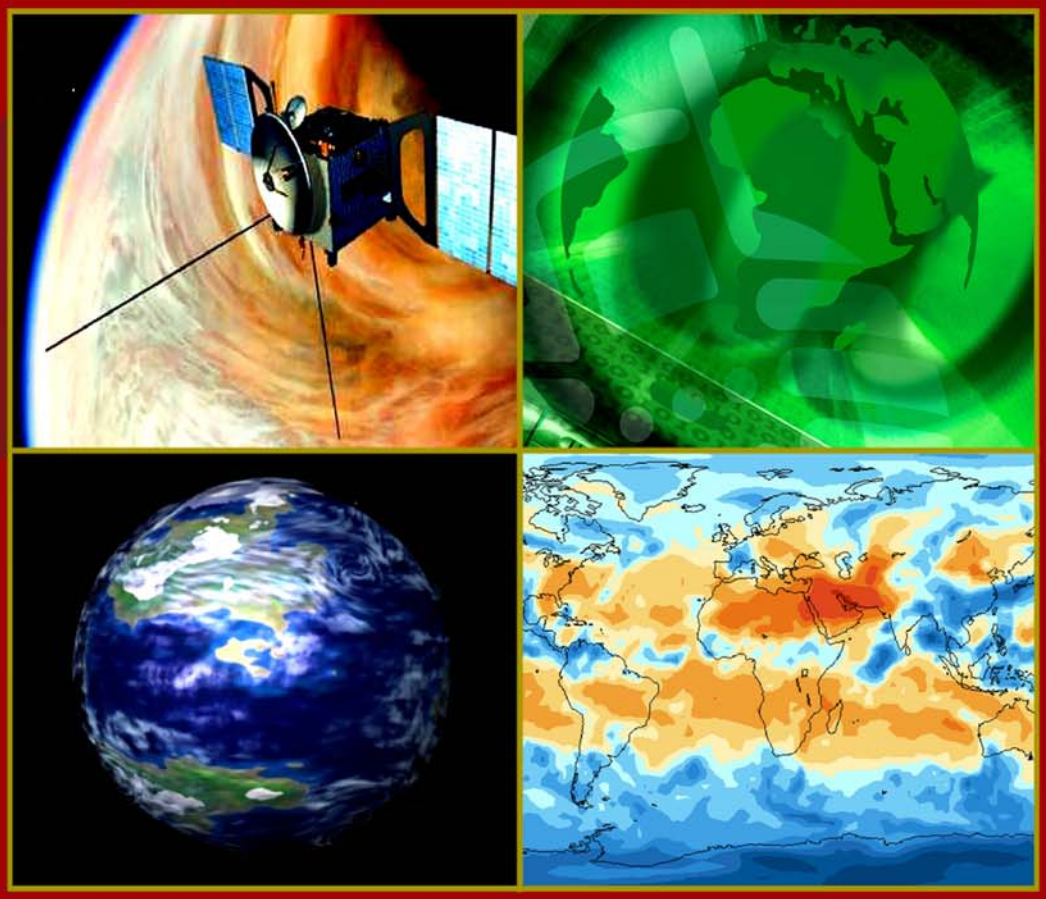

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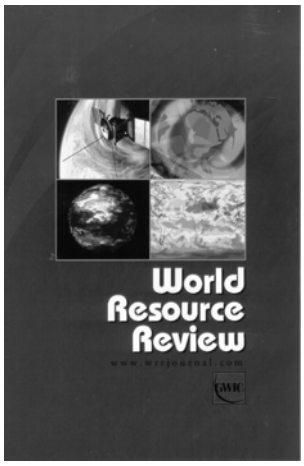

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GIS Applications In Global Environmental Protection: The Case Of Environmental Monitoring Of Fossil Fuel Emission From Oil And Gas Activities in Africa

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ABSTRACT

The practical applications of a mix scale approach involving GIS and remote sensing offers governments and enterprises a solution for monitoring the carrying capacity of fragile ecosystems, such as the River Niger Delta.

In the last decades, policy debates within the field of global environmental protection have identified the continuous release of carbon into the atmosphere from the consumption of fossil fuels emanating from oil and gas activities. This article uses descriptive statistics, geographic information systems (GIS) and remote sensing techniques to examine fossil fuel emission trends and the state of emission sinks in a tropical ecosystem using Nigeria and Ghana as case study. Research was conducted by comparing data from Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory National Energy Center coupled with land use and land cover analysis from Landsat images. The results showed that the study area experienced significant changes in its emission of fossil fuel due to the burning of oil and gas.

The land cover area analysis shows the extent and nature of variation in carbon sinks (forest areas) were also quite pronounced in the oil rich Niger Delta of Nigeria. In the conclusions, the paper outlined various policy recommendations made up of continuous involvement for national and city governments in global forums, setting up of regional information network for

West Africa, the development of energy efficiency and economic diversification in the region as well as policy research and development. The paper suggests a Regional Information Network for West Africa.

INTRODUCTION

In the last several years, the total emissions for Africa rose by 9 times since 1950 reaching 235 million metric tons of carbon in 2002. This is still less than the emissions for nations such as the U.S. China, Russia and others. Although per capita emissions in 2002, of 0.29 metric tons of carbon, were 2.6 times above the 1950 levels, they were still only 5.4% of the comparable value for North America. In the African continent, emissions from solid and liquid fuels stayed at equal levels, while gas fuels account for 15.6%. Quite a few number of nations are mostly responsible for African emissions from fossil fuels and cement. The breakdown of the estimates for individual nations shows South Africa alone emits 40% of the continental total. The remaining combined 44% of the CO_2 originates from five countries (Egypt, Algeria, Nigeria, Libya and Morocco). These five nations are the only ones on the continent with annual CO_2 emissions above 10 million metric tons of carbon (Marlands, et al., 2003).

Because most developing nations in Africa lack a systematic operational monitoring network to identify the pollutant concentration at the national level, Ghana and Nigeria need to establish geo-based approach in monitoring the threats of fossil fuel emission for the purpose of environmental protection. Monitoring in the West African nations can play a role in the development of environmental policy by using monitoring data as a preamble in policy formulation pertaining to global climate change and the growing interest in environmental reporting among public and private sectors associated with oil and gas activities. Not withstanding its increasing role in program evaluation, monitoring plays a key role in setting targets and establishing priorities in the management and implementation of environmental programs (Messer, 2003). The other reason as to why monitoring is pertinent in environmental protection hinges on the fact that most environmental action plans first requires systematic monitoring mechanisms in place. This provides feedback by measuring the attributes of different variable linked with their emission sources.

Conceptually, the monitoring approach deals with the baseline conditions of criteria emission pollutants in the atmosphere such as fossil fuels (US EPA, 2002). Measuring the effects of these pollutants in the atmosphere helps shed light on the extent to which nature can withstand the intense stress emanating from pollutants. The knowledge of carrying capacity of the atmosphere is not only

important in developing the pollution prevention strategy but it is also important in prioritizing the implication for economic activities especially in resource dependent nations such as Ghana and Nigeria. As many nations are beginning to accord high priority to environmental safety before the start of development projects, the effectiveness of such approach in the West African region will come to rely on the baseline information provided through monitoring. Without knowing the baseline conditions, the predicted environmental impacts of development programs become a subjective exercise. This may be attributed to the fact that the national environmental standards associated with emissions not only hinge on the carrying capacity but also on the change in baseline conditions which act as the precursor for environmental legislations in addressing regional problems caused by air pollution and global warming variables such carbon dioxide emissions through fossil fuel. Considering the gravity of the problem, there is an urgent need for a GIS based monitoring approach in the West African region.

METHODS AND MATERIALS

Methods Used

This paper stresses a mix scale approach involving the integration of primary and secondary data provided through government sources and data bases from other organizations. The raw spatial data and satellite images used in the research were procured through The United States National Aeronautical and Space Administration (NASA), United States Geological Survey and the United States Department of Energy.

METHODS AND DATA COLLECTION

Step 1: Data Acquisition

The first step involves the identification of the variables needed to assess environmental change at the regional level. The Global inventory data was available for other countries but given the regional scale of the project, the paper focused on both Ghana and Nigeria as the basis for the West African case studies. The other variables consist of socioeconomic and environmental information, including amount of cropland, human settlement, water bodies, forest types, and population (See Table 2.1 and Appendix 3). This process continued with the design of data matrices for the variables covering the various periods from 1986 and 2000 and beyond. In addition, to the design stage, databases and abstracts that are presently available within the Federal archives in Nigeria and Ghana were accessed. The United States National Aeronautical and Space Agency (NASA)

and host of other organizations helped facilitate the search process. The spatial data acquired from NASA consists of two Satellite images for the separate periods of 1986 and 2000. The path was 188 and 189; and 57 for the row. The emission data for fossil fuel for both Nigeria and Ghana from 1994 to 2002 were obtained from the United States Department of Energy Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory National Energy Database.

Step 2: Geo Spatial Data Processing and Analysis

To facilitate the GIS modeling of emission in the two countries simultaneously, one contiguous data set was created in which each country represented a homogenous unit. This spatial arraignment of data-values involved the summation and mapping of emission information for each country. The spatial distribution of emission sources and types were modeled through a system in which each cell polygon represents the proportion of the country's emission. The data were averaged to provide sample values for these countries in the study area. For the measurement of changes pertaining to carbon sinks and other variables in the Niger Delta of Nigeria, two Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) multi-seasonal images of 20 May 1986 and 19 June, 2000 were obtained for this study. The Landsat TM and ETM+ satellite data were processed using ERDAS IMAGINE 8.7 image processing software. The images were imported into ERDAS using ERDAS native file format GEOTIFF. Since the images were in single bands, they were stacked together using ERDAS layer stack module to form a floating scene. Path 188 and 189 were mosaicked to form seamless image. The 1986 image was co-registered with the 2000 image and later geo-linked to allow for the subset of both images to the study area. Enhancement of all the images using histogram equalization techniques was later performed. The images were classified using an unsupervised classification technique to identify land cover features within the study area. The remaining procedure involves spatial analysis and output (maps-tables-text) covering the study period, using ARCVIEW GIS. The spatial units of analysis consisted of the states located in the delta region of Nigeria and Ghana. Outputs for the region were mapped and compared cross time. This process helped show the extent of temporal-spatial evolution of ecological change induced by oil and gas.

Study Area: The West African Region of Nigeria and Ghana

The study area in Figure 1 located in the West African region comprises of Ghana and Nigeria. Nigeria is the most populous country in Africa and it is situated along the Gulf of Guinea. Its neighbors are Benin, Niger, Cameroon, and Chad. The lower course of the Niger River flows south through the western part of the

country into the Gulf of Guinea. The country covers an area of 923,768 square kilometers with a population of 131 million in 2006. Ghana's population doubled over the 24-year period, 1960 to 1984, from 6.7 million in 1960 to 12.3 million in 1984. In 1984, the density was 52 people per square kilometer. Projections indicate the population is likely to reach 27 million by 2010, and 33.6 million by the year 2020. The urban population in both countries as indicated in the Appendix 1 accounts for a greater proportion of population distribution. Apart from the rapid population growth Ghana and Nigeria share numerous problems pertaining to energy utilization and production that are associated with fossil fuel emission.

In 1970, oil was discovered offshore between Saltpond and Cape Coast of Ghana. Although this discovery was classified as noncommercial, the oil price increases of 1973–74 compelled the government to reclassify it as commercial in 1974 and to undertake further development. In 1974 and 1980, substantial amounts of natural gas were discovered offshore to the south and west of Cape Three Points. Although, oil production in the Saltpond area began in 1978, but all crude oil is exported in order to reduce the country's international trade deficit. As a predominantly oil exporting county, Ghana spent sizable amount of its foreign exchange earnings on crude oil imports during the crisis era of the 1980s. Though the figures dropped to 16 percent in 1988 and 24 percent in 1989, crude oil imports still constitutes the single largest user of the county's export earnings, even though petroleum provides only 13 percent of the energy consumed in Ghana. Despite Ghana's dependence on fuel wood for 80 percent of its energy, energy utilization and production constitute the most pervasive source of environmental pollution in the country. The depletion of the forests for biomass energy reduces the size of carbon sink and contributes to carbon emission, loss of biodiversity and soil erosion in the country.

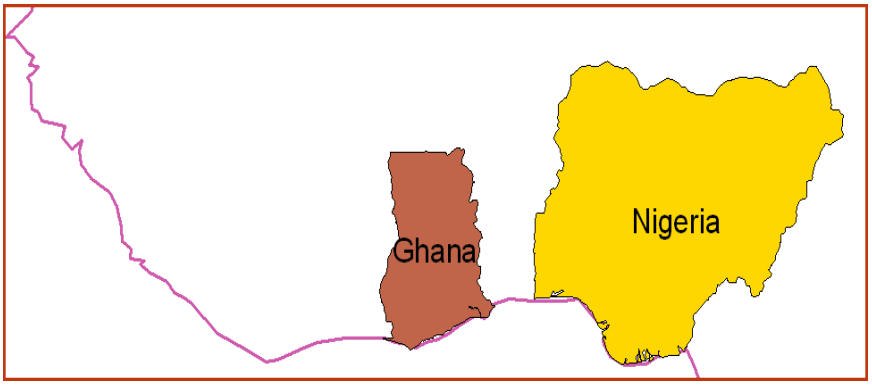

Figure 1 Map of the Study Area

Nigeria's economy remains heavily dependent on the oil sector, which accounts for 80 percent of government revenues and over 90 percent of foreign exchange earnings (Ikeme, 2001). Nigeria is believed to have an estimated 124 trillion cubic feet (Tcf) of proven natural gas reserves, the 9th largest in the world. Due to a lack of gas utilization infrastructure, Nigeria currently flares 75 percent of the gas it produces and re-injects 12 percent to enhance oil and recovery. This is chiefly disturbing because fossil fuel is a major source of global warming. Current action to reduce the emission of greenhouse gases as stipulated in the Kyoto protocol is restricted to the developed countries or annex 1 countries. This requires the developed nations to cut their green houses gas emissions by 5 percent compared to 1990 levels by 2008-2012. Nigeria which belongs to the non -Annex 1 countries is not expected to take any abatement action for now. However, the impact of global warming on Nigeria stems partly from the threat to her economy posed by the measures being adopted by the international community. Nigeria will incur income losses when the global community begins to substitute renewable energy alternative for fossil fuels. Given the dependence on fossil fuels for economic growth and the predominant focus on further expansion of this sector of the economy by the Nigerian government, the impact of global shift away from fossil fuels will stifle the Nigerian economy (Ikeme, 2001). There are also plans for the design of major oil and gas pipeline stretching through Nigeria to other West African countries including Ghana. In light of these concerns and the other environmental issues, the extent of fossil fuel emission in both Nigeria and Ghana merits some attention with the latest advances in geospatial information technologies.

RESULTS AND DISCUSSIONS

This section presents the results of the data analysis by first providing a brief synthesis of the descriptive statistics and geospatial analysis (GIS and Remote sensing analysis) of the changes and their impacts along the Niger Delta. Later, it highlights the factors associated with change in ecological resources in the study area and frameworks and suggestions to reverse the trends.

FOSSIL FUEL EMISSION IN NIGERIA AND GHANA 1994-2002

Regarding the CO_2 emission trends for Nigeria in Table 1.1, the percentage of total quantity of fossil fuel showed a continuous increase in six out of the 9-year period under analysis. Aside from the sequence of double digit

declines of -29.3 percent from 1994 to 1995, as well as -19.percent reduction between 2001 and 2002 experienced in the country. The distribution of total CO_2 grew respectively most of the time at double-digit rates of 16.3 percent from 1995-1996 and 12 percent from 1998-1999. The two rates of emission represent the highest levels of emission for the country. Although the percentages of change for the other CO_2 emission factors such as gas fuels, liquid fuels exhibited similar attributes in variation, the change pattern for bunker fuel emissions reveal a steady rise, with 1995 and 1996 emerging as the years under triple digit increases. In the 2001 and 2002 period when the country experienced a decline of -4.8 percent in bunker fuel emission, the per capita segment of the CO_2 emission factor stayed relatively stable. In the case of Ghana as presented in Table 1.2, the percentage of change in total fossil fuel emission stayed on the rise with the exception of double-digit declines (of -32 percent) during the 1997 and 1998 period along with -14 percent in 1999 through 2000. Of all the years under analysis, Ghana's 11.2 percent increase from in 1996 to 1997 and the 26.2 growth in total fossil fuel emission in 2001 and 2002 were the highest levels of change for the country. The changes in the other emission factors were somewhat similar to the trends in Nigeria. For the spatial distribution of emission, trends in both Ghana and Nigeria see Figures 2.1 and 2.2.

Table 1.1 CO_2 Emissions For Nigeria in Thousand Metric Tons

Years	Total fossil fuel	Percentage Change (%)	Gas fuels	Percentage Change (%) for Gas fuels	Liquid fuels	Percentage Change (%) for Liquid fuels	Solid fuels	Per capita emission rate	Bunker fuels	Percentage Change (%) for Bunker fuels
1994	12368	0	2803	0	9466	0	99	13	298	0
1995	8744	-29.3	2747	-2.0	5891	-37.8	106	0.09	298	0
1996	10170	16.3	2784	1.3	7280	23.6	106	0.1	652	118.8
1997	10711	5.3	2911	4.6	7694	5.7	106	0.11	702	7.7
1998	10625	-0.8	3123	7.3	7455	-3.1	47	0.1	719	2.4
1999	11904	12.0	3287	5.3	8571	15.0	46	0.11	831	15.6
2000	12411	4.3	3732	13.5	8632	0.7	47	0.11	876	5.4
2001	12833	3.4	3287	-13.1	9497	10.0	49	0.11	976	11.4
2002	10405	-19.0	3366	3.0	10357	9.1	48	0.12	929	-4.8

Table 1.2 CO_2 Emissions For Ghana In Thousand Metric Tons

Years	Total fossil fuel	***Percentage*** Change (%)	***Liquid Fuels***	Percentage Change (%) for Liquid Fuels	Solid Fuels	Per Capita Emission Rate	Bunker Fuels	Percentage Change (%) for Bunker Fuels
1994	1359	0	1174	0	2	0.08	23	0
1995	1453	7.0	1274	8.5	2	0.08	24	4.3
1996	1540	6.0	1334	4.7	2	0.09	24	0
1997	1713	11.2	1479	10.9	2	0.09	58	142.0
1998	1659	-3.2	1435	-3.0	2	0.09	68	17.2
1999	1639	1.2	1283	-10.6	2	0.08	76	12.0
2000	1616	-1.4	1349	5.1	2	0.08	85	12.0
2001	1622	0.4	1361	0.9	2	0.08	83	-2.4
2002	2047	26.2	1786	31.2	3	0.1	78	-12.0

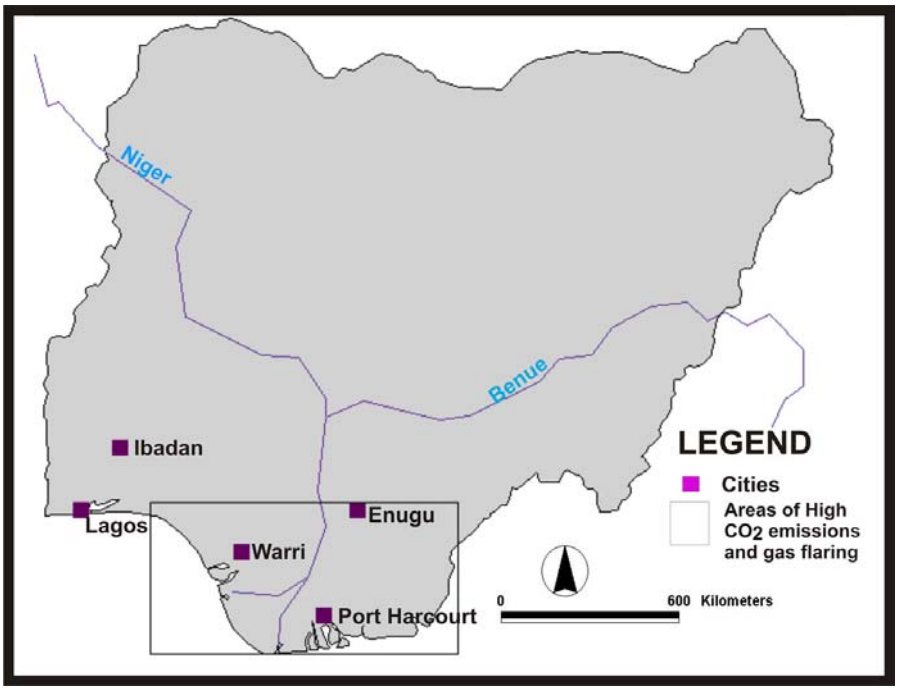

Figure 2.1 Areas With Concentrations of Carbon Dioxide Emissions In Nigeria

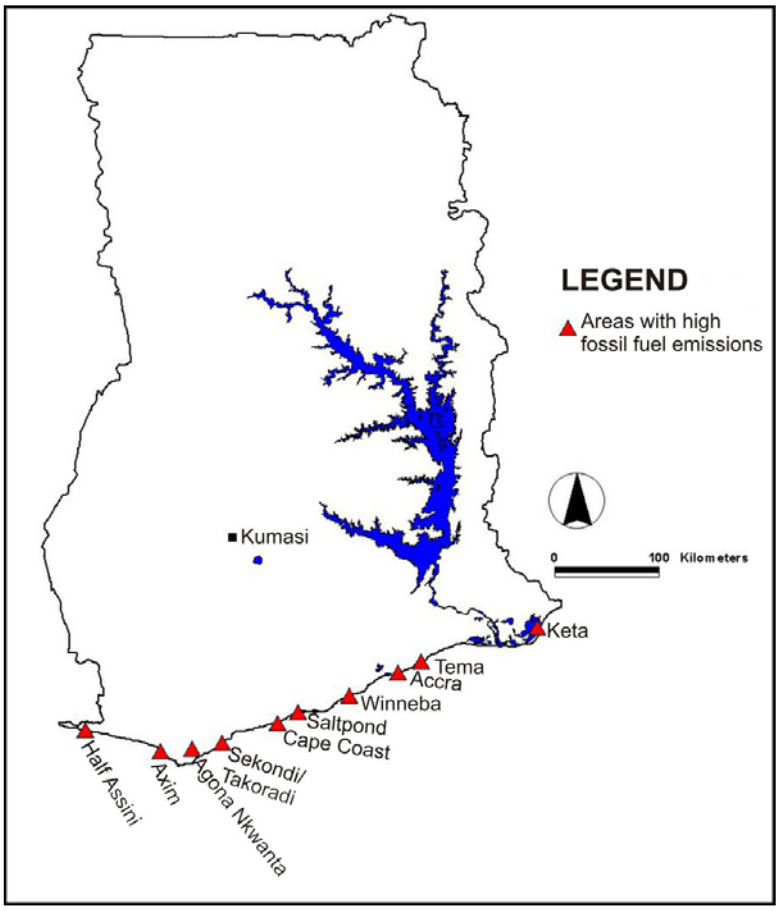

Figure 2.2 Areas with Fossil Emission In Ghana

GAS FLARING IN NIGERIA

The issue of flaring in the Niger Delta is a notable source of ecological decline considering the fact that Nigeria flares more gas than the other petroleum producing countries (Ishisone, 2004). In the eight year period spanning from 1980 through 1998 as shown in Figure 3.1 Nigeria recorded its highest level of gas flaring in 1980 estimated at about 11737.4 thousand metric tons. Apart from the 8072.4 thousand metric tons that were flared in 1981, in the ensuing years of 1982 though 1998, the pattern of flaring stayed relatively stable with a mix of slight increase and minimal decline in the quantities flared. Presently, Nigeria

flares 56.6 million m3 of associated gas on a daily basis (Gerth and Lablon 2004), making it the world's largest source of gas flaring at an annul rate of 16 percent (Ikporukpo, 2004.) As Appendix 2 indicates, while less than 5 percent of the world's production is flared, the estimate for Nigeria is 76 percent. From the table, the percentage for Nigeria is 15 times more than the Worlds' and 4 times much higher than the Organization of Petroleum Exporting Countries (OPEC) average. In fact, the World Bank estimates that 10 percent of the global CO_2 emission comes from Nigeria. Nigeria's gas flaring alone which occur mostly in the Niger Delta, emits 35 million tons of CO_2 and 12 million tons of CH4 (methane) and propane, which has a much higher warming potential than CO_2. In addition to the Green House Gases (GHGs), the gas flaring also generates toxic compounds that harm human health and the ecosystem. In the Niger Delta, flaring creates unfavorable environmental conditions particularly in areas around the stacks. Several studies have shown that not only is plant productivity affected, but also soil characteristics. Ukegbu and Okeke (1987) showed that there was a 100 percent loss in yield of crops cultivated within 200 meters and a 45 percent loss within 600 meters. A reduction of 20-30 percent in bacterial species abundance and 35-61 percent for fungi was also reported in the study. While these effects declined with distance from flare stacks, flaring in the Delta has been partly attributed to a lack of utilized infrastructure for managing associated gas during oil production (Watts, 2001).

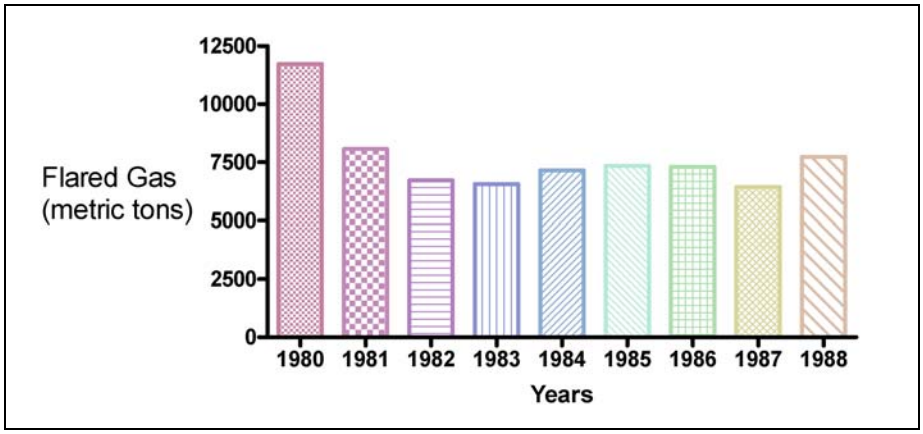

Figure 3.1 The Amount of Gas Flared In Nigeria

ENVIRONMENTAL CHANGE PERTAINING TO CARBON SINKS AND OTHER VARIABLES IN NIGERIA

Overall land cover change for the duration of 14 years between 1986 and 2000 is given in Table 2.1 and Figures 4.1 and 4.2. The accuracy of the results was compared to government statistics and available information on the area. From Figures 2 and 3, and Table 2, water bodies experienced a slight decline from 399,346 to 305,207 hectares. Mangrove also posted an overall decline of 11 percent. The biggest decline in the area was the closed forest. It declined from an initial estimate of 357,657hectares in 1986 to 108,759 hectares representing an overall decrease of 70 percent. While mangrove, water bodies and closed forest were decreasing, settlement, agricultural and economic activities were increasing as well. Agricultural and economic activities increased from 17,810 hectares to 116,092 hectares, representing a change of 552 percent. Settlement also shows an overall change of 190 percent from 10,968 hectares in 1986 to 31,839 hectares in 2000. The number of forest areas degraded also increased during the 14 years' period. For example, from the initial estimate of 73,097 hectares in 1986, it increased to 309,921 hectares in 2000 representing an overall increase of 324 percent.

Table 2.1 Results of the Classified 1986 and 2000 Images

Classes	Area (ha) in 1986	Area (ha) in 2000	% change (1986-2000)
Water	399,346	305,207	-24
Agriculture/economic activities	17,810	16,092	552
Settlement / bare areas	10,968	31,839	190
Mangrove	114,266	101,326	-11
Closed forest	357,657	108,759	-70
Degraded forest	73,097	309,921	324

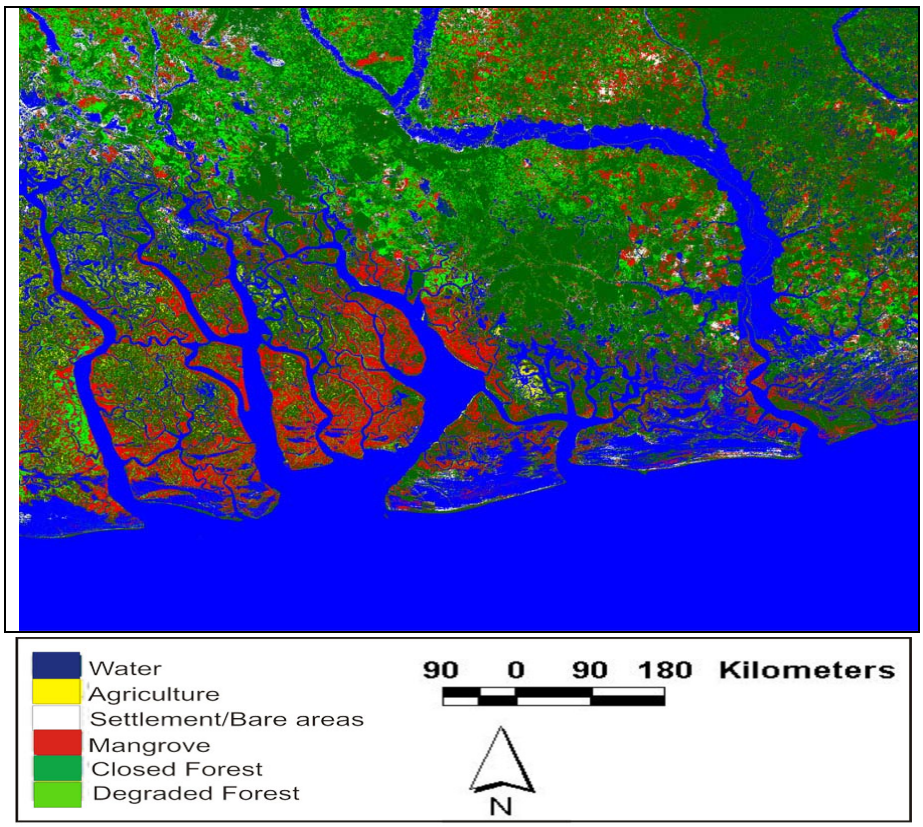

Figure 4.1 Classified Image of Landsat TM, May 20, 1986

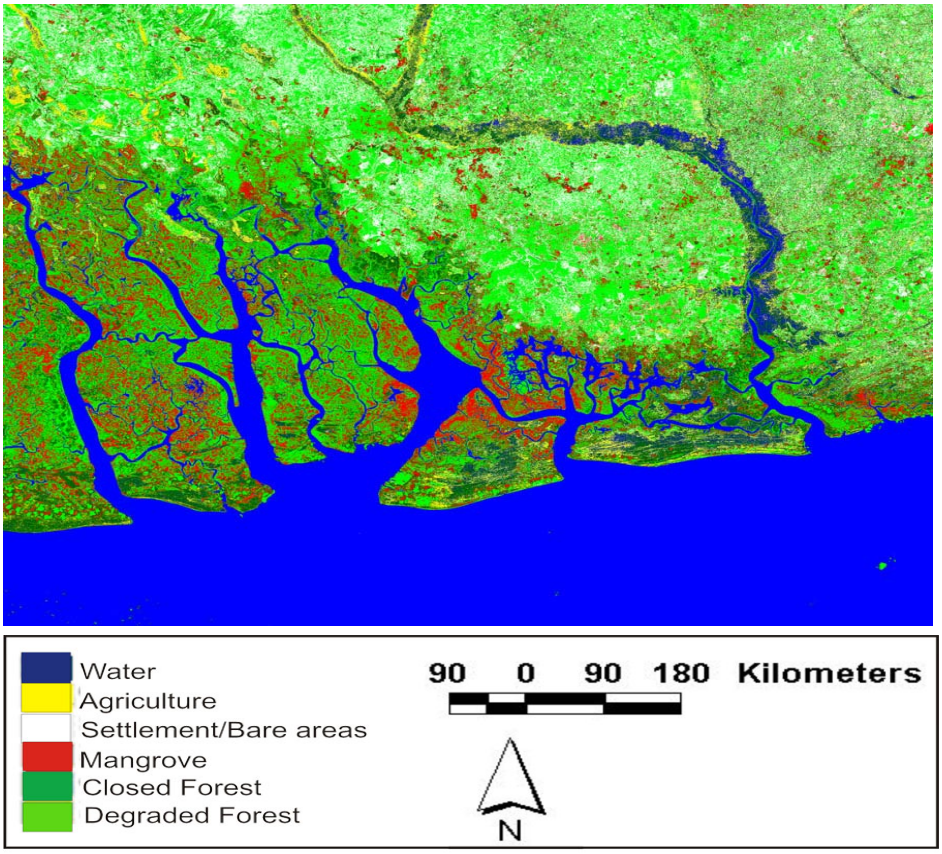

Figure 4.2 Classified Image of Landsat TM, June 19, 2000

MITIGATION EFFORTS

In the West African region of Ghana and Nigeria, several efforts have been made to curb the proliferation of fossil fuel emissions. These efforts consist of capacity building and outreach programs.

Capacity Building Initiative

In Nigeria, there is an ongoing capacity building initiative known as "The Canada-Nigeria Climate Change Capacity Development Project". This is an

initiative involving Global Change Strategies International Inc. (GCSI) of Canada and the Nigerian Environmental Study Action Team (NEST). The effort funded by the Canadian International Development Agency (CIDA), focuses on strengthening the capacity of Nigeria to respond to climate change and to participate in global efforts to combat the problem. The project not only focuses on capacity building initiatives that assess the risks coming from climate change, but it strives to determine options for managing the risks by enhancing institutional readiness in implementing recommended measures. The other aspects of the efforts cover inventory and mitigation activities, with a focus on vulnerability and adaptation assessment. To achieve these objectives, proponents of the initiatives are counting on strong public and political support through targeted public information and consultation efforts (NEST, 2006).

Climate Change Outreach Program

In the case of Ghana, various levels of environmental monitoring activities aimed at curbing the impacts of fossil fuel emissions have been initiated through partnerships with multilateral agencies. Responding to the needs of the countries and following the requests of United Nations Framework Convention on Climate Change Secretariat (UNFCCC), the United Nations Environment Program (UNEP) has initiated and implemented a major program on climate change outreach that directly supported the UNFCCC New Delhi Work Program on Article 6 (Education, Training and Public Awareness) in Ghana. The objective of this project is to provide to governments such as Ghana additional tools for promoting climate change awareness at the national level. The program also supports efforts by associations and Non Governmental Organizations (NGOs) to disseminate accurate information from the Intergovernmental Panel on Climate Change to target audiences, such as youths and raise awareness of the general public on climate change problems with easily understandable graphic materials. The implementation process in Ghana covered local needs by prioritizing collaboration between stakeholders through popular brochures in local languages and the mass media.

DISCUSSION

The results reveal not only that the study area experienced significant changes in its emission of fossil fuel due to the burning of oil and gas, but also that the extent and nature of variation in carbon sinks (forest areas) were also quite pronounced in the oil rich Niger Delta of Nigeria. Accordingly, the environment and socio-economic activities in both countries remain quite

vulnerable due to the potential impacts. The Nigerian portion of the study area especially the Niger Delta region remains an ecosystem under stress with decades of widespread cases of gas flaring threatening the natural environment and human health in the region. Considering the rate of development in Nigeria's oil sector and the proposed mega pipeline linking Nigeria and other West African countries including Ghana, the coastal area of Ghana risks a similar fate that befell the Niger Delta. Gas flaring emanating from the oil sector has been linked with continuous growth in oil and gas production in Nigeria (as shown in Appendix 3) a lack of utilized infrastructure for managing associated gas during production, as well as the emission of CO_2 and methane (Watts, 2001). For pictorial depiction on the nature of gas flaring in Nigeria, refer to images in Appendices 4.1 to 4.4. While the ecological factors showed some variations across time and space, these changes are associated with socio-economic variables and a host of other factors connected to oil and gas exploitation. This could be buttressed from increases in oil and gas indicators associated with production in the Nigerian oil sector in Appendix 3. In the Nigerian area, the results point to a decline in waterbodies and emission sinks such as, mangrove forests, closed forests and increase in human settlement. There were also notable changes in the area's mixed forests and cropland. The resultant intensification in agriculture and human settlement makes the region's natural systems overly vulnerable to the threats of climate change. This will not only threaten the carrying capacity of an already fragile ecosystem, but if not taken seriously, poses enormous challenges for both environmental and natural resource managers and policy makers in the region, and those involved in climate change mitigation.

In light of this finding, the practical use of a mix scale approach using GIS and remote sensing in monitoring emission trends, factors and impacts from oil and gas activities stands as an update to the current literature on global environmental monitoring of CO_2 emissions in a West African tropical ecosystem along the region of Niger Delta of Nigeria and Ghana. Considering the minor efforts in monitoring emission trends from oil and gas in Nigeria and Ghana with geospatial technologies, GIS technology as used in this paper has fulfilled a useful purpose in mapping and inventorying of emission and other related ecological data. Geospatial technology helped quicken the spatial display of the factors, patterns and environmental effects of oil and gas activities and their implications for Global climate change in the region. Furthermore, the paper also stands as an effective tool for resource management and environmental health monitoring in tropical ecosystems of West Africa. Integrated data analysis using remotely sensed satellite imagery and GIS modeling, facilitated the analysis of the spatial diffusion of CO_2 emission and the potential environmental change

involving forest cover and hydrological changes occurring in the Niger Delta environment across time.

RECOMMENDATION AND CONCLUSION

To address some of the concerns identified in the current research, five recommendations anchored in ecosystem monitoring are hereby made as part of the remedies.

Economic Diversification, Policy Research and Development

In terms of policies for ameliorating the situation, Nigeria needs to diversify its economy from the current over-dependence on oil and gas production. This will enable the country and the West African regional economies to absorb the fiscal volatility that may arise from the anticipated global switch away from fossil fuels and the subsequent cutback in fossil fuel demand. More so, extensive research on climate change and the socio-economic implications for Nigeria and Ghana is indispensable as the region embarks upon the design of effective response strategies. Further scientific enquiry on global warming impacts on the region is very important for sensitizing decision-making and in providing the critical data for implementing policies satisfactorily. The significance of this observation comes from the ample recognition of rarity of climate data in Nigeria and Ghana as major constraints to adequate prediction and formulation of adaptation policies. In that light, long-term studies on national and regional climate change in the region should be undertaken.

Institutional Arrangements and Capacity Enhancement

Many developing countries such as Ghana and Nigeria may not have adequate institutional and technical capacity to generate reliable activity data and to produce complete emission inventories. Thus, it is necessary to develop appropriate institutions and earmark resources to enhance regional research capacity in this important area. Multilateral institutions including the World Bank and others could supplement national and regional efforts through financial support, coordination, promotion of information sharing, training and capacity enhancement that strengthens the role of local institutions in the region. Such an approach when implemented will enable scientists to use inventories of emissions as tools when developing atmospheric models. It will also assist policy makers in developing cost effective emission control strategies that are necessary for tracking the progress of policies towards emission reduction. The other

significance of this framework is that not only do regulatory agencies and corporations rely on inventories to establish compliance records within allowable emission rates, other interest groups in the region will use such inventory to understand the sources and trends in emissions.

Involvement of National and City Governments in Global Forums

Greater government involvement in the ongoing Global change debate in order to bargain a better position for Nigeria and the West African region is necessary. The idea of compensating oil-producing nations for their probable revenue losses due to the implementation of the Kyoto protocol and assisting their pursuit of economic diversification must be persuasively argued and campaigned for by Nigeria. Nigeria can only ensure that her interests are not trampled upon in the growing global abatement strategy by maintaining a visible presence. The presence of Nigeria will be strengthened through studies highlighting different phases of the global warming debate. Another dimension to the strategies is the need to involve large cities such as Lagos and Port Harcourt in climate change mitigation. This is because a growing number of local governments in developed nations are joining global efforts to mitigate climate change through the powers vested in them over land use regulation. The extent of local regulations initiated by these entities in Nigeria can assist in cutting GHG emissions by enhancing energy efficiency measures.

Develop Energy Efficiency

To reduce their contribution to climate change, the mandate for Nigerian and Ghanaian energy planners is to institutionalize the development of energy efficiency and renewable energy with appropriate goals and timetables for increasing the use of renewable energy resources in areas where opportunities for the use of renewable energy is economically warranted. This should be accompanied by an built-in mechanism for stocktaking and reassessment of progress towards the objective. In addition to building an institutional framework, Nigeria and Ghana should also adopt specific regulatory measures based upon comprehensive air quality standards. They can attain their goals also by creating national energy efficiency codes that can furnish the preamble for rapid development of energy efficiency and renewable energy opportunities.

Regional Information Network for West Africa

During the start of this project, energy and emission data on Ghana and Nigeria were not only scattered in different areas, but they appeared in different

forms. Apart from the Global CO_2 emission data provided through the United States Department of Energy, there was no centralized energy data agency serving the West African region. In light of this, the region lacks a comprehensive networking and information-sharing capabilities among the countries. Accurate and reliable activity data and emission factors that are available regionally is a prerequisite for the preparation of good quality national Green House Gas inventories which are needed for national planning, including the promotion of conservation and sustainable development. National and regional networking of institutions and experts should be encouraged in both Ghana and Nigeria in the area of activity data generation and inventory in order to share and validate the information generated. This will help both nations fulfill the requirements regarding the reporting of activities under Articles 3.3, 3.4, and 6, and potentially Article 12 of the Kyoto Protocol involving full carbon accounting and verifiable changes of carbon stocks.

CONCLUSION

This paper has presented the applications of GIS and remote sensing tools in monitoring the emission of carbon dioxide from fossil fuel due to the impacts of oil and gas activities in a tropical environment along the West African region of Nigeria and Ghana. The paper outlined an overview of the global issues leading to climate change due to the burning of fossil fuel with a focus on two cases in the West African region of Nigeria and Ghana. The study presented a review the essence of GIS and remote sensing based approach, the importance of monitoring and the analysis of environmental effects and factors associated with the problem and efforts to mitigate the problems.

Notwithstanding the gravity of the trends in the region, there has not been any major effort by ecological planners and decision makers aimed at analyzing and monitoring fossil fuel emission trends in Nigeria and Ghana. Considering the growing pressures mounted by oil and gas activities in the Delta area of Nigeria region and the gradual rise of emissions in Ghana. The results from the data analysis reveal that the current changes experienced in coastal environments especially on the surrounding ecology of River Niger Delta forests are bound to have catastrophic effects along the coastal regions due to the current rate of CO_2 emission. These changes are attributed to socio-economic and environmental variables and host of other factors linked with four decades of intense oil and gas exploitation. The results point to a decline in water bodies, and emission sinks such as mangrove forests, mixed forests, forest degradation, increase in human settlement, cropland and agricultural intensification coupled

with intense gas flaring ravaging both the natural and human environment. This will not only threaten the carrying capacity of an already fragile ecosystem, but it poses enormous challenges for environmental and resource managers and policy makers working to mitigate global warming impacts. To deal wit these problems, the paper offers some recommendations as part of the monitoring strategies for the region. The recommendations range from economic diversification to the formation of a regional information network for monitoring emission trends.

The practical applications of a mix scale approach involving GIS and remote sensing for the monitoring of fossil fuel emission and the monitoring of the potential ecological change prompted by oil and gas activities showed some interesting results in a tropical ecosystem of the West African region of Niger Delta of Nigeria and Ghana. It is evident that GIS technology as used by scientists for mapping of data with a spatial reference stands as an effective tool for ecosystem management and the provision of emission sink information pertaining to the surrounding ecology of River Niger Delta for future monitoring. Using remotely sensed satellite imagery and GIS modeling quickened the analysis of the geographic diffusion of ecological change involving emission trends and emission sinks such as forest cover, hydrology and demographic variables of human settlement on the Niger Delta. The spatial display of the carbon dioxide emissions in both Nigeria and Ghana helps raise their implication and awareness for global warming in Nigeria's coastal region. In closing, it is the understanding that a successful implementation of some of the mitigation strategies outlined here could lead to effective monitoring of fossil fuel emission and global environmental protection.

APPENDICES

Appendix 1 Demographic and Environmental Change in the Study Area

Population	**Nigeria**	**Ghana**
Population 2025 (projected)	190,287,000	32,846,000
Population 2050 (projected)	258,108,000	47,314,000
Population Change 2005-2050 (projected %)	96	115
Population Doubling Time (years	29	31
Population Mid-2005	131,530,000	22,019,000
Urban Population (%)	44	44
Environment	**Nigeria**	**Ghana**
CO_2 Emissions per Capita, 1998 (metric tons)	0.6	0.2
Energy Use Per Capita 2002 (kg oil equivalent)	718	411
Forest Area, Change in 1990-2000 (1,000 hectares)	-3,984	-1,200
Number of Vehicles per 1,000 People, 2000	28	8
Threatened and Endangered Animal Species (number)	39	23
Threatened and Endangered Plant Species (number)	119	115

Appendix 2 Flaring of Natural Gas in Major Producing Countries In 1991

Country	Percentage Flared
USA	0.6
Holland	0
Britain	4.3
USSR	1.5
Mexico	5
OPEC Countries	
Nigeria	76
Libya	21
Saudi Arabia	20
Iran	19
Algeria	4
Sub-total	18
World total	4.8

Appendix 3 Oil and Gas Production In Nigeria

Years	1998	1999	2000	2001	2002	Percentage Change (%) 1998-1999	Percentage Change (%) 1999-2000	Percentage Change (%) 2000-2001	Percentage Change (%) 2001-2002
	Natural Gas (million cubic liters)								
Gross	36,037	36,156	47,537	57,530	70,000	0.3	31.5	21.0	21.7
Dry	10,887	12,667	21,945	39,640	45,000	16.3	73.2	80.6	13.5
	Petroleum (thousand gallon barrels)								
Crude	7,880,000	777,000	783,000	823,000	773,000	-90.1	0.8	5.1	6.1
	Refinery Products								
Liquefied	2,000	100	170	1,000	2,300	-95	70	488.2	130.0
Gasoline	18,300	10,000	8,000	24,400	22,400	-45.4	-20	205.0	-8.2

Appendix 4.1 Offshore Gas Flaring On Wetlands

Appendix 4.2 Gas Flaring From a Refinery

Appendix 4.3 Gas Flaring From Oil Pipeline

Appendix 4.4 Gas Flaring From Ruptured Pipeline

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