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Assessment of Thermal and Landuse/Cover Dynamics in a Flare Area Using Remote Sensing and GIS Techniques

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Abstract:
Flaring in Nigeria contributes a measurable percentage of the world's total emissions of greenhouse gases; due to the low efficiency of many of the flares much of the gas is released as methane (which has a high warming potential), rather than carbon dioxide.This gas flaring expends huge amounts of energy and causes environmental degradation. This work quantitatively assess baseline changes near a flare area in the study area, especially with relation to the spatial variation through time, in landuse and thermal conditions, to determine risk scenarios or environmental exposure using Remote Sensing and GIS tools. The landuse/landcover change analysis was conducted using datasets obtained mostly from Landsat TM imagery obtained for a period between 1986 and 2010.The quantitative evidences of land use dynamics revealed the dynamic growth of artificial surface. Rate of change of built-up areas was as high as 3.55% between 2000 and 2007 indicating an upward trend in the growth of human population residing in the flare area. This indicates growing exposure to thermal pollution in the study area.Long term impact of gas flaring may be verified by studying medical history of residents within the buffered impact zone and those outside the area.

1. Introduction

Activities associated with the petroleum industry are by nature particularly targeted at the extraction of crude oil from the Earth's surface and associated substances. These activities through the established project workflows-prospecting, exploration, development, production and decommissioning have various inevitable adverse impacts on the immediate environment. These impacts include but are not limited to air and thermal pollution and environmental degradation arising from impacts on landcover, soil and even groundwater pollution in severe cases. Harmful substances in alarming proportions are released, and in general the equilibrium of the natural environment is eventually altered, with emerging risk to both flora and fauna in various magnitudes. A very significant activity associated with the production stage in oil and gas development is the flaring of natural gas....... Generally, it appears that the issue of gas flaring attracts little attention from concerned parties when compared to other adverse impacts such as oil spillage, being that the effect of gas flaring is not easily and immediately visible.

However, the World Bank estimates show that more than 100 billion cubic meters of gas is still flared or vented worldwide annually. As at 2001, more gas was flared in Nigeria more than anywhere in the world (EIA, 2003). The statistics publisher in the gas industry, Cedigaz, indicates that Nigeria accounted for 17.2% of global flaring in 2001, more than the second (Iran) and third (Indonesia) countries combined. The UNDP/World Bank in 2004 estimated Nigerian flaring at close to 2.5 billion cubic feet daily (over 70 million cubic meters daily), amounting to about 70 million tonnes of carbon dioxide (UNDP/World Bank, 2004). Approximately 75 percent of total gas production in Nigeria is flared, and about 95 percent of the "associated gas" which is produced as a by-product of crude oil extraction from reservoirs in which oil and gas are mixed (Khan, 1996). Currently, Nigeria has more than 100 gas flaring sites in the Niger Delta area, some of which have been burning ceaselessly for almost 50 years From the environmental health safety perspective, the most hazardous components are oxides of nitrogen (NO), oxides of sulphur (SO2), carbon monoxide (CO), particulates and the products of incomplete burning of hydrocarbons. Flaring in Nigeria contributes a measurable percentage of the world's total emissions of greenhouse gases; due to the low efficiency of many of the flares much of the gas is released as methane (which has a high warming potential), rather than carbon dioxide. At the same time, the low-lying Niger Delta is particularly vulnerable to the potential effects of sea levels rising. Eight countries—Algeria, Angola, Indonesia, Iran, Mexico, Nigeria, Russia, and Venezuela— account for 60% of flaring and venting worldwide, according to World Bank estimates.

1.1. Environmental Impact of Gas Flaring in Nigeria

Near flare areas, another widely noted kind of pollution arising from the activity gas flaring) is thermal pollution. One study of flares in the Niger Delta found that air, leaf and soil temperatures were increased up to eighty or one hundred meters from the stack, and species composition of vegetation was affected in the same area. There are many claims and counter claims about the spatial impact of thermal anomalies in flare areas. James Argo, in his 2001 Report prepared for 'Save Our Seas and Shores' (SOSS), Canada, described flaring as a broad multi faceted disturbance of the system of human activities for as much as 30km from any flare. The report stated that when sea-water containing chloride is introduced into the flare containing organic matter, dioxins which have serious health effects are formed. Argo further stated that there are about 100-150 chemicals created during flaring. The 2001 Report titled 'Unhealthy Effects of Upstream Oil and Gas Flaring' described flaring among others, as follows: "A well operating flare is opposed to well – accept principles of sustainable development. A poorly operating flare is a travesty against the entire biosphere within up to a 30km radius. It is axiomatic that where a flare is smoking no one should be downwind.'' Many studies also indicate that communities do believe that the flaring has led to very serious pollution of air and marked increase in temperature around the flare areas (Africa News Service 2003).

A press release from the United states Department claimed that ''apart from the release of green house gases into the atmosphere, gas flares are said to release some 45.8 billion kilowatts of heat into the atmosphere of the Niger Delta from gas flared daily. As a result of this incineration of the environment, gas flaring has raised temperatures and rendered large areas uninhabitable.''

Summarily, all these claims are indications of thermal anomalies near flare areas. Also, although some flare locations are very remote areas, others are located in some areas experiencing rapid rural-to-urban growth which indicates a higher risk impact ratio. The focus study area of this research falls into this category.

Surface air temperatures are definitive indicators of UHIs but require many measurement stations and meteorological models to determine air temperature patterns. Surface temperatures are more easily measured or estimated. However, surface temperatures are only indirect indicators of air temperatures. Air from differing thermal regimes mixes within the atmosphere and causes the relationship between surface and surface air temperatures to be somewhat variable. Air movement can create an urban thermal plume downwind from the heat source.

2. Aims and Objectives of the Study

Oil companies operating in the Niger Delta, like Shell has adopted the three pillars of sustainable development" because it makes good business sense to do so. Shell recognizes the interrelatedness of the three dimensions of sustainable development corporate financial responsibility, corporate environmental responsibility, and corporate social responsibility. On environmental issues, available evidence suggests that, Shell and other few oil companies have satisfied the operating guidelines established and supervised by government authorities - Department of Petroleum Resources (DPR) and the Federal Ministry of Environment (FMEV). These include the execution of Environmental Impact Assessments (EIA) for new projects as well as Environmental Evaluation Reports (EER) for ongoing operations

In 2009 briefing notes of SPDC, it was noted that

'' In general, flares were originally located away from where people were living. However, attracted by economic opportunities, communities have since grown around some areas of our operations.'' In an earlier development, a World Bank Report in 1995 indicated that any negative effects of flaring were confined to the immediate vicinity of the flare and would have little or no impact on the population. But with the growing awareness on the contributions of CO_2 emissions to climate change, there is need to study trends in thermal flux around sensitive production facilities like gas-flaring sites.

A major aim of this study therefore is to quantitatively assess baseline changes near a flare area in the study area, especially with relation to the spatial variation through time, in landuse and thermal conditions, to determine risk scenarios or environmental exposure using Remote Sensing and GIS tools. This would be achieved through the following objectives:-

- Carry out an assessment of the of land use change dynamics in the area of study through a time-lapse series analysis in order to identify the pattern of landuse/landcover change in the study area.
- To determine risk scenarios arising from changes in landuse pattern and surface temperature flux in the study area and human population exposure to pollution risk
- To compare thermal anomalies at different flare sites by cross examining Land Surface Temperature in flare and no-flare areas with similar landuse cover pattern

3. Study Area Overview

The Obigbo Field was discovered in 1963. The Field itself is situated in the eastern part of the Niger Delta, some 18 km northeast of Port Harcourt. It lies within OML 11 and OML 17 and covers approximately 50 square km. The geographical profile of the area falls within 510000 – 520000 E and 95000 –100000 N co-ordinates. The actual study area is the Obigbo North in Rivers state and adjoining areas. These adjoining areas include areas around part of Elelenwa fields, Agbada, Ajokpori and Isimiri fields. The study area covers a total area of about 576sq.km. Oil and gas activities in the area stretch back in time to the 60s.

The map below shows the actual study area, with flare sites, the area chosen as calibration area; area with similar landuse cover but no physical flare sites and the existing flare areas in the Niger Delta.

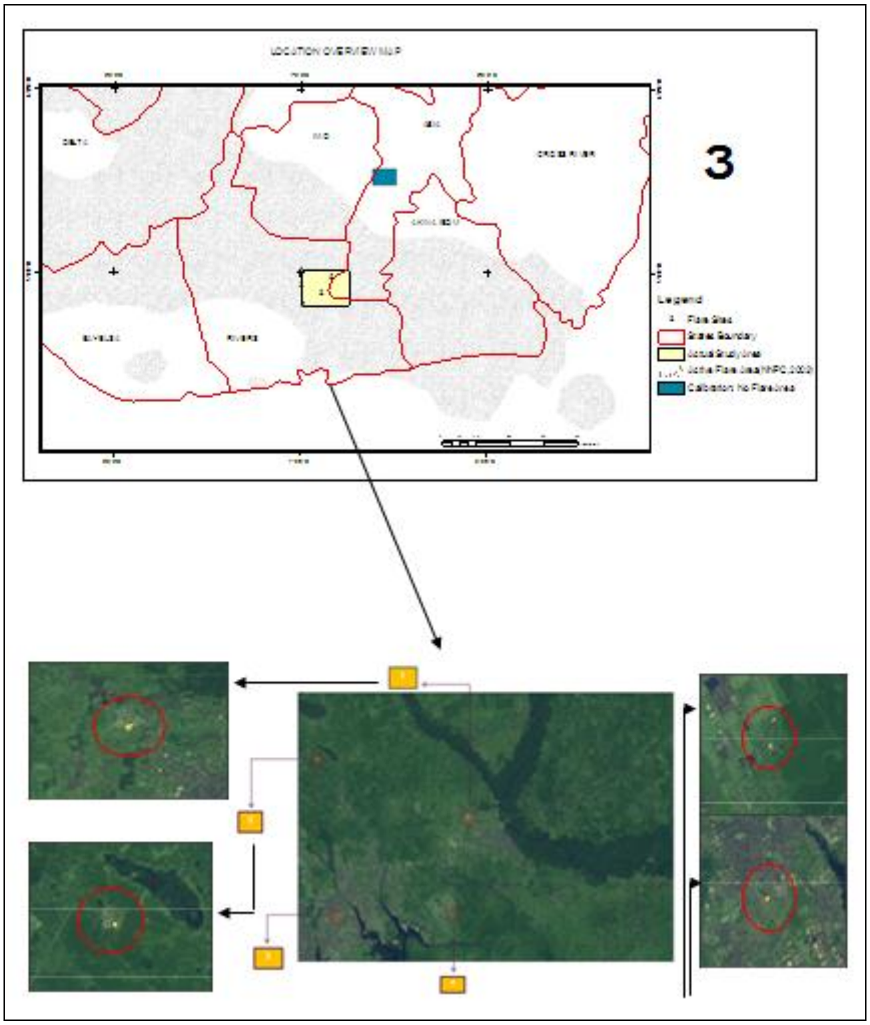


Figure 1

Derived Band 753 ETM Landsat Composite showing location of Flare sites (in the flare area) on Imagery (Source; Global Land Cover Facility Website). Notice the Y-shapedImo River in the centre of the Imagery with adjoining heavy forest and swampy locations (wetlands) south west with settlements and farmland showing the sensitive ecosystem in the area.

Reference Year	Sensor	Resolution	Path/Row	Date of Acquisition	Source
1986	Landsat TM	30m	188/57	19th Dec, 1986	Global Landcover Facility Website(GLCF)
2000	Landsat ETM	30m	188/57	17th Dec, 2000	Global Landcover Facility Website(GLCF)
2007	Landsat ETM	30m	188/57	19th Jan, 2007	Shell Petrolem Development Company (Geomatics Division)
2010	Geo-Eye Imagery	0.6m		January 2010	Shell Petrolem Development Company (Geomatics Division)

Table 1: Showing Summary of Dataset and their Sources

The landuse/landcover change analysis was conducted using the following datasets, mostly products of space-based remote sensing from the Landsat platform. An investigation of landuse cover pattern in the flare area with 2010 geo-eye high resolution imagery was done to map even more recent landuse pattern and relate exposure to risk scenarios.
Table 1: Showing Summary of Dataset and their Sources
Other data sources include topographic maps and existing landuse maps of the area obtained from the Rivers State Geographic Information Systems (RIVGIS),EIA reports, Environmental Evaluation Reports, Shell Briefing Notes, and online journals.
Software utilized in this project includes ERDAS Imagine 9.2, ArcGIS 9.3 and Microsoft Excel. Hardware includes 17'inch size monitors and a System Unit of 8GB of RAM (Random Access Memory), with 3.0 GHZ processing frequency for the Central Processing Unit.

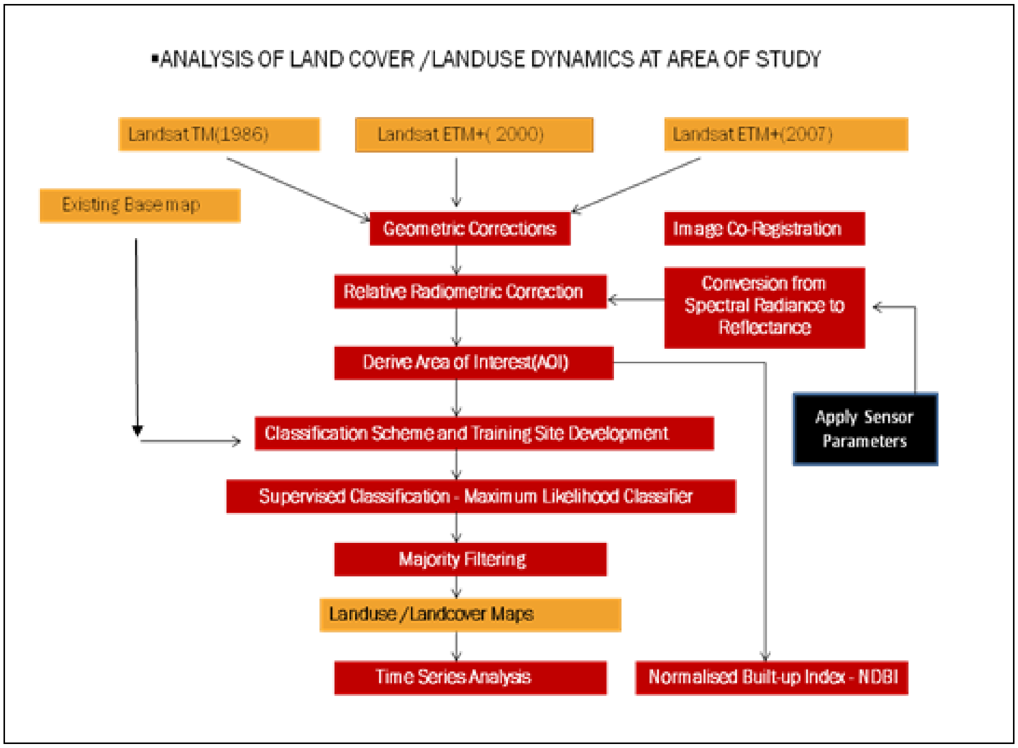


Figure 2

The whole workflow was implemented with Erdas Imagine 9.1. The temporal window within which the Land change/Landcover analysis was conducted was 1986-2007, while the 2010 high resolution imagery was used to highlight risk arising from increasing settlement density in the flare area.

3.1. Mapping of Land Surface Temperature using Space-based Imagery

To check for vital signs of thermal anomalies in the flare area, one of the objectives of the study was to derive Land Surface Temperature (LST) maps of both the flare and a non-flare area, with similar landuse configuration to compare and contrast their LSTs in order to investigate if there are significant differences that may arise from gas flaring in the flare area.

The derivation of land surface temperature from Landsat satellite imagery from available literature is essentially a three-step process which involves:-

- The conversion of Digital Number of the Raw Imagery to Spectral Radiance.
- The conversion of the Spectral Radiance to Land Surface Temperature(in Kelvin)
- The standardisation of derived temperature values to the Celsius Scale

.

Thermal Data Derivation was executed with ERDAS IMAGINE 9.1 using the Visual Programming Module, Spatial Modeler, an interface that allows the interaction of raw imagery and scripts. The parametric equations that govern each stage of the thermal data derivation are defined in function boxes in the form of scripts which are connected to holders that allow these functions to act upon the input raw imagery (band 6).

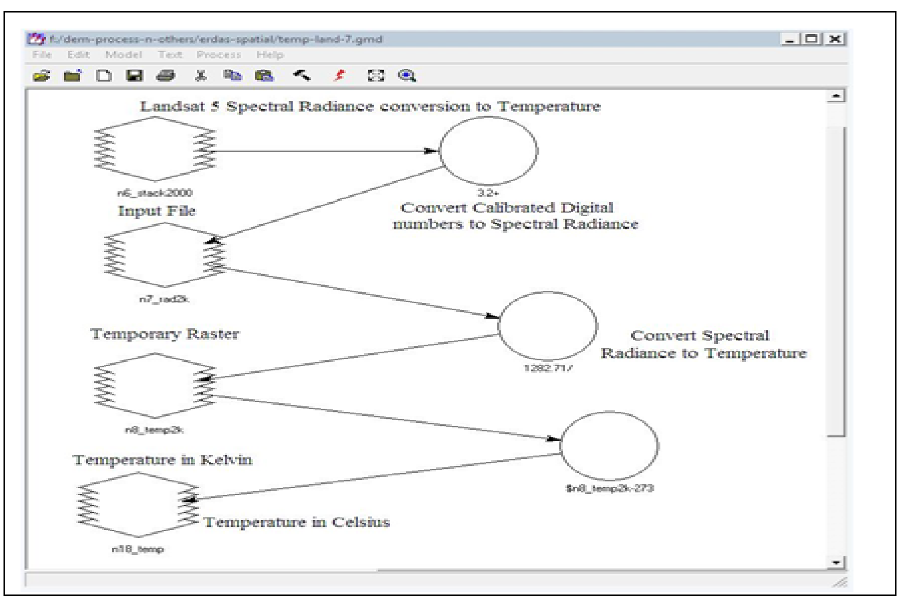


Figure 3

Programming the Thermal Derivation Process with Erdas Imagine Spatial Modeler. The thermal derivation was conducted for 1986 and the year 2000.

4. Result and Analisis

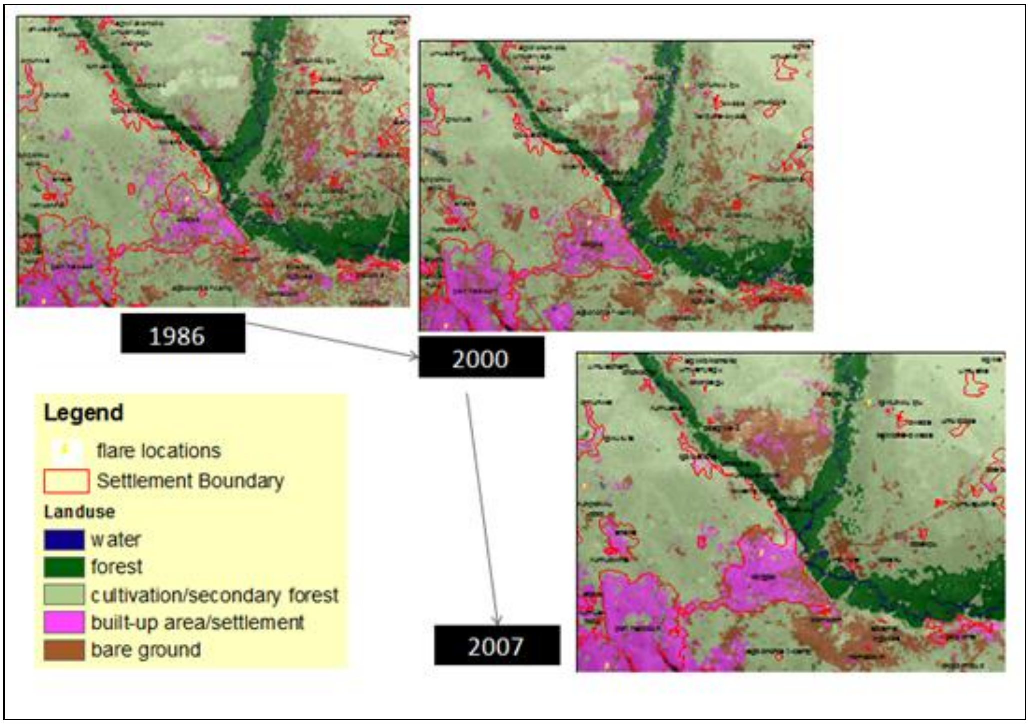


Figure 4: Analysis of Landuse Dynamics in the Flare Area

	Temporal Change Rate (%)		
Landcover Type	1986-2000	2000-2007	1986-2007
Forest	-2.46	+1.11	-1.35
Cultivation	+4.36	-0.85	+3.51
Bare Ground	-2.61	-3.64	-6.25
Built-up area/Settlements	+0.5	+3.55	+4.05
Water	+0.21	-0.17	+0.04

Figure 5

The table above (from analysis conducted from the interpreted imageries above) shows that there has been an increase in the density of built-up area around the area of flaring. Another indices from the space-based imagery used to establish increasing density of the built-up area in the flare in the 21 year(1986-2007) period was the Normalised Bulit-up Index(NDBI), which in literature is given by;

$$NDBI = \frac{MidIR_{TM5} - NIR_{TM4}}{MIdIR_{TM5} + NIR_{TM4}}$$

The bands used are the Mid Infra red Band (Band 5) and the Near Infra Red Band (Band 4)

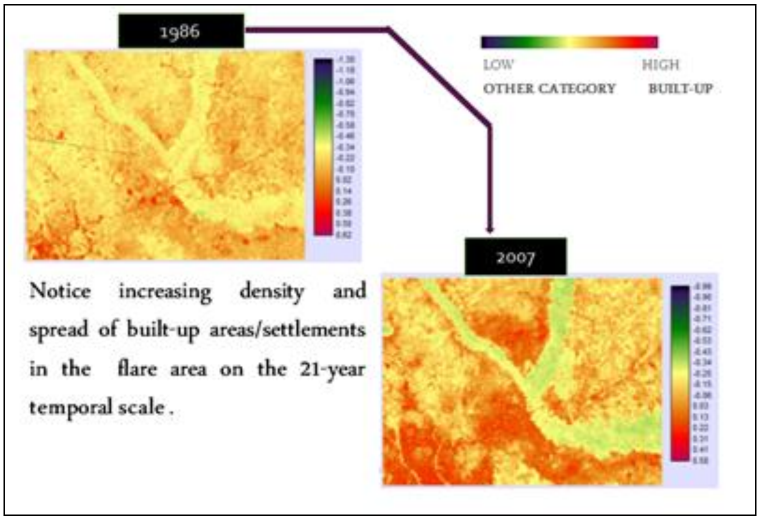


Figure 6

Earlier environmental assessment shows that urban landuse in the area has evolved with increasing industrial activity in the area which can be directly linked with increasing population in the study area, as economic activity attracts human settlers by geographic connotations. Over the 21-year period, the Shell'soperations in the area has expanded with the need to construct more roads in the study area, and other socio-economic facilities. The relative stability of the fresh water forest along the Imo River can be attributed partly to traditional values where part of these forests are regarded as sacred areas reserved for spiritual symbolism in their traditional religion, although the small areas cleared are converted mostly to agricultural use. Another reason may be attributed to difficult terrain as a lot of wetland surrounds the forest.

However, The overall disturbance of the ecosystem in the area appears to be on the low side given the low level changes in the forested area which adjoins a major river passing through the area(the Imo River) – as low as 1.35% in a span of 21years. This is an interesting development given the role of forests as carbon sinks.

Nevertheless, it is significant that the increasing presence of human settlement in the area indicates increasing risk to thermal pollution in the study area.

4.1. Thermal Anomalies Investigation

One location not in the flare area (see first map above) was compared to the area of flaring to investigate whether they are significant differences in thermal composition. To ensure that the comparison is as justified as possible, the LST was derived from areas with similar landuse configuration and imageries of the flare and non flare area captured in the dry season spanning 14 years (1986-2000). Imagery below shows 543 band composite of the flare and no flare area

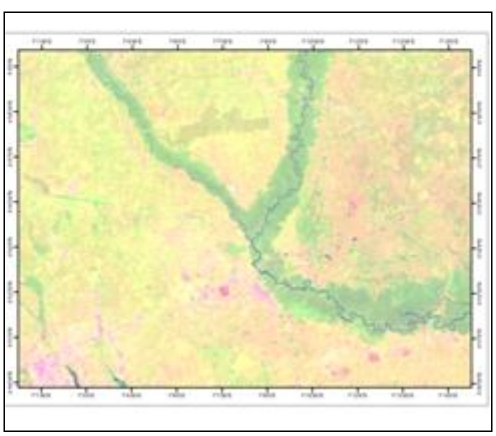


Figure 7: Flare Area (Ogbibo and environs)

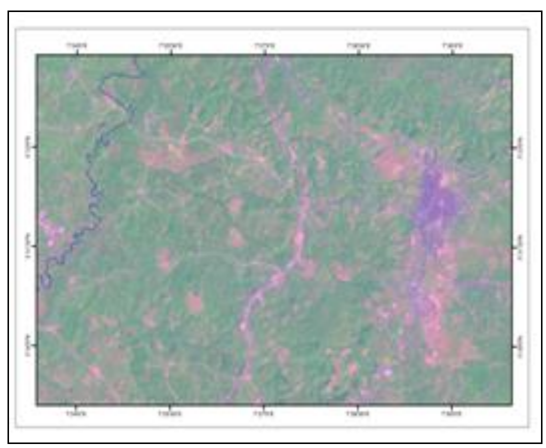
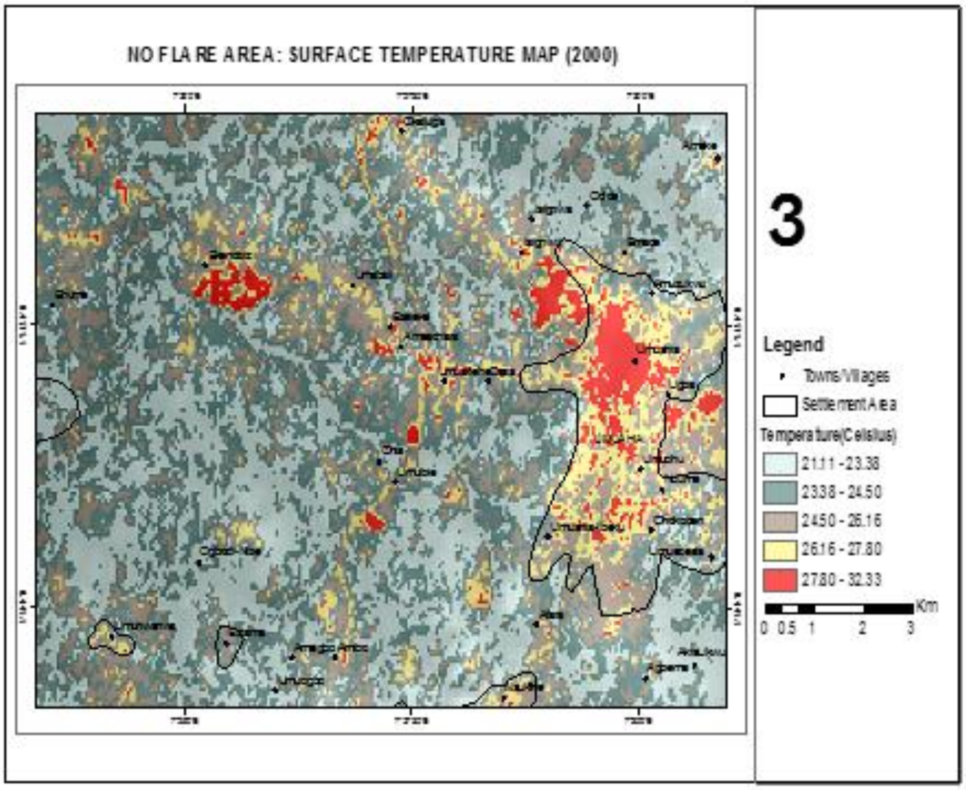
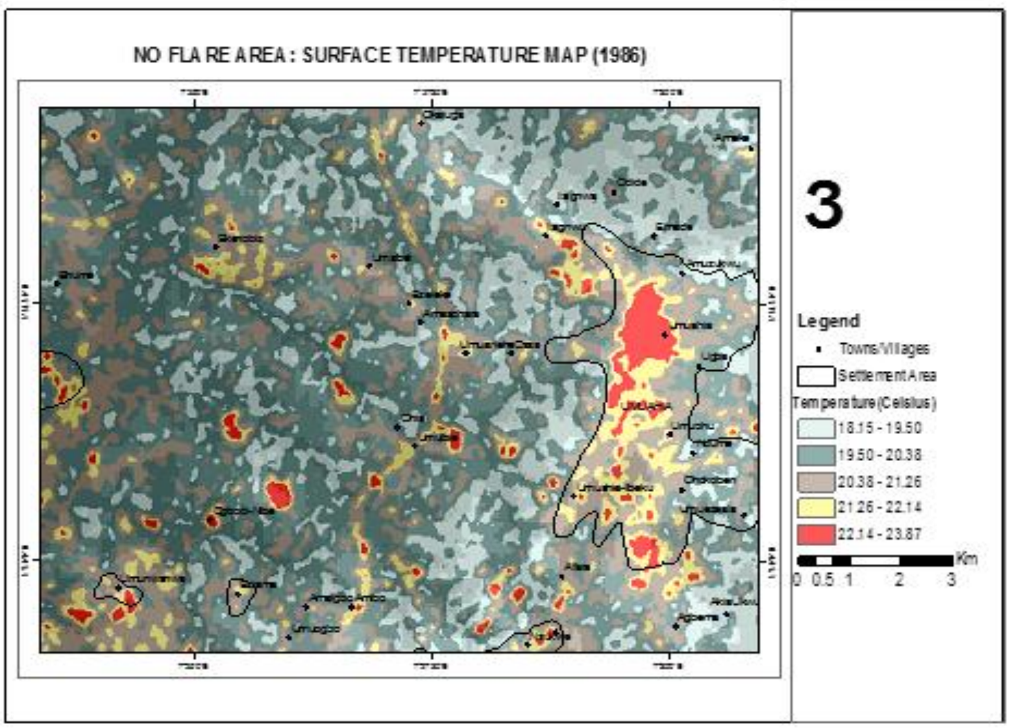


Figure 8: Area around Abia State (no Flare Area)

The two areas have a common eco-system; they are urban/semi-urban in form with similar vegetative characteristic- farms, rivers, previous cultivation, bare surfaces and expanding settlements. The No-Flare area is in Abia State.


NO FLARE AREA: SURFACE TEMPERATURE MAP (2000)
3
Legend
Towns/Villages
Settlement Area
Temperature(Celsius)
21.11 - 23.38
23.38 - 24.50
24.50 - 26.16
26.16 - 27.80
27.80 - 32.33
Km
0 0.5 1 2 3


NO FLARE AREA: SURFACE TEMPERATURE MAP (1986)
3
Legend
Towns/Villages
Settlement Area
Temperature(Celsius)
18.15 - 19.50
19.50 - 20.38
20.38 - 21.26
21.26 - 22.14
22.14 - 23.87
Km
0 0.5 1 2 3

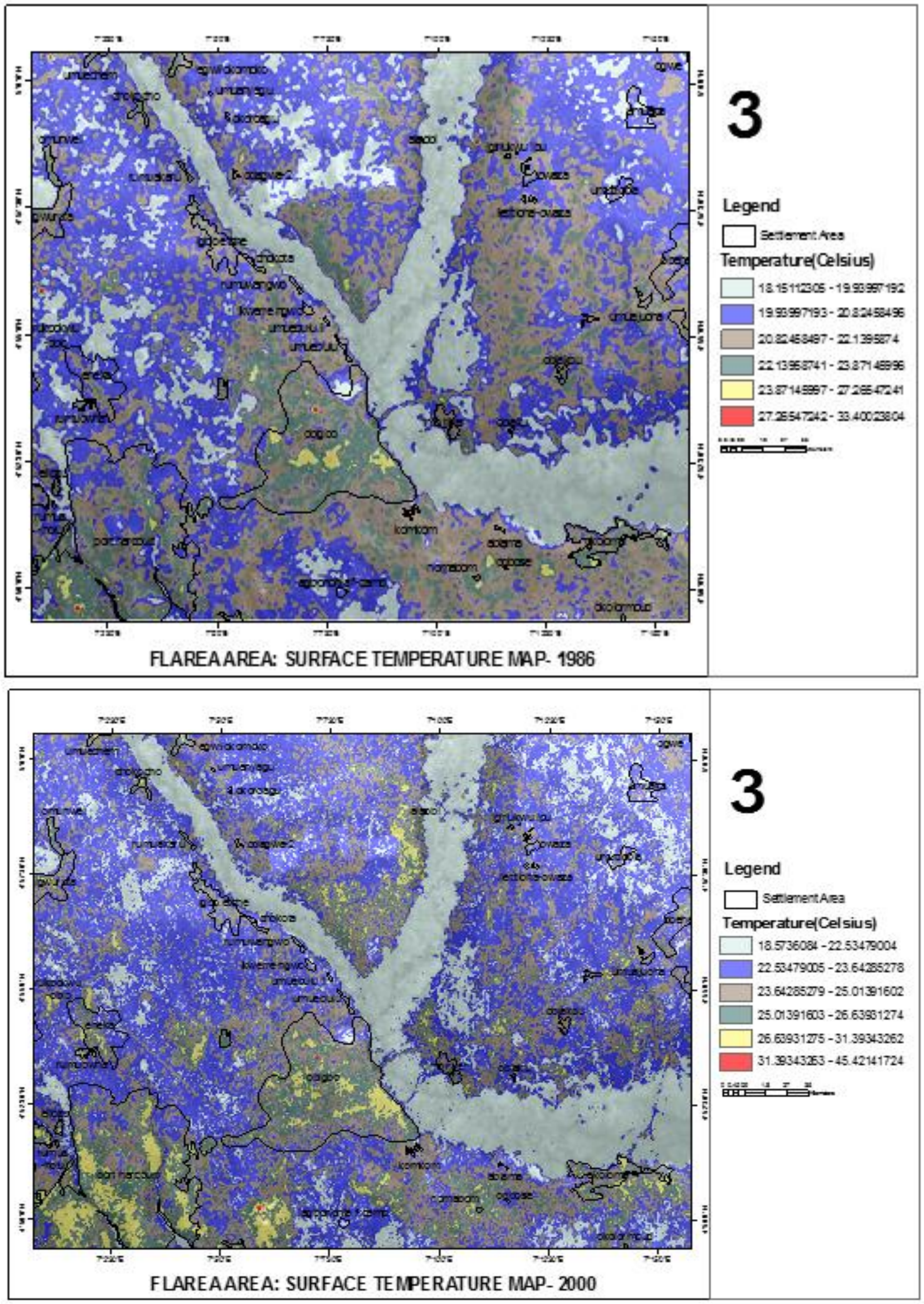


Figure 9

Generally, temperature ranges are 18-23(degree Celsius) in the no flare area and 18 to 33 in the flare area in 1986 and 21-32 in the flare area and 18-45 in the no flare area for the year 2000. There is every likelihood that the higher range Land Surface Temperature ranges in the flare area in both years (1986, 2000) are influenced by the gas flaring.

The land surface temperature maps derived from the landsat imagery show a spike in temperature at flare locations compared all other locations and generally lower temperatures in the no-flare area compared to the flare area. To investigate the influence or likely impact of the gas flaring, thermal profiles showing changing distance with temperature was drawn from the flare sites using ArcGIS 3D Analyst.

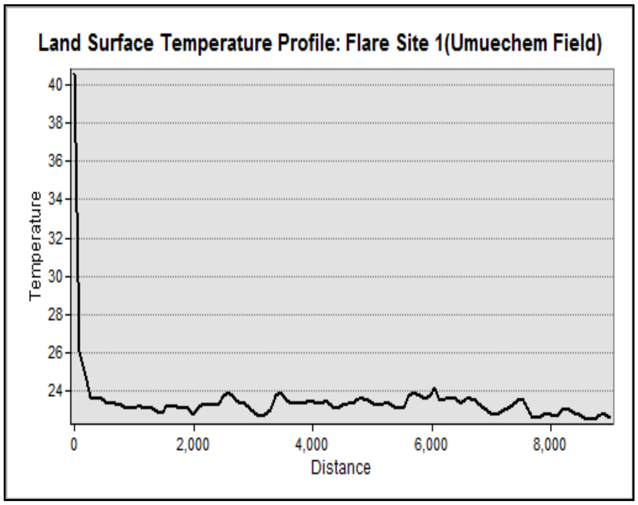


Figure 10

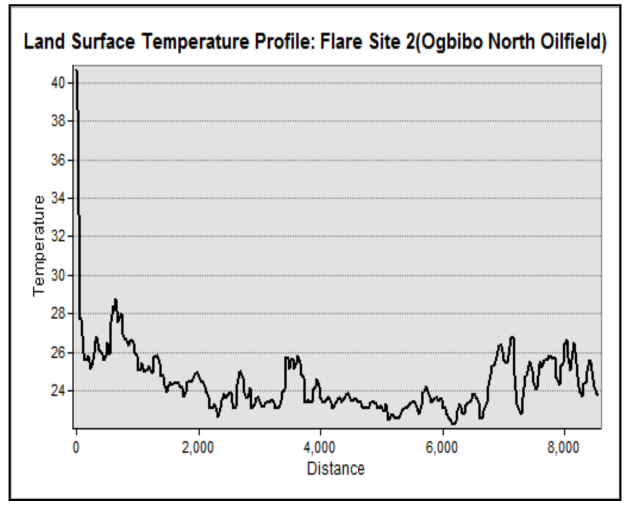


Figure 11

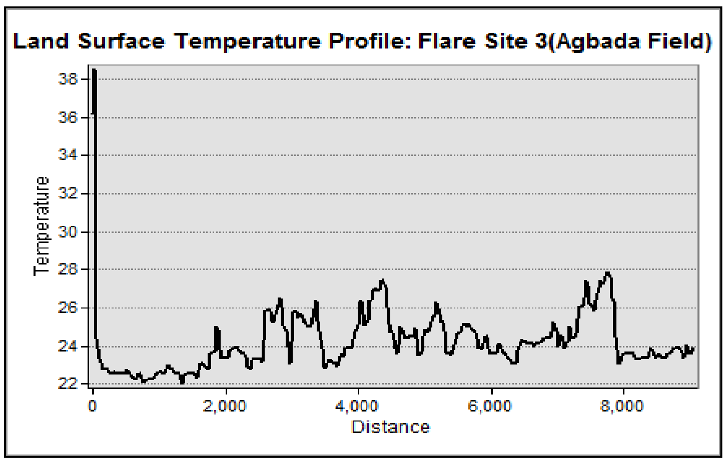


Figure 12

5. Conclusions and Recommendations

Thermal anomalies do exist in a flare area with the impact of thermal pollution being mostly local (200-300m), as confirmed by cross-examination with an area free of the influence of flaring. Higher temperatures in built-up areas shows that growth in urbanization can also be associated with rising thermal profiles, as they are low temperatures around the heavily forested area in the flare area.

- In some locations in the study area, there is high density of built-up area within the immediate vicinity of the flare locations. This may have health implications. Long term impact of gas flaring may be verified by studying medical history of residents within the buffered impact zone and those outside the area, if the health impact of gas flaring is to be determined as they are claims that some kind of respiratory diseases are associated with pollution from flaring.

-The quantitative evidences of land use dynamics revealed the dynamic growth of artificial surface. Conversions of land from cultivation and bare areas to built-up areas and settlements represent the most prominent land cover change, where the rate of change of built-up areas was as high as 3.55% between 2000 and 2007 indicating an upward trend in the growth of human population residing in the flare area. The trend and extent of urban change between 2000 and 2007 is likely to continue with the rapid development of infrastructure and increasing population. This indicates growing exposure to thermal pollution in the study area.

The scenario is highlighted here with a 2010 landuse map of the area showing an analysis of pollution risk in the study area- with increasing density of built-up area around the vicinity of the flare area especially around obigbo.

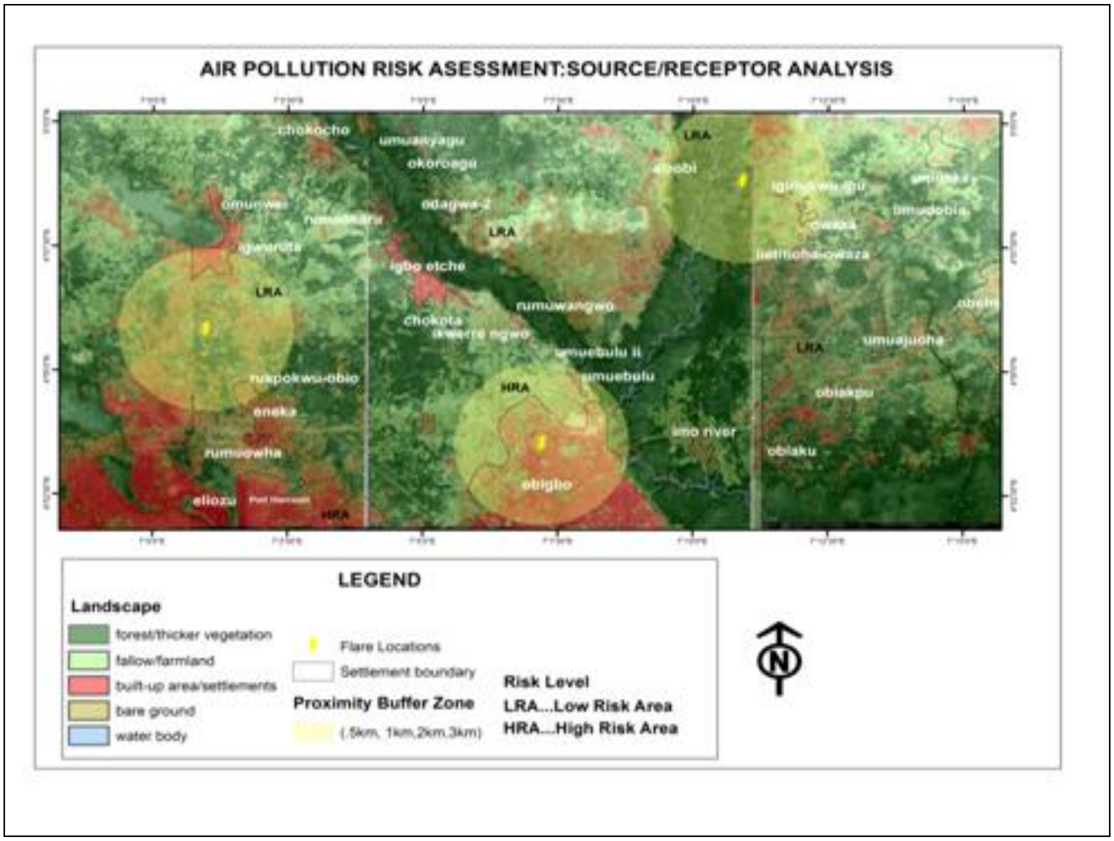


Figure 13

6. Acknowledgements

This research was undertaken in collaboration with the Geomatics Dept, Shell Port and Warri Locations, and Teaching Faculty, in the University of Ibadan and the Federal Polytechnic Ado-Ekiti. Many thanks to the Shell Environmental and Geomatics Department in SPDC Port Harcourt, for contributions they made towards the project, by providing satellite imagery and Environmental Evaluation advice.

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