Evaluating Environmental Change Impacts on Ecological Services in the Niger Delta of Nigeria

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Abstract

This study evaluates the implications of the environmental change on ecological service in the Niger Delta of Nigeria. The delta, being the most extensive forest and aquatic ecosystem in West Africa, provides numerous ecological services in biodiversity both to people living in the delta and West African economy as a whole. Despite these benefits, much has not been done in terms of examining ecological services provided by the delta and modelling the impacts of environmental changes on these ecosystem services. This study therefore uses Landsat satellite data (from 1984 to 2011), remote sensing change detection and ecological services valuation methodologies to assess the impacts of environment change on the ecological services in the delta. The results show that the Niger Delta of Nigeria has experienced tremendous environmental change over the past three decades. About 9000 km² forest area cover has been lost in the region between 1987 and 2011 and this has a great effect on ecological services provided by the delta ecosystem. Though the results of this study showed that forest contributes the highest ecological value coefficients ($ ha⁻¹ per year) for Niger Delta with total ecological services of 1102.65$/ ha⁻¹/year, followed by mangrove with 753.55$/ ha⁻¹/year. But over the years, the ecological services provided by the delta ecosystem have considerably reduced. This study concludes by examining the drivers of change and their significant implication not only on the delta physical environment but also the societal implications.

Introduction

Over the past few decades, environmental resources in the Niger Delta have been exploited without efficient management, thus the sustainability of these resources are imperative. Uncontrollable deforestation resulting from commercial logging, firewood collection by local people and clearing of the forest for agricultural purposes and pollutions from oil production constitute serious environmental problems in the region. These have resulted in conflicting landuse and degradation of the environmental resources in the Niger Delta (Eregha and Irughe, 2009). The implications of the environmental problems on ecological services in the Niger Delta are highly enormous. The region, being the most extensive forest and aquatic ecosystem in West Africa, provides numerous ecological services not only to the people living in the delta, but also to the whole West African economy. These ecological services range from environmental benefits that accrue not only to humans but also to both plants and animals (Li and Ren, 2008; Kreuter, 2011).
Until recently in many developing countries, ecological services assessment has been limited by the philosophical and methodological obstacles in allocating monetary value to ecosystem (Rasul, 2009). Such limitations pointed out by earlier philosophers include the fact that economic valuation is not enough to value both direct and indirect services obtained from ecosystem. General opinion then was that economic valuation remains an indication rather than an actual value derived from ecological services. Despite this limitation, several scientists in the western nations have estimated the values of ecological services. In recent years, there is growing scientific research and tremendous recognition of the ecological services on health, social, cultural, and economic needs of human society all over the world. Studies have shown the impacts of environmental change on ecological services in both local and global scales (Zhao et al. 2004; Rasul, 2009; Badola, et al., 2010; Li, et al., 2010; Kreuter et al, 2011). For example, Loomis et al. (2000) applied a building block approach developed by an interdisciplinary team to evaluate ecosystem services of the Platte River. Christopher et al (2005) and Chen et al (2009) employed spatial modelling method to assess ecosystem services production in watersheds based on the conceptualization of agricultural watershed as a complex adaptive human ecosystems and that spatial methodology should be used to evaluate it. Other studies analysed “market actors” decision criteria related to stakeholders in forestry and environmental services (Amirnejad et al. 2006; Sell et al. 2006; Bateman et al. 2011).

The majority of these studies assessed the impacts of landuse change on ecological services in the United States of America, China and other developed countries. The results from these previous studies showed that, in this age, it is valuable to recognise the importance of ecosystem services and how economic valuation of these services helps in improving ecosystem management. It is clear from the previous studies that this level of ecological research is not only creating awareness about impacts of environmental change on ecosystems, but also provides a ‘market’ for ecosystems (Zhang and Lu, 2009; Yoshida et al. 2010). Generally, earlier studies have pointed out that these economic values of ecosystem services are not usually credited for, especially in the economic market until they become depleted (Kumar, 2005; Kreuter et al., 2010). Kumar (2005) also noted that economic valuation of ecosystem services provides insights about the cost and benefits facing human societies due to ecological degradation and loss of ecological services. Till the time of this study, much has not been done in assessing the impacts of environmental changes on ecological services in the Niger delta, despite considerable amount of studies that have been done in other parts of the world. To ensure effective management and utilization of environmental resources for sustained economic development in the region, there is a need for an in-depth and integrated study of spatio-temporal environmental change using remote sensing and assessment of the implication of such changes on ecological services in the delta.

Surprisingly, there are little studies on the impacts of Niger Delta environmental change on ecological services provided by ecosystem in the region. There is no doubt that the ecological services derived from the Niger Delta ecosystem are a great deal. In general, the ecological services derived from this region can be grouped into four major as presented in Table 1. Consequences of these environmental problems on ecosystem and human health are enormous. Therefore, this research applies remote sensing techniques to examine environmental change in the Niger Delta and the implications of these changes on ecological services in the region.

Materials and Methods

The study area: ecology of the Niger Delta

The Niger Delta ecology is characterised by a large area of floodplain which is built up as a result of deposition and accumulation of sediments washed down for over 100 million years from the Benue and Niger Rivers. It is a low-lying region within the continental shelf of the Atlantic Ocean in the Southern part of Nigeria. The region is approximately 3.5m above the sea level. The ecology of the Niger Delta is characterised by varieties of vegetation (Figure 1). Mangrove vegetation covers the entire coastal zone of
the Niger Delta (Figure 1) along the brackish lagoons and marine rivers system and consists of dense evergreen vegetation. The freshwater swamp zone is generally characterised by quite a lot of tall trees, many of which are used as timber (Sorgwe 1997). This ecological zone is subject to the silt-laden ‘white water’ of the Niger River and the major zone of timber resources. Rainforest is the most complex in terms of species diversity. Derived savannah is found in the northern parts of the Niger Delta and comprises savannah type grasses and shrub, with a few scattered trees. It is believed that what is known as derived savannah today was once a secondary rainforest but reduced to open woodland of climbers and shrubs as a result of clearing of rainforest for agricultural activities.

Table 1: The ecological services derived from Niger Delta ecosystem.

<table>
<thead>
<tr>
<th>Category of ecological services</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Provisioning</td>
<td>Drinking water, food and raw materials</td>
</tr>
<tr>
<td>2 Supporting</td>
<td>Protection of biodiversity, genetic resources, nutrient cycles and traditional medicine</td>
</tr>
<tr>
<td>3 Regulating</td>
<td>Erosion control, control of climate and diseases</td>
</tr>
<tr>
<td>4 Cultural</td>
<td>Spiritual and recreational benefits</td>
</tr>
</tbody>
</table>


Figure 1: Map of the Niger Delta showing ecological zones. (Modified from NDDC 2001).
Environmental change assessment

Landsat TM image series over the period of 1984 to 2011 were used to model environmental change in the delta. The Landsat was launched in 1972 and it is a series of Earth-observing satellite missions jointly managed by NASA and the U.S. Geological Survey (NASA, 1979). It has provided one of the longest satellite dataset of the Earth from space and the data provided has support a series of environmental change studies such as examination of landuse and landcover; resources assessment and management; hazard monitoring; environmental change detection and management. Landsat TM has been carried by Landsat since 1982 while ETM+ is the latest version of the TM, which was launched in 1999. A primary limitation of using recent Landsat 7 ETM+ data for modelling environmental change is that due to breakdown of scan-line corrector (SLC) since 2003 about 22% data is lost providing gaps in the imagery. To ratify this problem, Geostatistical Neighbourhood Similar Pixel Interpolator (GNSPI) was employed to fill the gaps in the Landsat 7 data from 2003 to 2011. Pringle et al. (2009) have reported that the GNSPI approach improves accuracy compared to other methods.

Maximum Likelihood classification, post-classification and GIS methods were used to model environmental change. Thus, using classification and post-classification methods, the change detection statistics were derived for each of the LUC classes and for the Landsat image time series. Maximum likelihood analysis is based on the Bayesian equation which is expressed as:

\[
D = \ln\left(\alpha_c\right) - \left[0.5 \ln\left(\text{COV}_c\right)\right] - \left[0.5(X - M_c)T(\text{COV}_c - 1)(X - M_c)\right]
\]

Here, the equation computes the weighted distance or likelihood \(D\) of unknown measurement vector \(X\) which belongs to one of the known classes \(M\). The unknown measurement vector is assigned to the class in which it has the highest probability of belonging. Post-Classification comparison change detection was carried out after classifying the calibrated images separately for the time periods (1984 to 2011). Results from Post-classification comparisons helped in identifying the percentage change, trend and rate of change in landuse between 1984 and 2011.

Methods of ecological services valuation (ESV)

The approach by Costanza et al. (1997) has been widely used to valuate ecological services. Costanza et al. (1997) presented an outstanding model for placing an economic value on different biomes and the services that they provide. This approach is not only ecosystem management mechanisms, but it also provides a framework for accurate decision making toward protecting ecological biodiversity. This approach helps in understanding ecosystems in general by evaluating the costs and benefits of human interaction with ecosystem. Therefore, the approach was adopted in this study to evaluate impacts of environmental change on ecological services in the Niger Delta. There is no doubt that valuation of ecological services plays an important role in decision making on the cost and benefit of deforestation, oil and gas exploration, extensive urbanisation and other ways human impacted environment of the delta.

In the present study, six landuse categories were derived from classification analysis of the Landsat data sets. These classes corresponds to the tropical terrestrial biomes identified in Costanza et al.(1997) ecosystem services valuation model (Table 2). For effective analysis, the landuse category used in this research represents the most representative biome in the Niger Delta. Considering the actual ecological situation in the Niger Delta, the Biome equivalence for the six landuse categories and the corresponding ecological value coefficients were calculated. Thus, the change in ecosystem service values was estimated by calculating the temporal differences between the ESV values for each land use category over the years 1984 and 2011. The results of these analyses were presented under results and discussion section.
Table 2: Biomes equivalence for the six landuse categories in the Niger Delta. The landuse category equivalence of Costanza et. al.’s. (1997) biome category.

<table>
<thead>
<tr>
<th>Landuse category</th>
<th>Description category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rain/fresh swamp</td>
<td>Forest land</td>
</tr>
<tr>
<td>Mangrove</td>
<td>Mangrove/tidal marsh</td>
</tr>
<tr>
<td>Farmland</td>
<td>Cropland and plantation</td>
</tr>
<tr>
<td>Water</td>
<td>rivers and coastal</td>
</tr>
<tr>
<td>Urban</td>
<td>Urban</td>
</tr>
<tr>
<td>Bare ground</td>
<td>Rock and open ground</td>
</tr>
</tbody>
</table>

Thus, Costanza et al. (1997) methodological approach of ecological services valuation was used in the present study to evaluate the implication of notable environmental change in the Niger Delta of Nigeria. The value of ecosystem services was calculated as follows:

\[
ESV = \sum_{i=1}^{6} (VC_k \times A_k) \quad (2)
\]

\[
ESV_i = \sum_{j=1}^{13} (VC_{ki} \times A_k) \quad (3)
\]

Where: ESV is the estimated ecosystem services value. \( VC_k \) is the value coefficient for land use category \( k \) (i.e. the ecosystem service coefficient according to Costanza et al. 1997) and \( A_k \) is the area (km\(^2\)). \( VC_{ki} \) is the value coefficient for services function \( i \) and ESV\(_i\) is the ecosystem services value for services function \( i \) ($/ha/yr).

Results and Discussions

The results from classification analysis revealed three major environmental changes in the entire Niger Delta, over the study period. The rates of urban and farmland expansion have been increased while severe deforestation was observed for both rain/fresh water swamp forest and mangroves vegetation (Figure 2). It is also noticeable from Figure 2 that south-eastern part of the delta experienced higher rate of changes compared to other regions. Table 3 shows the general changes in the entire Niger Delta, with rapid increase in urban expansion and farmland (Figure 3). It is noticeable also that there are rapid downward trend for forest while mangrove showed a gradual downward trend (Figure 2). But, there appeared an upward trends for urban and farmland over the period of study (Figure 3). Meanwhile, bare ground declined from 1987 to 2011. The annual rate of change varies per land use class (Table 3) with a large reduction in forest and mangrove forest compared with freshwater forest. These changes are described in more details below. It appears that the rate of urban expansion has doubled in 2000s compared to the urban size in 1980s. In 1987 for example, urban class was just about 3428 km\(^2\), but increased to about 4894 km\(^2\) in 2001 and 6326 km\(^2\) in 2011 (Table 3).
Figure 2: Changes in landuse in the Niger Delta. Maps are classification results showing changes at various times.
Table 4 shows the annual rate of change over the period between 1984 and 2011. The rate of urban expansion varies annually: 1.9% in 1980s; 2.8% in 1990s and 1.9% in 2000s (Table 4). It is apparent therefore that the annual rate of urban expansion was the highest in 1990s compared with 1980s and 2000s. This value was not surprising, 1990s were periods of oil and economic boost for the country, thus the Niger Delta experienced high increase in population growth which led to rapid urban expansion. Besides, majority of these cities were located in the hinterland, region known as dryer part of the delta with little creeks and low flood incident. This encourages high rate of population thus increases the rate of urban expansion.

Table 3: Landuse change in the Niger Delta.

<table>
<thead>
<tr>
<th>Change (%)</th>
<th>1987</th>
<th>2001</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rain/fresh water swamp</td>
<td>-0.8</td>
<td>-0.5</td>
<td>-0.8</td>
</tr>
<tr>
<td>Forest</td>
<td>33004</td>
<td>27229</td>
<td>23798</td>
</tr>
<tr>
<td>Water</td>
<td>2449</td>
<td>2670</td>
<td>2581</td>
</tr>
<tr>
<td>Farmland</td>
<td>37426</td>
<td>40495</td>
<td>43877</td>
</tr>
<tr>
<td>Mangrove</td>
<td>13396</td>
<td>12838</td>
<td>12173</td>
</tr>
<tr>
<td>Bare ground</td>
<td>354</td>
<td>190</td>
<td>159</td>
</tr>
</tbody>
</table>

Table 4: Annual rate of change.

<table>
<thead>
<tr>
<th>Change (%)</th>
<th>1980s</th>
<th>1990s</th>
<th>2000s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rain/fresh water swamp</td>
<td>-0.8</td>
<td>-0.5</td>
<td>-0.8</td>
</tr>
<tr>
<td>Forest</td>
<td>-2.9</td>
<td>-0.2</td>
<td>-0.7</td>
</tr>
<tr>
<td>Mangrove</td>
<td>1.9</td>
<td>2.8</td>
<td>1.9</td>
</tr>
<tr>
<td>Urban</td>
<td>3.2</td>
<td>2.6</td>
<td>2.4</td>
</tr>
</tbody>
</table>

Figure 3: Changes in landuse in the Niger Delta, the classification results at various times.
Throughout the study period, forest has been gradually declining: from area cover of 33004km² in 1987 to 27229km² in 2001 and 23798km² in 2011 (Table 3, Figure 3). However, it is clear from Table 4 that the intra-annual rate of deformation varies from one decade to another. Intra-annual deforestation was higher in 1980s and 2000s (0.8%) compared with that of 1990s which was 0.5%. Change maps of farmland have revealed much change during the study period (Figure 2). Farmland increased from 37426 km² in 1987 to 40495 km² in 2001 and 43877 km² in 2011 (Table 3). High rate of farmland expansion was noted in the central east of the region where there is little forest reserve left. The farmland encroaches into the remaining forest located mostly around major river channels (Figure 2). Though, farmland appeared to increase generally over the periods of study, the intra-annual rate of change varied greatly (see Table 3 and Figure 3). The inter-annual rate of farmland expansions for the entire delta declined from 3.2% in 1980s to 2.6% in the 1990s and 2.4% in 2000s (Table 4).

**Implication of environmental change on ecological services values coefficients for the Niger Delta**

The results from this analysis showed that generally, the Niger Delta ecology has important significance for maintaining and conserving biodiversity. From Table 5, it is clear that the forest area has high ecological value (22.65$/ ha⁻¹/year) for biodiversity protection, followed by mangrove (17.37$/ ha⁻¹/year), water body (3.8$/ ha⁻¹/year) and farmland (2.4$/ ha⁻¹/year). For that reason, the major part of its ecological services involves biodiversity protection and conservation. The ecosystem services of the Niger Delta ecosystem presented also consist of ecosystem functions, processes, materials and energy obtained directly and indirectly by human and natural environmental system (Table 5). It has been pointed out by previous studies that the scale at which the ecological services analysis is carried out is an important issue when trying to determine the service value (Faber, *et al* 2002; de-Groot *et al*, 2002).

Climate regulation and purification (Table 5) of air include ecological services such as regulation of atmospheric chemical composition; greenhouse gas regulation involving regulation of global temperature, precipitation, and climatic processes in both global and local levels. In this case, rain/fresh water swamp forest and mangrove contribute high ecological values of 228 $/ ha⁻¹/year and 265 $/ ha⁻¹/year respectively (Table 5). There are several scientific evidences in the literature that showed that life on earth exists based on chemical balance in the atmosphere, land and oceans. Consequently in this study, the cumulative effects and implications of environmental degradation resulting from different changes in landuse and other human activities are considered to describe Niger Delta services. It is obvious that modification of this natural balance can have either positive or negative impacts on both natural environment and human society. De-Groot *et al* (2002) noted that local climate of a given location is apparently determined by interaction of regional and global circulation patterns with local topography and vegetation. On the other hand, water conservation includes water supply and regulation. There is no doubt that watersheds, reservoirs and aquifers help in storage and retention of water. The ecological services in this category also consist of regulation of hydrological flows. The water regulatory services deal with natural hydrological flows in this ecosystem. Thus, Niger Delta ecosystem provides services such as water filtering, retention and storage of water, mainly in streams and lakes. These are the major means of drinkable water for many people in the region.

Another category of ecological services of the Niger Delta include production of food, raw materials, source of traditional medicine and genetic resources. From Table 6, farmland (54 $/ ha⁻¹/year), mangrove (47 $/ ha⁻¹/year) and water (41 $/ ha⁻¹/year) provide higher ecological services values towards food production, compared to other landuse classes. For raw materials, source of traditional medicine and genetic resources, rain/fresh water swamp forest provide 315$/ ha⁻¹/year and 41$/ ha⁻¹/year respectively while mangrove contribute 162$/ ha⁻¹/year and 61$/ ha⁻¹/year ecological services value respectively (Table 5). These results are substantial because the delta region of Nigeria is well known for production of fish, crops, thorough fishing, hunting, gathering and subsistence farming. Up till today, Niger Delta diet still comes from wild plants, animals (usually called “Bush meat”) and foods derived from fishery, farm crops and domesticated animals. Besides, this ecosystem also provides many resources for traditional medicine, materials for clothing, building and genetic resources. The region is known for production of timber and fuel as industrial raw materials. Natural ecology of the Niger Delta provides...
chemicals that can be used as drugs and pharmaceuticals. Genetic resources include production of resources for scientific research, for example, plant pathogens and crop pests.

Table 5: Ecosystem services for six landuse categories and the corresponding value coefficients for Niger Delta ecological systems ($ ha\(^{-1}\) per year).

<table>
<thead>
<tr>
<th>The ecosystem services</th>
<th>Rain/fresh water</th>
<th>Mangrove</th>
<th>Farmland</th>
<th>Water</th>
<th>Urban</th>
<th>Bare ground</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate regulation and Purification of air</td>
<td>228</td>
<td>265</td>
<td>0.76</td>
<td>0.2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Water conservation</td>
<td>8</td>
<td>16</td>
<td>0</td>
<td>231.7</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Erosion control and Soil formation</td>
<td>255</td>
<td>11.88</td>
<td>6.54</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Decomposition of waste</td>
<td>87</td>
<td>165.6</td>
<td>11.39</td>
<td>58</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Biodiversity protection</td>
<td>22.65</td>
<td>17.37</td>
<td>2.4</td>
<td>3.8</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Food production</td>
<td>32</td>
<td>47</td>
<td>54</td>
<td>41</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Raw materials</td>
<td>315</td>
<td>162</td>
<td>5.91</td>
<td>4.1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Recreation</td>
<td>112</td>
<td>49.1</td>
<td>0</td>
<td>230</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Traditional medicine and Genetic resources</td>
<td>41</td>
<td>16.5</td>
<td>0.1</td>
<td>0.1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cultural</td>
<td>2</td>
<td>3.1</td>
<td>0.23</td>
<td>6.3</td>
<td>0.1</td>
<td>0.3</td>
</tr>
<tr>
<td>Total</td>
<td>1102.65</td>
<td>753.55</td>
<td>102.93</td>
<td>609.4</td>
<td>0.1</td>
<td>0.3</td>
</tr>
</tbody>
</table>

Niger Delta ecosystem aids erosion control, soil formation and decomposition of waste. Rain/fresh water swamp forest and mangrove have high ecological values for erosion control and soil formation with ESV of 225 $/ ha\(^{-1}\)/year and 11.88 $/ ha\(^{-1}\)/year respectively (Table 5). It is obvious that these values are far apart, because both the vegetation types in the delta contribute higher ecological values towards erosion control due to the nature of its terrain. Studies have shown that tree roots stabilize the soil and foliage intercepts rainfall, consequently helps in controlling erosion. Soil formation services include the accumulation of organic and inorganic soil materials and weathering processes (Costanza et al 1997; Li and Ren, 2008; Li et al., 2010). This service predominantly relates to acquisition, cycling and storage of nutrients for maintenance of crop productivity. Decomposition of waste involves recycling of organic and inorganic wastes through detoxification, waste treatment and pollution control (Bateman et al, 2011).

Recreation and cultural ecological services of the Niger Delta consist of providing opportunities for recreational activities as well as aesthetic, artistic, educational, and spiritual values of the ecosystems. In this case, forest and water have high ecological value of 112 $/ ha\(^{-1}\)/year and 238 $/ ha\(^{-1}\)/year respectively. These values are not surprising because several forest and game reserves are located in the Niger Delta, majority of which were used for recreation and cultural purposes. Therefore, part of the Niger Delta ecological services include provision of outdoor recreational activities, tourism, and sport fishing. There are many locations in the Niger Delta ecosystem with very high value such as a place where people go for relaxation, refreshment and recreation. Cultural ecological service for the Niger Delta includes spiritual, aesthetic and historic information. Water has the highest ecological value in this
regard, with ESV of 6.3 $/ ha⁻¹/year (Table 5). Till today, many forests and rivers have cultural antecedents for religious, sacred, and educational purposes (NDRDMP, 2006). Some communities still believe in worship of holy forests, rivers, animals and natural features and this has shown different means by which human interacts and benefits from the services provided by natural ecosystems.

On the whole, rain/fresh water swamp forest contributes high ecological value coefficients ($ ha⁻¹ per year) for Niger Delta, with total ecological services (1102.65$/ ha⁻¹/year) followed by mangrove (753.55$/ ha⁻¹/year), water body (609.4$/ ha⁻¹/year) and farmland (102.92$/ ha⁻¹/year). However, urban and bare grounds have very low contribution of 0.1 and 0.3 respectively. From the results, it is obvious that ecosystem services provided by forest shows the highest value (1102.65$/ ha⁻¹/year) and mangrove with 753.55$/ ha⁻¹/year. Despite these values, it is clear that both rain/fresh water swamp forest and mangrove have negative percentage change in area, with 27.9% and 9.13% respectively (Table 6). This implies that reduction in the area covers both forest and mangrove vegetation. Though, urban area expands greatly while bare ground reduces with percentage change in area of 84.5% and 55%, but their percentage change in ecological service values are very low, < than 0.005 respectively. These values from Table 6 are not surprising since both urban expansion and bare ground contributed the lowest (0.1 and 0.3 respectively) ecological services values to the delta. Farmland expands greatly (17.2%) in the Niger Delta with little percentage change in the ecological services values (5.6%). What is obvious from these results is that urban and farmland expand at the expense of both forest and mangrove vegetation. Significant losses in ESV of forest and mangrove could be due to the rapid change in landuse in the delta especially increased in urban and farmland.

Figure 7: Percentage change in six landuse categories and ecosystem services of Niger Delta.

Table 7. Change in landuse and ecosystem services for six landuse categories in the Niger Delta

<table>
<thead>
<tr>
<th>Landuse</th>
<th>Change in ESV</th>
<th>Change in Area</th>
<th>% Change in ESV</th>
<th>% Change in Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban</td>
<td>289.786</td>
<td>2897.86</td>
<td>0.0025</td>
<td>84.527</td>
</tr>
<tr>
<td>Forest</td>
<td>10150477.65</td>
<td>-9205.53</td>
<td>*85.8957</td>
<td>-27.892</td>
</tr>
<tr>
<td>Water</td>
<td>80459.082</td>
<td>132.03</td>
<td>0.6809</td>
<td>5.390</td>
</tr>
<tr>
<td>Farmland</td>
<td>664058.0415</td>
<td>6451.55</td>
<td>5.6194</td>
<td>17.238</td>
</tr>
<tr>
<td>Mangrove</td>
<td>921862.928</td>
<td>-1223.36</td>
<td>7.8010</td>
<td>-9.132</td>
</tr>
<tr>
<td>Bare ground</td>
<td>58.545</td>
<td>-195.15</td>
<td>0.0005</td>
<td>-55.029</td>
</tr>
</tbody>
</table>

*Indicates highest percentage change and reduction in ecological service value.
The drivers of environmental change in the Niger Delta

Different drivers of change are responsible for the trends and change in ESV in the Niger delta. Over the years the population in the delta has increased. The total population of the region at the time of 1991 census was about 20 million which was about 23% of Nigeria’s total population. The total population of the region, based on Niger Delta Development Commission’s (NDDC) study in 2006, was over 28 million people. It has the highest population density in the country (Barbour et al. 1982). Increasing the population densities in a region leads to the reclamation of adjacent forest in many communities for rapid urban expansion (AAS 1999; NCF 2006). Thus, increase in population in the major towns and cities in the Niger Delta have posed pressure on the environment in the region. The statistics have shown that the population of Niger Delta has continued to rise since 1960s after the discovery of oil and gas in the large quantities (AAS 1963; NDDC 2001). Census data (2006) showed a rapid increase in population of the region between 1990 and 2006 and that about 25% of the entire Nigerian population now lives in the Niger Delta (Figure 8). This is nearly as a result of high rate migration of people from other parts of Nigeria, who are searching for gainful employment in the oil industry.

![Figure 8: Niger Delta population trend (1990 to 2006).](image)

Source: Nigeria census 2006

Another driver of environmental change in the Niger Delta is urban expansion. This can be attributed to two main facts: Increase in population and creation of more states and associated local governments, where the headquarters became growth centres for regional development.

Many urban settlements in the Niger delta are now battling with uncontrollable rural-urban migration, which results to rapid urban expansion. Niger Delta Regional Development Master-plan (NDRDMP) reported that the rate of rural-urban migration is about 5.3% per annum in the Niger Delta (NDRDMP, 2006). Consequently, rapid urban expansion and increase in population density of major cities in the Niger Delta has had serious consequences such as environmental degradation; overcrowding; poor sanitation and increase in the spread of communicable diseases.

Impacts of oil production on the Niger environment are enormous. Pollution from oil and gas productions constitutes the predominant environmental problem affecting the Niger Delta (Ndubusi and Asia, 2007). Oil spills are the major environmental problem in the Niger Delta resulting in continuous degradation of the environment. A report by UNDP (2006) has estimated that between 1976 and 2001, over three million barrels of oil were lost during about 6,817 oil spillage incidences and about 65% was not
recovered and permanently impacted the environment. Also, within Bayelsa and Delta States only, the World Bank Report (1995) had noted about 2,300m$^3$ of oil spill during 250 separate incidents. A report by experts who visited the region in 2006 put the oil spill figure to be over 13 million barrels of oil over the past 50 years (NCF, 2006). Thus, the incidental rate (Figure 9) has increased over the past decades. A summary of major oil spills in the Niger Delta from 1979 to 2008 are shown in Figure 9. Aside from Forcados terminal oil spillage in July 1979 and Funiwa well blow out in January 1980, which were international most publicised oil spills in the region, several other oil spill incidents have occurred. In fact, Niger Delta of Nigeria has frequent occurrence of oil spills which were not internationally published like that of spill in the Gulf of Mexico, USA in 2010 (The Observer, 2010).

![Figure 9: Oil spill incidence and trend per year in the Niger Delta, 1976 to 2009. Source: NNPC Report](image)

**Conclusion**

This study aims at evaluating and modelling the implications of environmental changes on ecological services of the Niger delta. The results showed that the ecological service values of the Niger Delta have changed over the past three decades. Using Remote Sensing techniques in this research, it was possible to measure occurrence and rate of environmental changes in the Niger Delta without being affected by insecurity anxiety in the region. These environmental changes have led to losses of arable land, lives and properties. Environmental change in the Delta is a critical issue, though political and economic issues take center stage in national subject matter nowadays and environmental degradation in the region is yet to be seen as a problem. Several drivers of environmental change in the delta have been identified and most severe of these are environmental pollution from oil and gas production; land degradation due to commercial and communal logging; rapid population growth and urban expansion. These environmental changes are compounded by numerous conflicts, violence, kidnapping and insecurity in the region. The region has witnessed numerous conflicts in the past decades due to the government's empty promises of benefits for the region since the beginning of oil and gas exploration. On the other hand, the people of the Niger Delta are highly dependent on this decaying environment for their source of livelihood. Local inhabitants traditionally made their living as farmers, fishermen and hunters through exploitation of the resources from land, water and forest. However, the environment, health, social and the economic activities of the people were distorted as a result of the environmental degradation resulting from uncontainable environmental exploitation activities of multinational oil companies and other industries in the region.
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