaring gas on oil and gas exploration, exploitation, production and refining facilities is for the security and protection of these facilities, without harm when it is necessary to get rid of gas as a result of crisis or to avoid the malfunction or collapse of these facilities (Lu et al., 2020). The materials released from gas flaring into the environment are termed hydrocarbon pollutants (Mafimisebi & Ogbonna, 2016). Gas flaring in Nigeria is as old as when the crude oil is detected in the late 1950s (Morakinyo, 2015). The burning of gas is a continuous occurrence in all the oil and gas production locations in all the 9 states of the Niger Delta (Mafimisebi & Ogbonna, 2016); with about of total of 178 gas flaring sites (Ighalo et al., 2020). Some gas flares are burning vertically (Figure 1A) (Nwaogu & Onyeze, 2020) while others are burning horizontally on the ground (Figure 1B) (Seiyaboh & Izah, 2017).

Gas flare is ongoing in Nigeria because of the cheaper option of flaring gas as a waste product (Yomi, 2018). However, due to the downward trend in gas flaring in Nigeria, in 2018 Nigeria moved to the position of 7th country, followed Venezuela with 7.4 Billion Cubic Metres (BCM) in the world for gas flaring (NOOA, 2018). The 3 giant multinational petroleum companies with highest flaring records in Nigeria are Shell, Mobil and Chevron. Despite the fact that there has been a notable reduction in the volume of the % of gas flared in Nigeria, the persisting health hazards, economic loss, and environmental deterioration cannot be disregarded.

Gas flaring in the Niger Delta is the major sole donor of the discharge of the hydrocarbon impurities into the atmosphere with accumulation mostly depending on the magnitude of oil production at each location (Morakinyo, 2015). Gas flaring has been recognized by various studies as harmful to the environment and the people (Nwaogu & Onyeze, 2020). The people experience effects such as serious air pollution (Sekyi, 2017); increase in local/surface temperature (Lu et al., 2020); acid rain, surface and ground water pollution (Nwaogu & Onyeze, 2020); deterioration of soil structure, soil leaching and erosion (Mafimisebi & Ogbonna, 2016); retardation of crop growth, vegetation degradation and death (Seiyaboh & Izah, 2017; Dung et al., 2008); disturbance of ecosystem balance (Sekyi, 2017) etc. Therefore, the income of the people, particularly farming and fishing communities have been remarkably adversely attacked causing high level of poverty, youth unrest (Mafimisebi & Ogbonna, 2016); pipelines vandalization, oil theft and the economic loss to Nigeria is immense.

Several fundamental problems are related to the detection and monitoring of gas flaring sites, comprising their broad spreading and intrusion such as cloud cover, and forest fires (Liu et al., 2020). However, researchers have worked on detection and monitoring of gas flare platforms using Earth Observation (EO) data, for example Lu et al. (2020) worked on global offshore gas flaring sites using 1997-2018 datasets from the Defense Meteorological Program (DMSP) Operational Line-Scan System (OLS) Nighttime Lights, Advanced Along-Track Scanning Radiometers (AATSR), Moderate Resolution Imaging Spectroradiometer (MODIS) Active Fire, Visible Infrared Imaging Radiometer Suite (VIIRS Active Fire, VIIRS Nightfire, and VIIRS Nighttime Lights). Some also used Synthetic Aperture Radar (SAR) data (Liu, et al., 2018) while others used satellite-based optical remote sensing data (Liu et al., 2019) for their studies.

In addition, Elvidge et al. (2015) and Elvidge et al. (2018) developed a multispectral pyrometric system to estimate the global flared gas volume, using data from VIIRS. Casadio et al. (2012) used the AATSR data from 1991-2009, constructing ALGO3 algorithm for monitoring gas flaring on a global scale. Furthermore, some studies have highlighted more restricted regional gas flaring activity (Fisher & Wooster, 2018). The above mentioned studies have shown that thermal-infrared sensors or photomultiplier visible sensors are capable of mapping flares whether local, regional or global.

Critical knowledge gaps for the study are that no paper has been published on the following about the Niger Delta (1) Detection of gas flaring platforms using Land Surface Temperature (LST) flare signature from EO data; (2) Detection of the impacts of gas flaring over a long period by EO data. This is confirmed by Edino et al. (2010) who stated that there are limited studies to determine the impacts of gas flaring over a long period in the Niger Delta. (3) Retrieval of LST and Normalized Differential Vegetation Index (NDVI) at flaring sites from satellites data. Previous researches on LST retrieval in the Niger Delta (Nwaerema et al., 2019; Nwaerema & Ajiere, 2020) had focused on the results of urbanization related land changes in urban cities such as Port Harcourt (Rivers State) and Benin City (Edo State); (4) Application of 4 cardinal directions (North, East, South and West) plots for analysis of LST and NDVI; (5) Assessment of changes in LST and NDVI and their effects on vegetation cover and vegetation health by EO data. The major significance of this study is that it helps to distinguish gas flaring (with hotspots present every month of the year) from forest fire, agricultural fire and other small fires that are not repeated more than 3-4 months.

This study has two research questions: (1). How correctly can EO satellite sensors determine the impacts of gas flaring in the Niger Delta? (2). What is the geographical changeability and qualitative analysis of the multispectral reflectance bands 1-4, NDVI and LST retrieved at the flaring sites from EO data in the Niger Delta? Hence, the aim of the study is to examine the ability of Landsat 5 Thematic Mapper (TM) and Landsat 7 Enhanced Thematic Mapper Plus (ETM+) sensors for detection of the impacts of gas flaring activities in the Niger Delta. The objectives for the study are: (1) Choice of suitable flares sites in the Niger Delta; (2) Derivation of multispectral reflectance bands 1-4, and NDVI from atmospherically corrected Landsat data; (3) Retrieval of LST from the atmospherically corrected Landsat data. Fast growing of satellite remote sensing technology, which has the benefit of wide-reaching, short-term, high-precision, and economical as an alternative to conventional survey technique is the basis for this study (Cohen & Goward, 2004).

Materials and Methods

Study Area

Eleme Petroleum Refinery Companies I (1.6×1.1) km and II (2.2×1.3) km, Bonny Liquefied Natural Gas (LNG) plant (4.2×2.8) km, and Umurolo (4.2×2.4) km and Onne Flow Stations (175×130) m are 5 flare sites in River States considered for this study. They are all within the Latitude $4^{\circ} 40'$ and $5^{\circ} 01'$ N, and the Longitude $6^{\circ} 50'$ and $7^{\circ} 01'$ E (Morakinyo et al., 2022a, 2022b; Morakinyo et al., 2021; Morakinyo, 2015). The choice of the sites depends on the accessibility of in-situ data, and cloud free Landsat data in the United State Geological Survey (USGS) archive; topography of the site; and size and purpose of the facility. Figure 1 show (A) Gas flare burning vertically at Eleme Refinery I; (B) Gas flare burning horizontally on the ground at Onne Flow Station; (C) Land pollution at Bonny LNG; (D) Environmental degradation at Umurolo Flow Station; and (E) Air pollution at Eleme Refinery II.

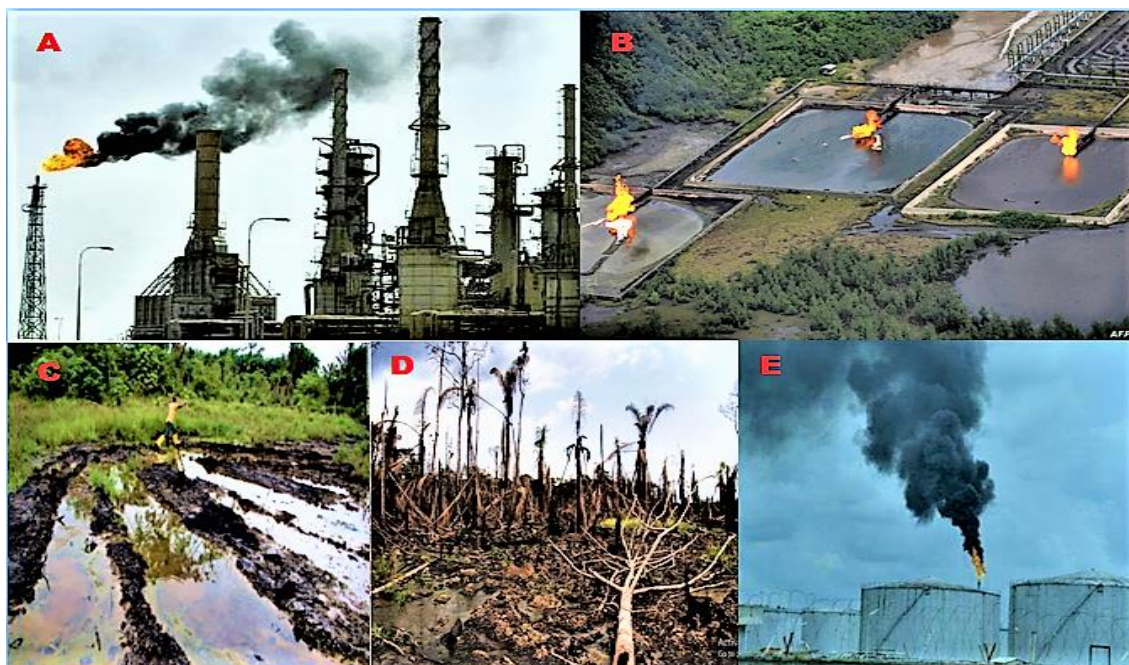


Figure 1: (A) Gas flares burning vertically at Eleme I; (B) Gas flares burning horizontally on ground at Onne Flow Station; (C) Land Pollution at Bonny LNG; (D) Environmental degradation at Umurolo Flow Station; (E) Air pollution at Eleme II.

Datasets and sources

6 Landsat 5 TM images and 13 Landsat 7 ETM+ images dated from 17/01/1986 to 08/03/2013 with $< 5\%$ cloud cover used were obtained from the USGS website (<http://earthexplorer.usgs.gov/>). Landsat 5 TM data have 7 spectral bands while Landsat 7 ETM+ contains 8 bands; both have spatial resolution of 30 m for bands 1-5 (Blue, Green, Red, Near Infrared and Short-wave Infrared) and 7 (Short-wave Infrared). Landsat 7 ETM+ band 8 (Panchromatic) have a spatial resolution of 15 m. The spatial resolution for Landsat 5 TM band 6 (Thermal infrared) is 120 m while for Landsat 7 ETM+ is 60 m but both are resampled to 30 m pixels (Chander, and Markham, 2003). The area of 12 by 12 km is investigated with the flare stacks at the centre of the site in order to have enough data for the retrieval of NDVI and LST.

Methods

Computation of reflectance for Landsat bands 1-4

The computation of reflectance for band wavelength (λ) is carried out by assuming Lambertian surface reflectance (Chander and Markham, 2003) (Eq. 1) (NASA, 2022; Chander and Markham, 2003).

$$\rho_p = (\pi \times L_\lambda \times d^2) \div (ESUN_\lambda \times \cos \theta_s) \quad (\text{Eq. 1})$$

Where:

ρ_p = Unitless effective at-satellite planetary reflectance;

L_λ is measured per unit solid angle;

πL_λ = Upwelling radiance over a full hemisphere;

d = Earth-Sun distance in astronomical units

$ESUN_\lambda$ = Mean solar exoatmospheric irradiances.

θ_s = Solar zenith incident angle in degrees.

Figure 2 show the workflow methodology for processing Landsat data to obtain reflectance (bands 1-4).

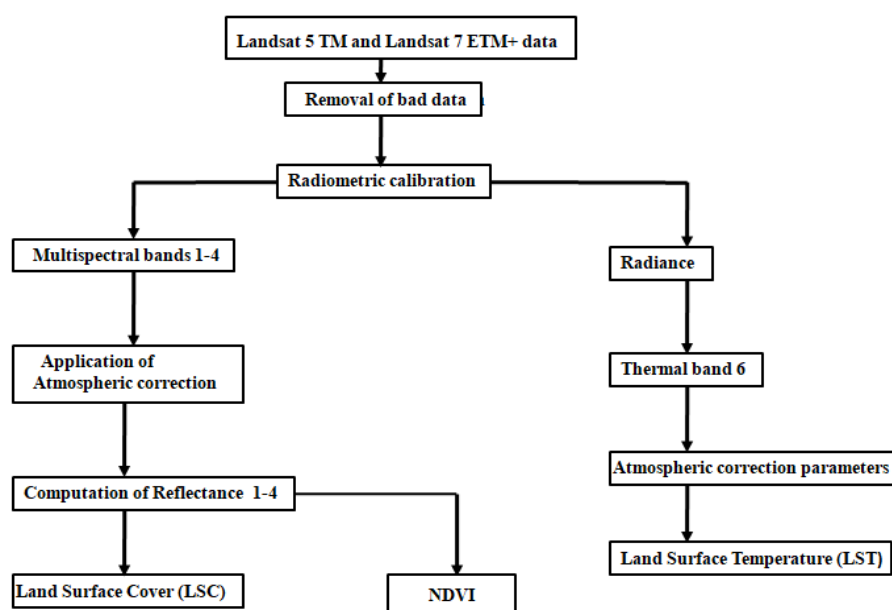


Figure 2: Datasets and workflow methodology used in this study.

Computation of Normalized Differential Vegetation Index (NDVI)

NDVI values are from -1 to $+1$ (Song et al., 2018), developed from Near-infrared (NIR) and Red (R) bands reflectance obtained from satellites data (Pervez et al., 2021). NDVI has been applied for measurement and monitoring of vegetation surface, coverage, quantity, greenness and vigour (Guechi et al., 2021); and also for examining the connection between vegetation and LST (Pervez et al., 2021). When vegetation cover is polluted by hydrocarbon discharge, it undergoes changes in the biophysical and biochemical attributes that are discoverable through changes in reflectance (Adamu et al., 2015). Vegetation spectral reflectances depend on the chlorophyll and water absorption in the leaves, which get changed by hydrocarbon pollution (Morakinyo, 2015). Hence, NDVI is a reliable parameter adopted to ascertain vegetation health polluted by oil production discharges (Adamu et al., 2015).

Red band reflectance is mostly absorbed by healthy vegetation, and a large portion of Near-infrared light is reflected (Guechi et al., 2021). When the value of $NIR > R$, + NDVI value is obtained, which suggests vegetated surface that is green and healthy (Weiss et al., 2004) while sparse and diseased vegetation feature low NDVI values (Adamu et al., 2015). When NDVI value is $-$, it suggests surfaces like cloud, ocean, ice, water etc. However, heterogeneous surfaces make difficult interpretation of NDVI (Weiss et al., 2004); NDVI values near zero indicate bare soil, sparse vegetation range from (0-0.01) to (0.1-0.5), and dense green vegetation is 0.6 above.

For this research, atmospheric effects on Landsat data were corrected; and NDVI computed was applied as a means for determining the impacts of flared gas on the vegetation cover. The atmospherically corrected reflectance of R and NIR (bands 3 and 4) were adopted for the computation of NDVI (Eq. 2) (Figures 3-7).

$$NDVI = (NIR - R) / (NIR + R) \text{ (Allam et al., 2021; Guha et al., 2020) (Eq. 2)}$$

Where:

NIR =Near Infra-Red band reflectance;

R =Red band reflectance.

Figure 2 show the methods and stages involved in the processing of Landsat data for the computation of NDVI.

Retrieval of Land Surface Temperature (LST) from Landsat 5 TM and Landsat 7 ETM+ Dataset.

Atmospherically corrected Landsat data was used for the computation of LST by inverting the formula for computing surface-leaving radiance (L_λ) (Eq. 3) (Morakinyo et al., 2020a, 2020b; Coll et al., 2005). 4 land cover (LC) classes (Vegetation, soil, built area and water) at flaring sites (Morakinyo et al., 2019) which were confirmed during the ground validation (Morakinyo et al., 2021) exercise in 2019 and 2021 were obtained from bands 1-4 atmospherically corrected reflectance. The emissivity (ϵ) for each site LC type was estimated using 4 similar LC types present in all the sites; and their values were calculated using look up table (LUT) (Figure 2). Figure 2 show the stages applied for the retrieval of LSTs from Landsat datasets. LSTs were retrieved for the 4 LC types but only vegetation LSTs are considered in this study (Figures 8-12).

$$L_\lambda = \frac{C_2}{\lambda \ln[(C_1 / \lambda^5 B(\lambda, T)) + 1]} \quad (\text{Eq.3})$$

Relationships between NDVI and LST have been studied for different purposes for example, LC changes (Imran et al., 2021); vegetation monitoring (Pervez et al., 2021); vegetation growth (Robinson et al., 2019); vegetation change detection (Meera et al., 2015); global LST monitoring (Song, et al., 2018); studying environmental changes and land use planning (Deng et al., 2018); and drought assessment (Karnieli et al., 2010). Furthermore, some researchers have applied 4 cardinal directions previously to their studies and they recorded reliable results, e.g. assessing air toxic near oil and gas drilling sites (Alhaji, 2011) and measuring forest sample plots (Vastaranta et al., 2015).

In this study, 4 cardinal directions (Morakinyo et al., 2022b; Morakinyo et al., 2020b; Morakinyo et al., 2015) were adopted for the analysis of NDVIs and LSTs. Pixels adjoining to the flare stack were used as the starting point for the 4 directions (North, East, South and West). Mean of the NDVIs and LSTs data used for the analysis in each direction has a Matrix dimension of 14 rows and 9 columns i.e. 14×9 . 30 m, 60 m and 120 m are distance intervals which is similar to the original and resampled resolution of Landsat 5 TM and Landsat 7 ETM+ band 6 data. Computation of mean and standard deviation for NDVI from the 9 pixels at each distance from the stack was carried out. Plotting of NDVIs and LSTs against distance from the flare stack for all the 4 directions was done. The first 30 m covered the pixel for the flare stack.

Results

Comparison of reflectance signature for Landsat bands 1-4 and NDVI

For the purpose of monitoring vegetation cover and interpretation of LC at each flaring site, transect plots of reflectance for bands 1-4 signature and NDVIs results through the flare stack pixel in the South towards North direction (direction of prevailing wind in the Niger Delta) (Morakinyo et al., 2022; Morakinyo et al., 2015) were obtained (Figures 3-7). Dashed line indicates the flare location.

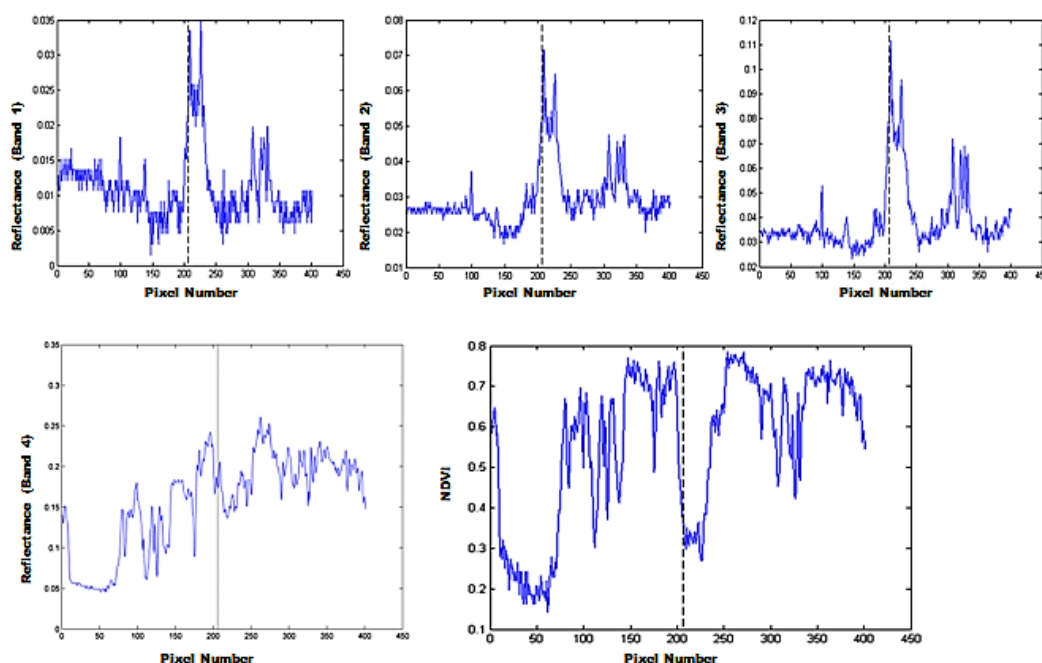


Figure 3: Blue, Green, Red and Near Infrared reflectance and NDVI for Eleme Refinery I (17/01/1986).

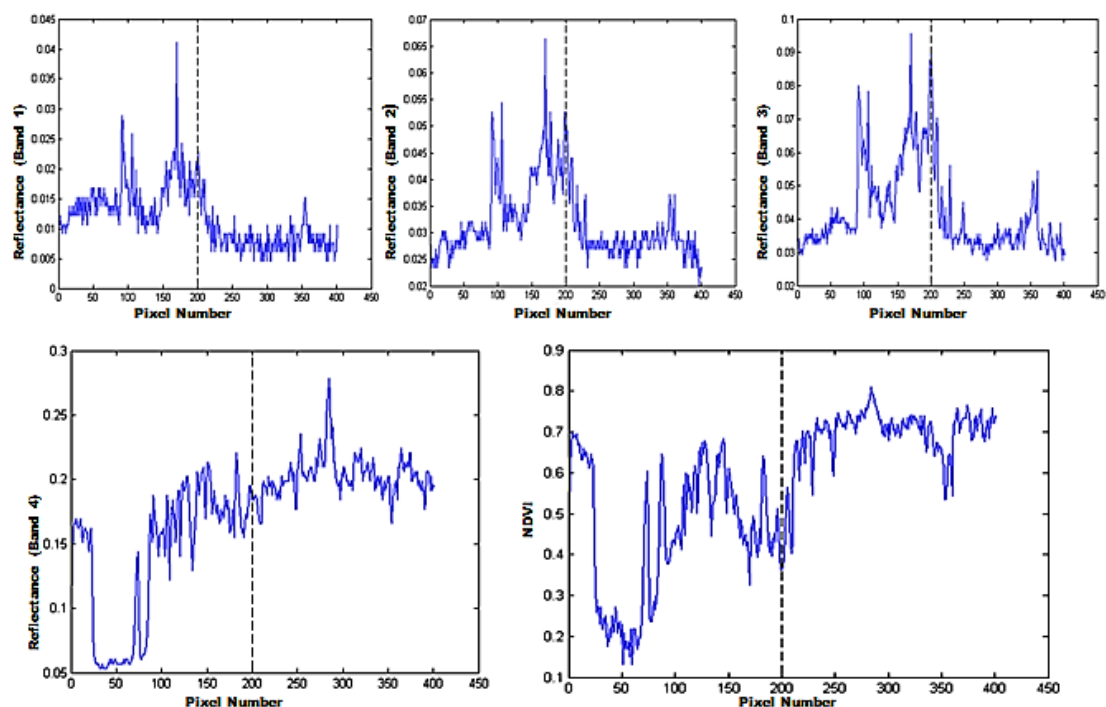


Figure 4: Blue, Green, Red and Near Infrared reflectance and NDVI for Eleme Refinery II (22/12/1990).

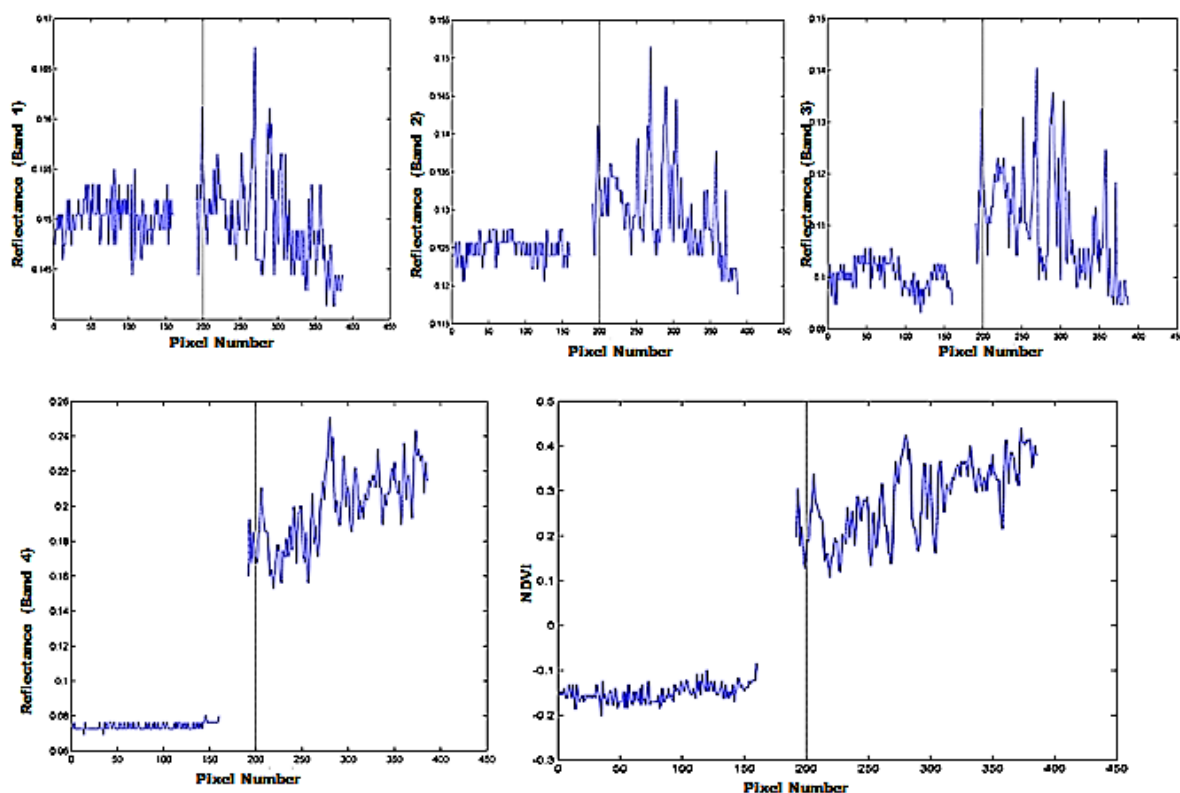


Figure 5: Blue, Green, Red and Near Infrared reflectance and NDVI for Bonny LNG (17/12/2000).

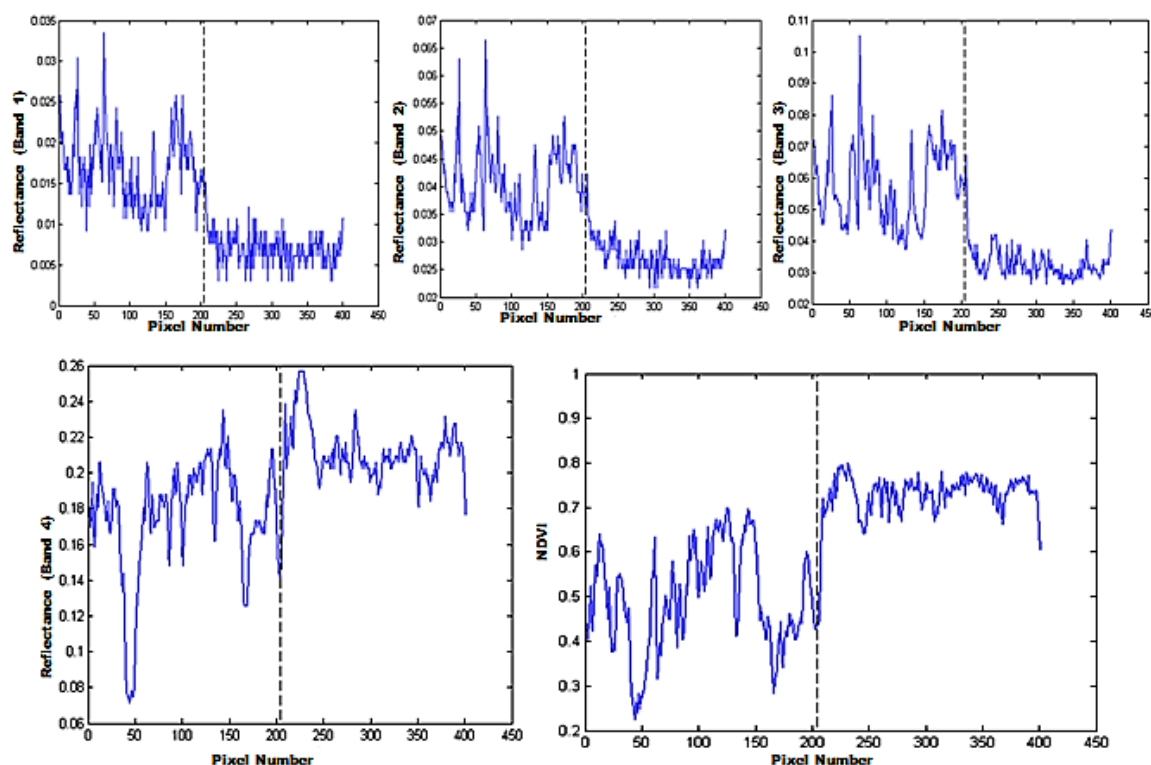


Figure 6: Blue, Green, Red and Near Infrared reflectance and NDVI for Umurolo (21/12/2007).

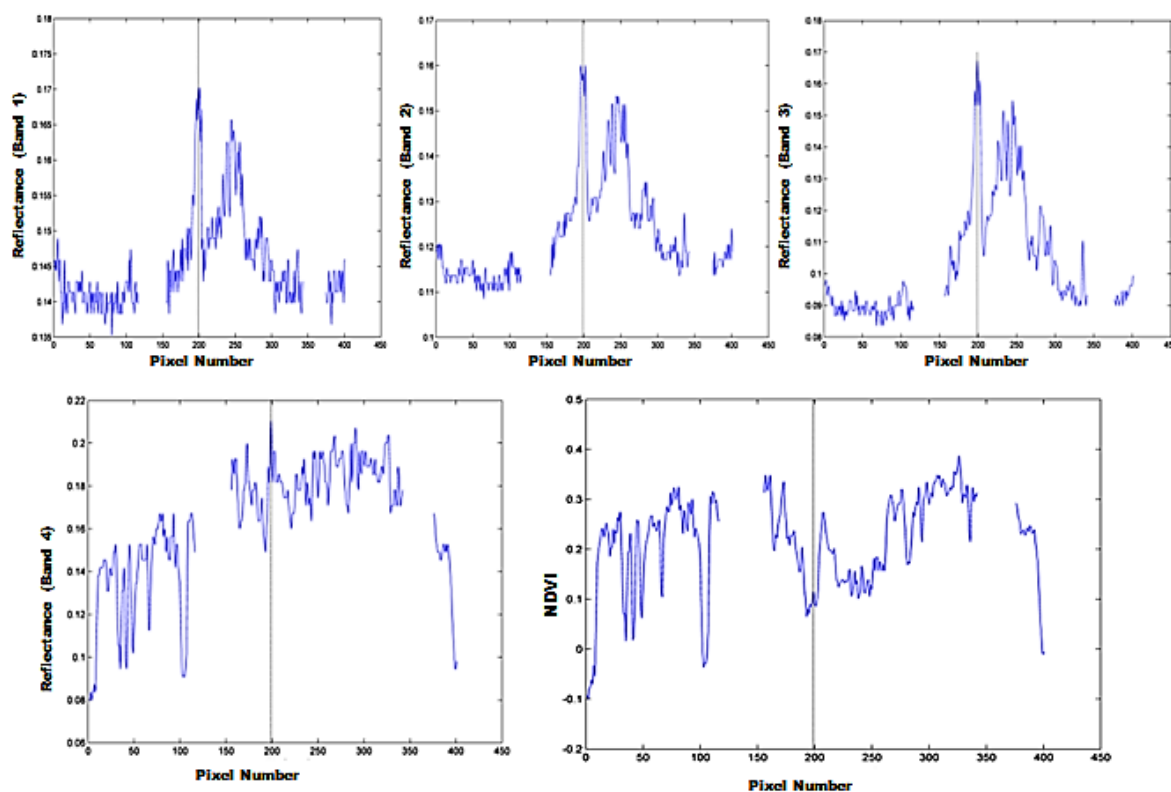


Figure 7: Blue, Green, Red and Near Infrared reflectance and NDVI for Onne (08/03/2013).

Table 1 presented facility sites, their flare stack heights, minimum and maximum value of NDVI; and range of NDVI values around the flare within an area of 150 m².

Table 1: Minimum and maximum NDVI value for the study sites

Facility site	Height of the flare stack (m)	NDVI values around the flare for an area of 150 m ²	Minimum NDVI values	Maximum NDVI values
Eleme 1	50	(0.25-0.28)	0.15	0.65
Eleme 2	65	(0.40-0.42)	0.13	0.80
Bonny NLG	25	(0.12-0.15)	-0.18 (Water body area)	0.43
Umurolu	60	(0.36-0.40)	0.22	0.78
Onne	3.5	(0.07-0.08)	-0.10 (Water body area)	0.12

Analyses of NDVI and LST using Four Cardinal Directions

Extraction of NDVIs and LSTs slopes in the North, East, South and West directions were carried out in order to investigate NDVI and LST results (Figures 8-12), with LST shown at the lower part and NDVI at the upper part of each cardinal plot. The plot is a 2 × 2 matrix with the following order: Top left (North), top right (East), lower left (South), and lower right (West). The missing data points in the plot for example in Figure 9 show cloud cover, water, and Landsat 7 scan line correction error. Symbols used for LSTs of 4 LC types are clearly shown in the figure keys as presented in Figures 8-12. The square shape green points show vegetation LST obtained at 60 m and 120 m distance; and vegetation LST obtained for 30 m pixel size is represented with black vertical or point in between the 2 green points. For this research, only vegetation LSTs is considered.

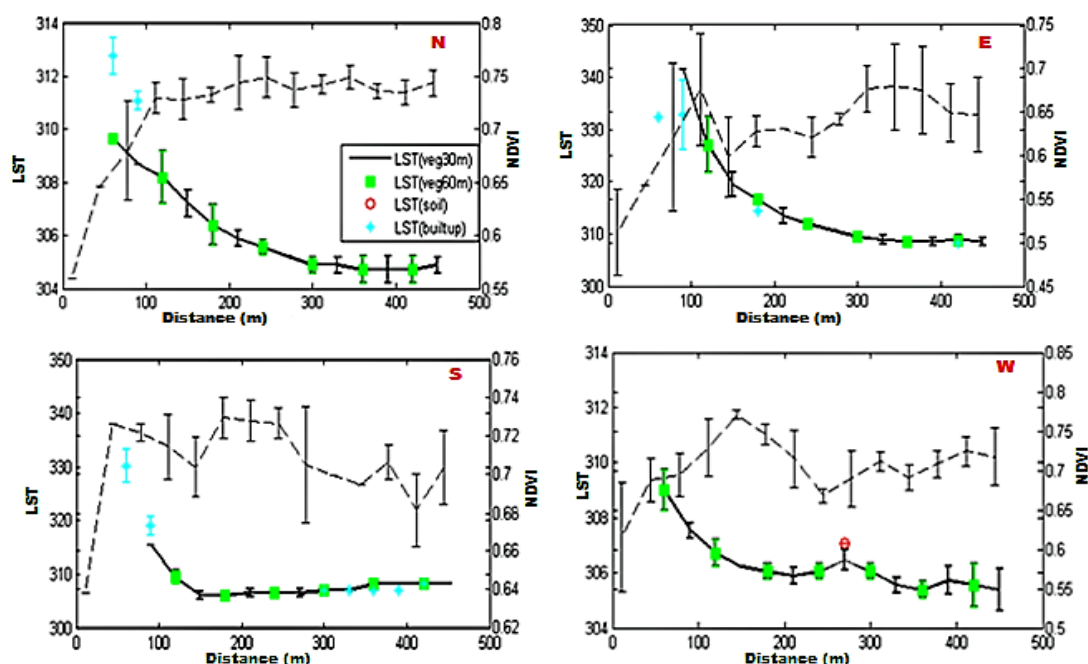


Figure 8: LST and NDVI (17/01/1986) for Eleme Refinery I, NDVI in dashed black line

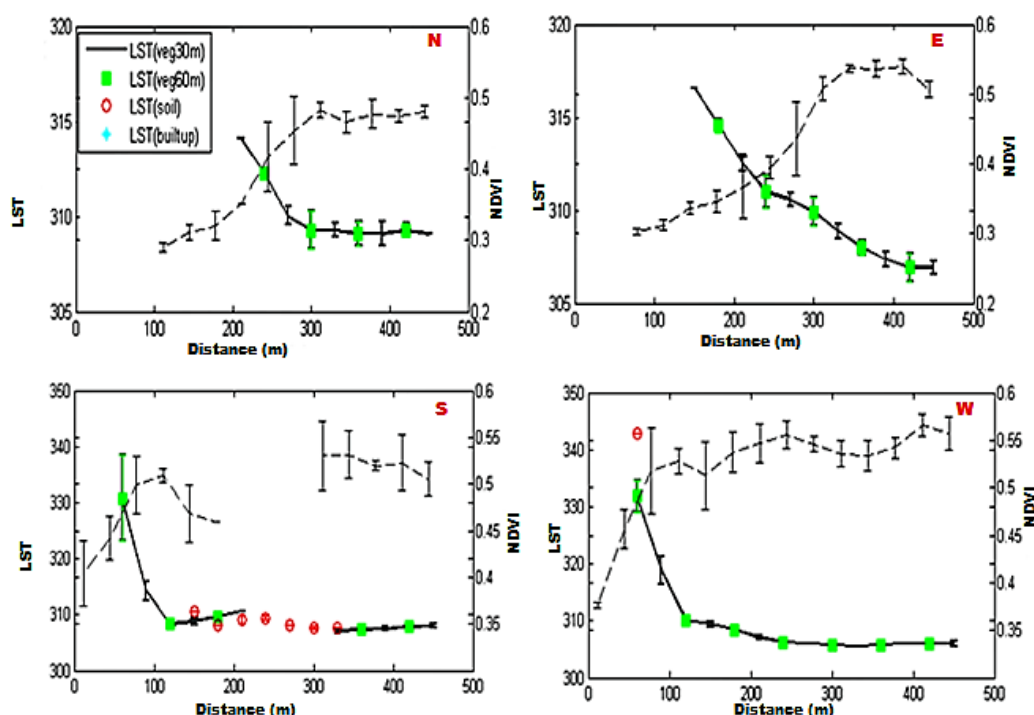


Figure 9: LST and NDVI (22/12/1990) for Eleme Refinery II NDVI in dashed black line

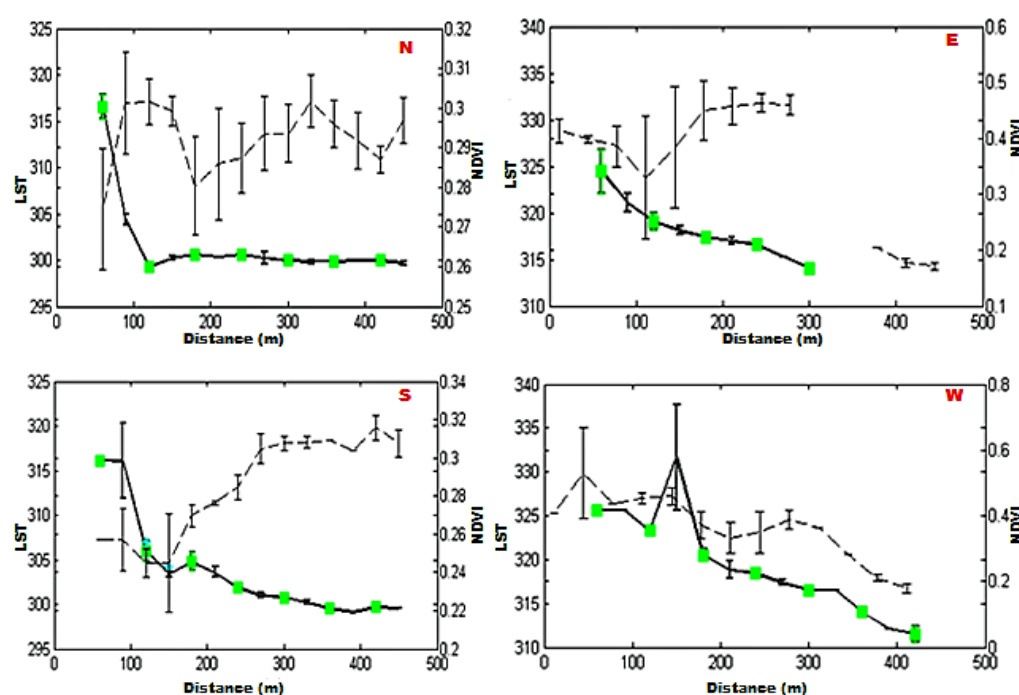


Figure 10: LST and NDVI (17/12/2000) for Bonny LNG NDVI in dashed black line

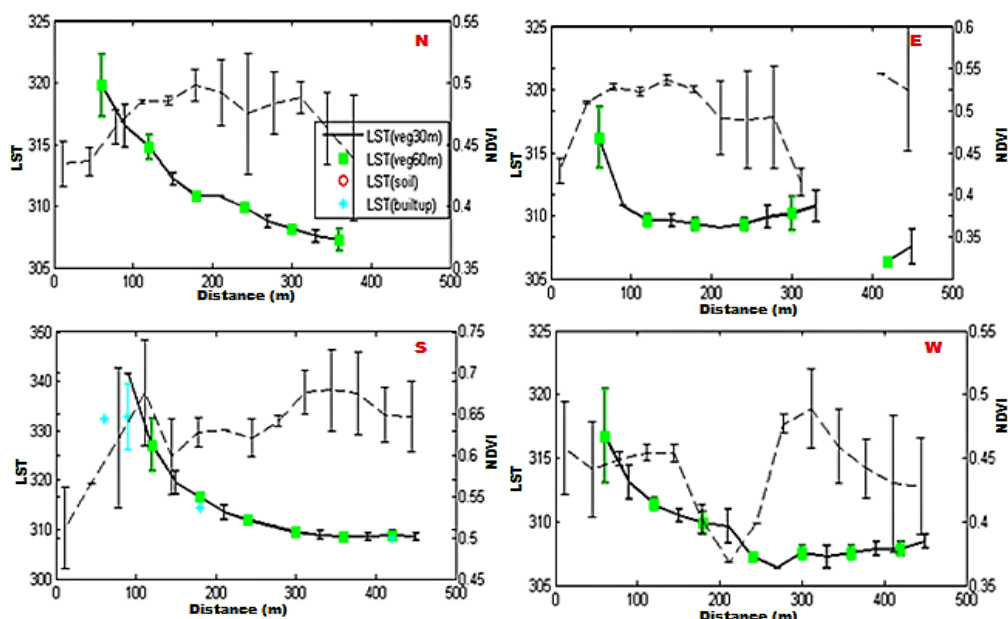


Figure 11: LST and NDVI (21/12/2007) for Umurolo Flow Station NDVI in dashed black line

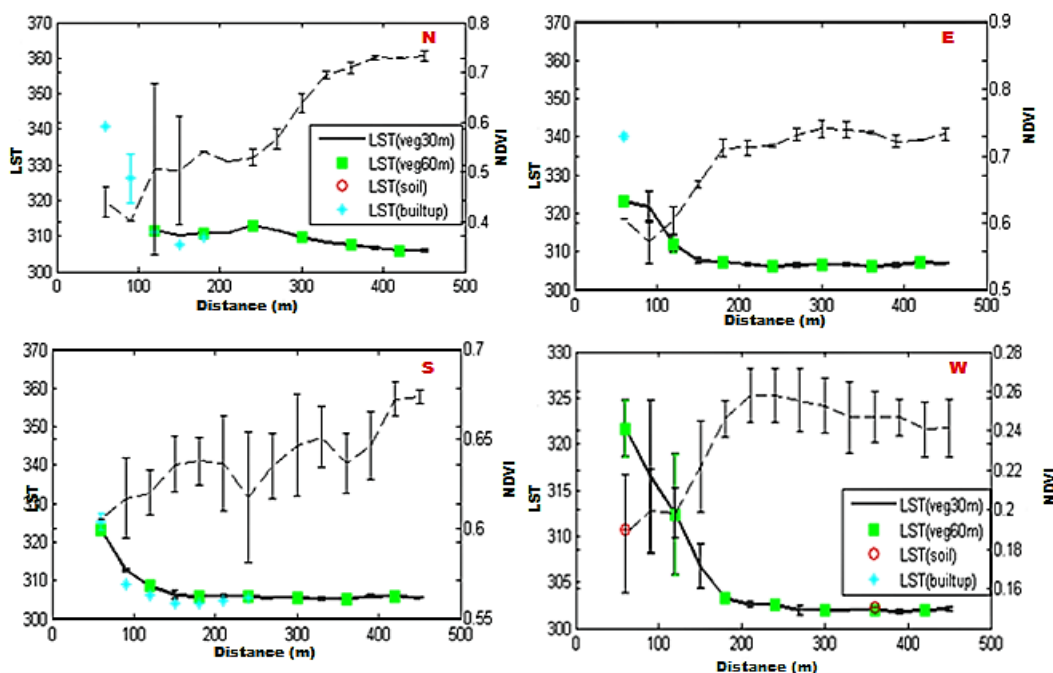


Figure 12: LST and NDVI (08/03/2013) for Onne Flow Station NDVI in dashed black line

Discussion and Conclusion

For Eleme I (Figure 3), the range of reflectance recorded for bands 1-4 are (0.002-0.036) m, (0.002-0.007) m, (0.010-0.110) m, and (0.050-0.260) m respectively; for Eleme 2 (Figure 4), we have (0.005-0.042) m, (0.020-0.067) m, (0.023-0.095) m, and (0.055-0.255) m respectively; for Bonny LNG (Figure 5), we recorded (0.005-0.145) m, (0.012-0.013) m, (0.005-0.140) m, and (-0.007-0.250) m respectively. For band 4, the minimum reflectance is recorded for the Northern part of the transect (lower pixel numbers) which suggests that the area is covered with water. Figure 6 presented Umurolo site with the Southern part of the site (higher pixel numbers) recorded the water body as shown in the reflectance for bands 1-3; and so we have (0.0053-0.034) m, (0.021-0.067) m, (0.025-0.105) m, and (0.07-0.248) m respectively and (0.136-0.170) m, (0.110-0.140) m, (0.020-0.169) m and (0.040-0.210) m for Onne (Figure 7) respectively.

Furthermore, the range of NDVI values obtained are (0.150-0.650) m, (0.130-0.800) m, (−0.018-0.430) m, (0.220-0.780) m, and (−0.100-0.120) m for Eleme I and II, Bonny LNG, Umurolo and Onne sites respectively. The almost zero reflectance for Bonny band 4, and −NDVI values for Bonny LNG and Onne Flow Station shows that pixels 0-199 are covered with water for Bonny as well as pixels 0-12.5 for Onne site. These results show non vegetated (water surface), bare soil, and sparse vegetation, which suggests that the effects of gas flaring has been displayed in all the sites examined.

Mean and standard deviation of NDVI obtained for the 5 sites are as follows: Eleme I (1.9166×10^{-5} , 2.0689×10^{-4}), Eleme II (1.5010×10^{-5} , 1.3596×10^{-4}), Bonny LNG (2.1294×10^{-5} , 8.2903×10^{-5}), Umurolo (5.8057×10^{-5} , 7.4988×10^{-5}) and Onne (2.2849×10^{-6} , 7.9515×10^{-5}). Generally, for the entire flare stack pixels, NDVI value reduced for all the 5 sites.

From Table 1 the range of NDVI values obtained for 150 m² area within the site is directly proportional to flares stack height. The lower the flares stack height, the lower the range of NDVI values recorded and vice versa. This suggests that the flare stack height of the facility has direct impact on the retrieved NDVI results. NDVI values recorded around the flare shows that the vegetation cover and vegetation health have been negatively affected which is supported by Adamu et al. (2015). In summary, Figures 3-7 and Table 2 shows that NDVI values and Landsat bands 1-4 reflectance has depicted the effects of the flare gas within the 5 sites considered for this study.

Figures 8-12 show that LSTs and NDVIs results exhibited opposite spatial distribution patterns at the 5 flaring sites examined. Generally, LST show the opposing direction with the correlated NDVI in the North, East, South and West directions examined. For all sites, flare stacks gives the highest LST values; LST decreases as distance from the flare stacks increases while NDVI values for vegetation cover increases. This is supported by some previous researchers (Imran et al., 2021; Pervez et al., 2021; Robinson et al, 2019; Song et al., 2018; Deng et al., 2018; Karnieli et al., 2010) who have used the relationship of NDVI and LST for their studies. They found negative relationship between them. However, Karnieli et al. (2010) used the same LST and NDVI relationship to assess the scope of moisture and climatic/radiation regimes during the months of April to September in the North America. From their results, they discovered that a positive correlation exists between LST and NDVI when energy is the restricting factor for vegetation growth in higher latitudes and elevations at the beginning of the growing season. They concluded that in North America, solar radiation is the principal factor propelling the correlation between LST and NDVI at the beginning and the end of the growing season although other biophysical parameters play a minor role. This suggests that the use of LST-NDVI relationships must be with caution; it must not be generalized for all studies but must be specific for local analysis.

Furthermore, the increase in surface temperature (Lu et al., 2020) around the flare stacks suggest that the vegetation within that area could have been badly affected (Nwaogu & Onyeze, 2020). Low NDVI values around the flare stacks could mean sparse spatial distribution of vegetation cover, low photosynthetic activity, diseased vegetation or non-vegetated areas (Weiss et al, 2004); bad vegetation health (Adamu et al., 2015); retardation of crop growth (Seiyaboh & Izah, 2017); damage crops (Nwaogu & Onyeze, 2020) etc. Hence, the effects of flare gas on vegetation cover within the sites investigated have been display by Figures 8-12; and that the effects of flare gas on vegetation cover at the flaring sites can be accessed using Landsat data. Therefore, changes in the pattern of NDVIs and LSTs for vegetated areas at the

flaring sites examined from 1986 to 2013 could be attributed to the effects of flare gas from oil and gas production facilities.

LSTs results show the opposite trend with the corresponding NDVIs results in all the 4 directions for the 5 flaring sites examined. Higher values of LST correspond to lower values of NDVI. Pixels that are nearer to the flare stacks have lower NDVIs values with higher LSTs values and vice versa. This suggest that vegetations, crops, soil etc within the area have been negatively affected that could lead to vegetation stress/ death, lower photosynthetic activities, reduction and/ zero crops production etc. The results suggest that gas flaring has detrimental effects on the vegetation cover and vegetation health at all sites. If flaring of gas is not stopped, agricultural activities in the areas surrounding the flares will be reduced to a very minimal degree; and degradation of the environment will make fishing and farming difficult.

Determination of NDVI for the entire Niger Delta; and ecosystem, social and economic consequences of flaring gas in Nigeria are useful pieces of further researches to undertake. Their results will help in showing the details of the spatial variability of the results of the flare gas in the Niger Delta as a region. Also, such future researches can be used for assessing the effects of flaring on the people and on the ecosystem of the Niger Delta. From the results presented in Figures 3-12 and Table 2, it can be concluded that Landsat 5 TM and Landsat 7 ETM+ have the ability to record the impacts of gas flaring in the Niger Delta, Nigeria.

Finally, because the results obtained from this research has shown that pollution from flare gas significantly leads to the loss of vegetation cover; damage of vegetation health, reduction of vegetation growth, agricultural products etc. Therefore, these recommendations are made: (1) Large and small utilization of gas must be adopted in Nigeria; (2) Nigerian Government should change gas flaring policy that a penalty of a huge amount of money will be paid by defaulters; (3) Nigerian Government should control the amount of gas flared into the atmosphere by the oil companies; (4) Developing adequate technologies for utilizing Associated Gas (AG) through electricity production using gas turbines in Nigeria.

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