An Assessment of Land Cover Change and Erosion risk in Akwa Ibom State of Nigeria using the Co-ordination of information on the Environment (CORINE) methodology

By

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ABSTRACT

The aim of this research was to assess the effect of land cover change on erosion risk in Akwa Ibom State, Nigeria from 1987 when the area was constituted into a state. The methodology adopted involved the use of remote sensing and geographic information system [GIS] technologies. Land cover mapping was carried out using remote sensing techniques. Based on the Co-ordination of Information on the Environment (CORINE) model, the GIS technology was used to compile and integrate all the datasets for erosion risk assessment. Potential and actual erosion risk maps were produced. These maps revealed that the area under high erosion risk increased over the years as a result of changes in land cover. The study concluded that, with appropriate modifications, the CORINE model integrated with remote sensing and geographic information system technologies had great potentials for producing accurate and cost-effective erosion risk maps for many areas in Africa.

Keywords: Land cover change, erosion risk, CORINE model.

INTRODUCTION

Land is one of man’s most valuable resources. It is the means of life without which man could never have existed and on which his continued existence and progress depends (Munsi et al., 2010). In recent times, the impact of human activities on land has grown enormously, altering entire landscapes, and ultimately impacting the earth's nutrient and hydrological cycles as well as climate. Soil erosion is one of the major and most widespread agents of land degradation. The adverse influences of widespread soil erosion on land degradation, agricultural production, water quality, hydrological systems, and environment, have long been recognized as severe problems for human sustainability. Accurate and timely estimation of soil erosion loss or evaluation of soil erosion risk has become an urgent task. This is because assessing the soil erosion risk is essential for the development of adequate erosion preventive measures for sustainable management of land and water resources.

Unfortunately, there are many models for predicting soil erosion risk in the developed countries especially in Europe and America. This is not the case in most developing countries like Nigeria. In many countries, data availability plays a crucial role in selecting an appropriate erosion prediction model. In Akwa Ibom State, soil erosion caused mainly by water has been reported in many parts of the state. In spite of this, our knowledge of its dynamics/environmental impact is poor because the methodology and relevant datasets for such studies are yet to be identified and/or compiled for use. The aim of this study is, to assess land cover change and erosion risk in Akwa Ibom State since 1987 when it was created. This is with a view to identifying negative trends which could affect sustainable development. Without a study of this nature, we stand the risk of completely loosing or degrading our limited land resource.

The Study Area

Akwa Ibom State is situated in South Eastern Nigeria. It lies between latitude 4°30′N and 5°30′N and longitudes 7°30′E and 8°15′E [Fig1]. The area covers about 8000sq.km. Mean annual rainfall over the area decreases gradually from about 4050mm near the coastal area to about 2100mm in the north. The mean annual temperature is 26.9°C.
Relative humidity except for the short period of dry season remains at an average of 70% to 80% throughout the year. The area is noted for its wetlands, sandy coastal ridge barriers, brackish or saline mangroves, fresh and salt-water swamp forests as well as lowland rain forest. It is traversed and criss-crossed by a number of rivers and streams. The area has very high agricultural potentials and is rich in crude oil, gas and many other natural resources.

MATERIALS AND METHODS

Land Cover Mapping:

Definition of a classification scheme is an initial step in any image classification project. In this study, the land cover classes were grouped into five based on the FAO Land Cover Classification System. Supervised classification with the maximum likelihood algorithm was carried out to produce land cover maps for different time periods (i.e. 1986 and 2007) using landsat TM and NIGERSAT-1 imageries. The maps were then compared and relevant change statistics generated and presented in tabular form for analysis (Jensen, 2005). The classes in the classified maps were then re-grouped into two: fully protected [areas with forest cover] and not fully protected [farm/fallow land, built up area/baresoil]. This was done in line with the CORINE methodology.

Erosion risk assessment

There are many expert-based and model-based approaches that have been used for the development of erosion risk maps of various parts of Europe (Grimm et al., 2002). Of these models, the CORINE model was adopted in this study because the required datasets were available although they were outdated and had to be compiled and updated from different sources. The required database parameters were soil erodibility, erosivity, topography (slope), and land cover. The methodology considered two different indices of soil erosion risk. They were potential soil erosion risk and actual soil erosion risk. Fig 2 indicates the logic behind the methodology used in CORINE model.
Factors/Variables Used

The main factors affecting the amount of soil erosion include land cover, topography, soil, and climate (CORINE, 1992). In order to determine the areas with soil erosion risk and to develop adequate erosion prevention measures, erosion risk maps were generated based on these factors. Maps of the study area were produced to depict the distribution of these factors. The techniques used are discussed in more details below.

Potential soil erosion risk

Based on the CORINE model, the potential soil erosion risk was determined using the formula:
Potential Soil Erosion Risk Index = Soil Erodibility Index X Erosivity Index X Slope index

Soil Erodibility

<table>
<thead>
<tr>
<th>S/N</th>
<th>Maps</th>
<th>Date published</th>
<th>Publisher</th>
</tr>
</thead>
<tbody>
<tr>
<td>**1</td>
<td>Slope map of Cross River Basin</td>
<td>1982</td>
<td>Cross River Basin Development Authority</td>
</tr>
<tr>
<td>**2</td>
<td>Soil map of Cross River Basin</td>
<td>1982</td>
<td>Cross River Basin Development Authority</td>
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</tbody>
</table>
Table 1 Continues

<table>
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<tr>
<th></th>
<th>Qua Iboe River Basin Land Capability, soils and Development Potentials</th>
<th>1982</th>
<th>Cross River Basin Development Authority</th>
</tr>
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<tr>
<td>3</td>
<td>Qua Iboe River Basin soil map</td>
<td>1982</td>
<td>Cross River Basin Development Authority</td>
</tr>
<tr>
<td>4</td>
<td>Qua Iboe River Basin Land Classification for Irrigation</td>
<td>1982</td>
<td>Cross River Basin Development Authority</td>
</tr>
<tr>
<td>5</td>
<td>Soil map of Akwa Ibom State</td>
<td>1989</td>
<td>Akwa Ibom State</td>
</tr>
<tr>
<td>6</td>
<td>Soil Survey of Akwa Ibom State showing soil observation Points</td>
<td>1989</td>
<td>Akwa Ibom State</td>
</tr>
<tr>
<td>7</td>
<td>EIA report of Ibom Hotel and Golf Resort: Site map showing sampling locations</td>
<td>2006</td>
<td>Ministry of Culture and Tourism</td>
</tr>
<tr>
<td>8</td>
<td>EIA report of Qua Iboe field Development Project: Site map showing sampling locations</td>
<td>2005</td>
<td>Network E &amp; P Nig. Ltd</td>
</tr>
<tr>
<td>9</td>
<td>EIA report of Stubbs Creek Marginal Field: Site map showing sampling locations</td>
<td>2006</td>
<td>Universal Energy Resources Ltd</td>
</tr>
</tbody>
</table>

N.B. *Available in sheets; **the entire Akwa Ibom State is part of the basin; ***these maps cover more than 96% of Akwa Ibom State.

Source: Inventory by Author June, 2011.

In the CORINE methodology, soil erodibility is calculated by combining soil texture, soil depth, and stoniness. Maps showing these parameters were compiled from the existing soil map and other sources, using the GIS technology. Table 1 shows details of existing sources of Information on the properties of soils in Akwa Ibom State. Since all the existing sources of information were out-dated, the resultant maps were validated using information from current EIA reports. Environmental impact assessment (EIA) is an important procedure for ensuring that the likely effects of new development on the environment are fully understood and taken into account before the development is allowed to go ahead. It usually contains among other things, a lot of detailed information and data on the condition of the project area prior to the project's implementation. Since EIA studies are usually based on standardized procedures/methodologies carried out by experts in relevant fields and paid for by owners of projects, it is a cheaper and very reliable source of spatial data for environmental monitoring/management. In the EIA reports, details of soil characteristics at various sample points are given. Using the GIS technology, the various soil sample locations were overlaid on existing soil maps and their texture, depth and stoniness compared. Based on this overlay analysis, no change was observed between the soil properties as shown on the soil maps published in 1982 and the properties of sampled locations between 2005 and 2006. This was an indication that, as far as the soil parameters in question are concerned, the situation had not changed. Therefore, the soil map was still usable. From these sources, map layers on texture, depth and stoniness were compiled.

In line with the CORINE model, soil texture was classified into three classes including (1) Slightly erodible, (2) Moderately erodible, and (3) Highly erodible. It is obvious from Fig 3 that a greater percentage of the State is made up of sandy loam which is highly erodible.
By considering the percentage surface cover of stones, the stoniness was compiled from a map showing the physiographic features of the area and classified as (1) fully protected and (2) not fully protected soils. Figure 4 shows that the area with more than 10% stoniness is located in the northern part of the Study area.

Similarly, the soil depth was also classified as (1) slightly erodible, (2) moderately erodible, and (3) highly erodible soils, by considering the depth from the soil surface to the base of the soil profile. Fig 5 shows the highly erodible soils are found in the northern part and the eastern coastline.
Finally, the soil erodibility index was calculated as a function of soil texture, soil depth, and stoniness:

Soil Erodibility Index = Texture Class X Depth Class X Stoniness Class

The calculated erodibility index was reclassified into three classes including (1) low, (2) moderate, and (3) high erosion [Fig 6].

**Erosivity**

In the CORINE model, erosivity is calculated by combining two climatic indexes including the Fournier index [MFI] and Bagnouls-Gaussen aridity index (BGI). The Modified Fournier Index for seven meteorological locations was
calculated. The result revealed that MFI was greater than the CORINE value of 160 in all the locations. This implied that MFI can be ignored as it will not be responsible for any variation in erosion prediction within the study area. However, since in Akwa Ibom, there is a marked variation in rainfall from about 4000mm near the coastal area (the southern part) to about 2250mm in the north, it will not be right to ignore the variations of the impact that this can have on the soil. Consequently, in this study, the MFI for the 7 locations was used as basis to produce the erosivity map.

Fig 7: Akwa Ibom State: Erosivity

Fig 7 shows that the area with very high erosivity was in the southern part, the central part had higher erosivity while the northern part experienced moderate erosivity. Furthermore, the Bagnouls-Gaussen aridity index [BGA] was calculated as zero for the entire area. The value of zero in the CORINE model has an index of one [humid] indicating that if both MFI and BGA map layers were combined, the MFI values will not change. This also implies that BGA will not be responsible for any variation in erosion prediction within the study area.

Topography (Slope):

Fig 8: Akwa Ibom State: Slope
In this study, the slope data layer was derived from a 30m DEM data using spatial analyst extension in ArcGIS 9.2. The resultant slope map was classified into four classes according to the CORINE methodology. Fig. 8 revealed that the steep slopes were found mostly in the north eastern and central part of the state.

**Actual Soil Erosion Risk**

To generate actual soil erosion risk map, the land cover layer is combined with the potential soil erosion risk layer. It is important to state that all the data/map layers mentioned above were combined as shown in the flowchart [fig 2] using the arithmetic overlay/math [multiplication] operation in the spatial analyst tool of ArcGIS software.

**RESULTS OF DATA ANALYSIS**

**Land Cover Change**

The distribution of the two major CORINE based land cover types identified in the study area are shown in the land cover maps [Fig 9 and Fig 10]. It is obvious from table 2 that as at 1986 when Akwa Ibom State was not created, 71% of the area was fully protected. This reduced to 31% in 2007 as shown in table 3. Fig 9 and Fig 10 show the spatial distribution of these areas. As at 1986, swamp and secondary forest were found almost everywhere. In 2007, they became restricted to the coast and banks of Imo, Kwa Iboe and Cross rivers.

<table>
<thead>
<tr>
<th>CORINE Index</th>
<th>CORINE Classification</th>
<th>Area [Ha]</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fully Protected</td>
<td>475677</td>
<td>70.7</td>
</tr>
<tr>
<td>2</td>
<td>Not Fully Protected</td>
<td>196761</td>
<td>29.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>672439</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 2: Akwa Ibom State: CORINE land cover as at 1986

<table>
<thead>
<tr>
<th>CORINE Index</th>
<th>CORINE Classification</th>
<th>Area [Ha]</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fully Protected</td>
<td>210603</td>
<td>31.3</td>
</tr>
<tr>
<td>2</td>
<td>Not Fully Protected</td>
<td>461836</td>
<td>68.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>672439</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 3: Akwa Ibom State: CORINE land cover as at 2007

![Fig 9: Akwa Ibom State: Land Cover as at 1986](image)
Potential erosion risk

The result presented in Table 3 revealed that about 61% of the study area had high potential erosion risk, while the rest of the area was under low and moderate potential erosion risk. Fig 11 shows that areas with high potential erosion risk are found mostly in the north eastern and southern part of the State. The central part was where potential erosion risk was moderate while it was low in the north.

Actual erosion risk

The combination of the CORINE based land cover maps for 1986 and 2007 and the potential erosion risk map resulted in the production of the actual soil erosion risk map for 1986 and 2007. Fig 12 revealed that, as at 1986, the study area had 17% high, 52% moderate and 31% low actual erosion risk areas. This changed to 38.5% high, 44.6% moderate and 16.9% low actual erosion risk areas in 2007. The distribution pattern of these actual erosion risk areas are shown in Fig 13 and Fig 14.
Fig 11: Akwa Ibom State: Potential Erosion Risk

Fig 12: Comparison between potential and actual erosion risk in Akwa Ibom State
Source: Fig 11, Fig 13 and Fig 14
Fig 13: Akwa Ibom State: Actual Erosion Risk in 1986

Fig 14: Akwa Ibom State: Actual Erosion Risk in 2007
Table 4: Number of existing gully sites within high, moderate and low potential and actual erosion risk areas

<table>
<thead>
<tr>
<th>Risk Rating/CORINE Classes</th>
<th>Potential Risk</th>
<th>Actual Risk 86</th>
<th>Actual Risk 07</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>40</td>
<td>64.5</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td></td>
<td>41.9</td>
<td>36</td>
</tr>
<tr>
<td>Moderate</td>
<td>20</td>
<td>32.3</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>32.3</td>
<td>22</td>
</tr>
<tr>
<td>Low</td>
<td>2</td>
<td>3.2</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>25.8</td>
<td>4</td>
</tr>
</tbody>
</table>

Source: Fig 15 and Fig 16

Fig 15: Actual Erosion Risk in 1986 and existing gully sites

Fig 16: Actual Erosion Risk in 2007 and existing gully sites
Accuracy of erosion risk maps

The validation process was based on information on the existing gully erosion sites in the State. Using the administrative map of the State as guide, the communities where the gully sites are located were identified and their locations depicted on the erosion risk maps for 1986 and 2007. It is obvious from fig 15 and fig 16 and table 3 that, most of the locations of existing gully sites coincided with the areas classified as having either moderate or high potential/actual erosion risk. This is an indication of the accuracy of the erosion risk maps, the dataset from which the maps were produced and above all, the applicability of the CORINE model to the Nigerian situation.

DISCUSSION

The difference between the areas of potential and actual erosion risk as shown in Fig 12 indicates the effects of land cover on soil erosion. Land cover, is the most crucial element in erosion models, since it is the only factor that can readily be altered. Studies have shown that the presence or absence of vegetation cover more than any other factor is what determines the rate of soil erosion at any location. The role of vegetation includes providing shade and shelter, intercepting raindrops, reducing runoff and improving infiltration (Dengiz and Akgul, 2005; Bayramin et al., 2006).

The implication of the foregoing is that care must be taken to ensure that during the rainy season, the earth surface is not exposed for too long in areas with moderate and high actual erosion risk as is currently the case in construction/project sites. Plate 1 is an example of what to expect at such sites. This photograph shows a section of the gas pipeline route from Esit Eket to Ikot Abasi constructed in 2010. This route cuts through the swamp forest along Kwa Iboe river. The route lies within the area with moderate actual erosion risk.

CONCLUSIONS

This study has shown that using remote sensing and geographical information system technologies for erosion risk mapping, based on the methodology implemented in CORINE model, resulted in a cost-effective and accurate assessment of soil erosion risk in Akwa Ibom State. With appropriate modifications, CORINE model can be used in assessing erosion risk in any part of the world to safeguard our natural resources. Even where available data is outdated, we have also demonstrated how EIA reports can be used to assess and update available datasets.
REFERENCES


