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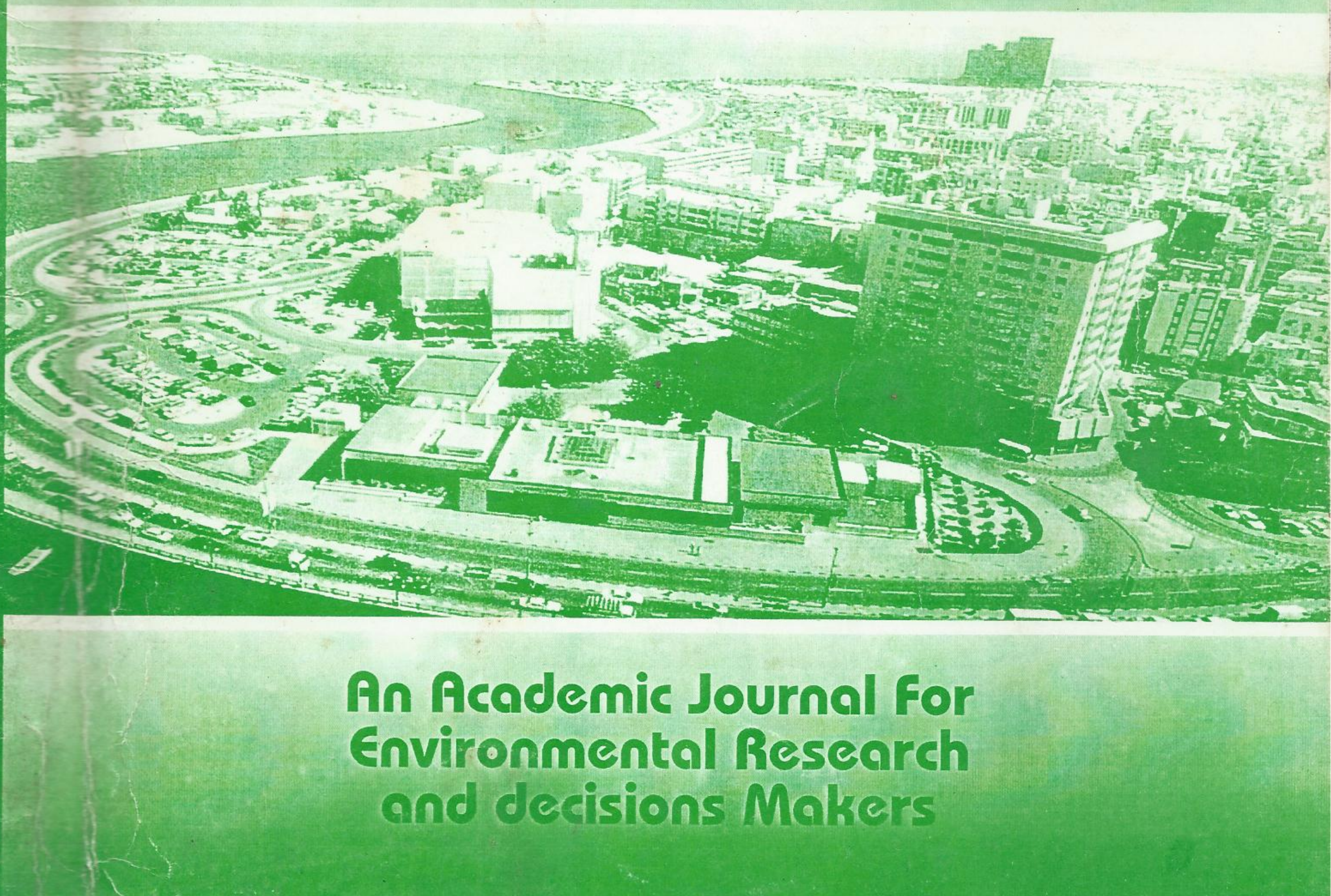

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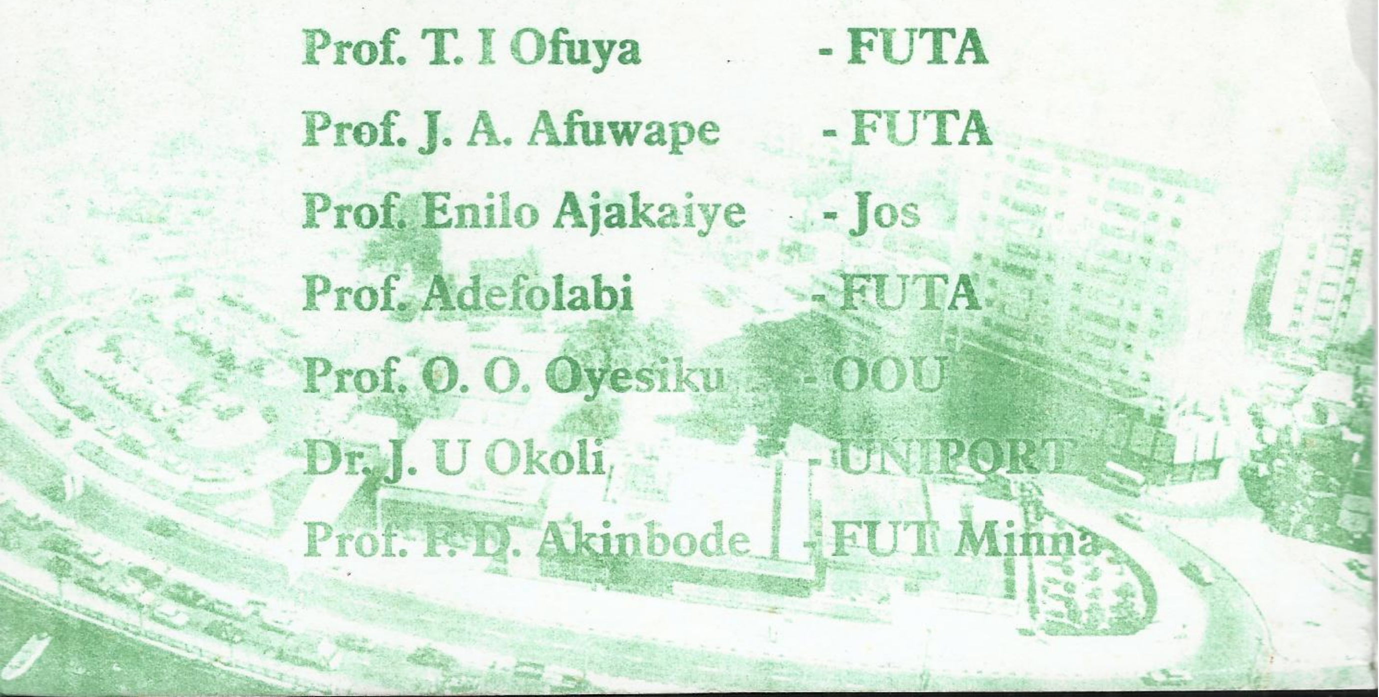

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# Coastal Flooding Risk and Community Adaptive Strategies in the Western Niger Delta

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## Abstract
The Western Niger Delta is an extensive low-lying area exposed to flood risk for several months during the year from excessive discharge from sediment-laden Niger River, high rainfall from the area and coastal storm surges. This study employs remote sensing data and GIS to delineate and classify the susceptibly of the study area to flood risk. Economic and social implications of regular seasonal flooding of the area were also considered. The results show that a total land surface of about 3183.45km$^2$ lies below 5m i.e. (between very high and moderate flood risk) and 1407km$^2$ of this lies below 1m (i.e. very high flood risk). 88 built up areas (30% of the total) with total area of about 9.69km$^2$, and 78.1km$^2$ of cultivated lands are always at the risk of serious impact by seasonal flooding. Local adaptive strategies of the inhabitants were examined and environmentally sustainable and locally appropriate coastal zone management strategies for flood management in the study area are suggested.

Keywords: Flood risk, elevation, GIS, accelerated sea level rise, adaptive strategies, coastal zone management.

## Introduction

The current climatic fluctuations and shift in global climatic normal, thought yet to be fully understood, is causing apprehensions r across the globe. This is because it is likely to give rise to more natural hazards. For example, available data on global climatic indicators have indicated net increase in global surface temperature to be between 0.3 and 0.5% over pre-industrial periods (Duraiappah, 1993). An estimated increase of between 1°c and 4.5° c over the current global temperature is therefore expected to trigger off accelerated sea level rise to the range of 0.2m and 1.4m (Wind, 1989; Ominde & June, 1991). This surely is no cheering news for coastal ecologies and other low-lying areas of the world as their lands and land resources are likely to be severely impacted. Natural environmental hazards such as earthquakes, volcanoes, hurricanes and tornadoes, droughts, forest and grass fires, floods, landslide (mass wasting), etc are often commonly described as acts of God. A hazard denotes potential for negative outcome such as loss or damage. Pramojanee, et al (1997) describe hazard as a potential event that can cause loss of life, or damage to property or the environment. Natural hazards, according to White (1974) are results of an interaction of people and nature governed by the coexistence state of adjustment in the human use system and the state of nature in the natural events system. Extreme events which exceed the normal capacity of the human system to reflect, absorb or buffer them are inherent in hazard and where this occurs, they lead to disasters. A disaster, if not well managed can be severe and require exceptional measures for the people or community to respond to it. Vulnerability is the degree to which an area, people, physical structures or economic assets are exposed to loss, injury or damage caused by the impact of a hazard. Risk means possibility of hazard (Frank, et al 2001), the potential for disaster (Pramojanee, et al, op cit) and the probability of hazard in a vulnerable environment (Dormany, 2000). However, Hewitt & Burton (1971) observed that it is important to establish the place of damaging events within the overall context of man's ecology. This is because many of the natural elements that cause damage are under more normal circumstances sources of livelihood and man's activities are closely integrated in them.

Floods, which may be defined as unusually high rates of discharge often leading to the inundation of land adjacent to the streams (Ward, 1975), is one of the commonest and most recurring environmental hazards or extreme events known to man. Globally, and in Nigeria in particular, widespread flood progressively cause devastating ecological havocs by destroying lives, properties, agricultural lands and social infrastructure (Fubara, 1987). The coastal floodplains and lowlands are especially vulnerable to coastal storm surges and susceptible to risk of inundation from an accelerated sea level rise. Arms, (1994) observed that millions of Bangladeshis live on sandbars in the Bay of Bengal that are washed away every year by high tides and floods. He further observed that 1200 people died and 25 million people left homeless in 1988 when monsoon rains flooded the Ganges River. The Mozambican coastal flood of 2000 and the recent flooding of coastal cities and settlements along the major rivers of most parts of Europe are all pointers to the vulnerability of coastal low-lying areas. The situation becomes even more critical where the area in question is a coastal wetland susceptible to both seasonal flooding due to high discharge from the upland rivers, and coastal storm surges from the ocean. Such is the case in the Niger Delta coastal wetlands of Nigeria. The growing increase in population and economic activities in the coastal wetlands of Nigeria have increased the need for disaster management and risk assessment in these areas.

## Problem definition and study objectives

Although some previous works have provided an insight into the flood problem in the Niger Delta area, none of them has actually combine the technologies of remote sensing and geographic information system (GIS) to assess and quantify the extent of land resources and settlements at risk from (accelerated sea level rise induced) flooding of the Niger delta. Some of the existing reports are either general observations on flooding problem or detailed small-scale engineering investigations on flood in specific settlements or part of a city in the Delta. The Niger Delta Environmental Surveys baseline assessment reports (NDES, 1997) describe flooding in the Niger Delta as a major largely uncontrolled environmental condition that controls to a degree the rhythm of life and human settlements are seriously subject to its vagaries. Dubblin-Green, et al (1997) identified the low topography of the Niger Delta area as making it susceptible to flooding especially at high tides and during the rainy season. This makes large areas of back beach perpetually wet and waterlogged, and many communities have to move upland dusting the rainy season to avoid floodwaters. This study takes the meso-scale, regional approach to flood studies in the delta.

### The objectives of this study are:

- To generate spatial data on settlements and land resources of the study area from existing base maps and archive remote sensing imageries.
- To overlay the land resources data with elevation data within a GIS environment.
- To delineate and classify the study area unto according to vulnerability to accelerated sea level rise induced flood risk.
- To quantify the extent of settlements and land resources that are likely at risk of accelerated sea level rise induced flood of a given magnitude.
- To identify the nature and range of adjustments mechanisms (adaptive/coping strategies) available to the inhabitants of the study area now and to suggest prevention and mitigation strategies necessary to prevent catastrophic outcomes in case of future flood hazard.

## The Study Area

### Location

The study area lies approximately between longitudes 5° to 6° east and latitudes 5° to 5° 30' north. It is about 3,500km$^2$ in extent running along a coastline distance of about 64km. It extends from the mouth of the Escravos River up to about 15km after the Ramos River transcending parts of Delta and Bayelsa coastline in the Western Niger Delta of Nigeria (figure 1).

### Geology, relief, and drainage

The study area falls into the sedimentary basin of West Africa. The western part of the Niger delta basin, according to Wright, at al, (1985) formed from the growth of the Delta into the Gulf of Guinea following gradual retreat of the sea after a short-lived Paleocene transgression on to the late cretaceous coal measures. It has few outcrops of the belt of post cretaceous sediments that are much younger around this area than the rest of the Niger Delta. The area is virtually flat with elevation ranges of 0m (along the coast) to about 7m in the upland. The soil consists of abandoned beach ridges near the coast; extensive mangrove swamps, wooded back swamps and freshwater swamps soils are found further away from the coast. The single dominant physical feature that has influenced all other physical-biological constituents of the study area (like the rest of the Niger Delta) is drainage. The Niger River produced intricately woven networks of creeks, rivers, rivulets, inlets and canals in the study area. The Forcados and Ramos rivers, which are distributaries of the Niger, are the major drainage systems within the study area and all other small creeks; rivers and rivulets are connected to these major rivers. Tidal information recorded at Forcadoes in the study area according to Dublin Green et al (1997) shows 1.402m, 1.128m, 0.152m, 0.823m and 0.427m for mean high water spring (MHWS), mean high water neap (MHWN), mean low water spring (MLWS) mean low water neap (MLWN) and mean sea level (MMSL) respectively. However, at violent tides and storm surges, mean high water spring could be as high as 4m. This often cause back discharge to the distributaries thereby raising water levels and flooding of adjoining lands.

Fig. 1: The Study Area

## Climate and Vegetation

The study area is a tropical coastal wetland with mean annual rainfall approaching 3000mm, and mean number of rainy days of about 180 to 200. Mean relative humidity is between 70-80%, mean annual temperature is about 27.8° C, and mean daily maximum temperature is 26.7°C. The major vegetation consists of freshwater swamps forest, mangroves, marsh, palm bush and tidal flats that are almost bare.

### The people

The study covers about mine local government areas in Delta and Bayelsa states. It is densely populated with no less than 500 settlements (towns, fishing villages and hamlets) having an estimated population of about half a million people. The Ijaws, Itshekiris and Urhobos, are the major inhabitants. Their major occupations are fishing, craft making and peasant farming.

### Methodology

### Data and data sources

The data used for this study are: Landsat TM satellite imagery acquired in March 1988, (dry season), path 188 Row 56, with original spatial resolution of 30mx30m resampled to 25mx25m and Nigerian 1:50,000 topographic map sheets (Forcados 317NW, NE & SE and Burutu 318NW, NE, SW and SE) acquired from the Federal Surveys Department for the purpose of extracting the locations and names of settlements by digitizing. They also serve as the base/ancillary data for interpreting the Landsat TM imagery. A 3 arc second DEM of the area produced from 1:250,000 map of the study area was also used.

### Procedure

A subset of the Landsat TM imagery created for the study area was imported into Arcview GIS 3.1 Software. Image georectification, resampling, and enhancement were done using Image Analyst 1.1. The enhanced image was visually interpreted and classified into feature classes using the head-up digitizing method. This becomes important against the inherent limitations of the automatic (supervised and unsupervised) classifications methods at differentiating terrain features with highly similar or homogenous spectral reflectance characteristics (e.g. sand bar and built up areas on coastline) in such an environment like the study area. A one-meter interval contour was generated from a 90m posting (horizontal accuracy) DEM of the study area produced from 1:250,000 topographic maps. The one-meter interval contour was converted to a triangulated irregular network (TIN) surface using Arcview's 3D Analyst. The TIN was further converted into a GRID surface of 50mx50m.

Fig 2: Flow chart of the research methodology

The GRID file was opened as an image analysis data and the image was classified into 30 categories (classes) using the Arcview's Image Analysis extension. The resulting categorized image was vectorised using Arcview Spatial Analyst. The resulting vector layer (polygon) was overlaid with the vector layer (polygon) generated from visual analysis of the landsat TM imagery. This was done to show extent of each area that falls within a given elevation value range. A query was also constructed to return the total areas and land resources at risk in areas that are <= 1m above sea level. The summary of the methodology used is shown on fig 2.

### Discussion of Results

The study area is about $3{,}560km^2$ in extent. The area is typically low lying with elevation ranging between 0m and 13m above sea level, and the gradient decreases westwards towards the gulf of guinea as shown in the 3D scene of the area shown on figure 3.

Fig 3: 3D scene of the Study Area

A flood risk/sensitivity map classifying the area into very high, high, medium and low flood risk zone (fig. 5) is produced from the 3D elevation model in fig 3.

The major land use/land cover classes of the area include built up areas, water bodies, mangrove, marshlands, swamp, cultivations/farmlands, thickets and secondary growths, palm bush and scrubland. The settlements are located along the raised riverbanks and beach ridges, while farmlands are found along the river valleys, encompassing the settlements and along old river channels and meandered belts (fig 4).

Fig 4: Settlements in the study area

Table 1: Flood Sensitivities of the Study Area

| Mean Elevation | Flood Risk | Area Sq Km | % |
|---|---|---|---|
| *0.00 | Water + Coastline | 1412.031 | 28 |
| 0.04 | Very High | 11.1521 | 0.22 |
| 0.13 | Very High | 17.6252 | 0.35 |
| 0.29 | Very High | 27.1128 | 0.54 |
| 0.5 | Very High | 36.4505 | 0.72 |
| 0.74 | Very High | 43.1638 | 0.86 |
| 1.0 | Very High | 1202.276 | 23.9 |
| 1.19 | High | 69.4439 | 1.38 |
| 1.41 | High | 78.2823 | 1.55 |
| 1.63 | High | 81.4771 | 1.62 |
| 1.83 | High | 76.369 | 1.52 |
| 2 | High | 752.3985 | 14.9 |
| 2.28 | Moderate | 43.9007 | 0.87 |
| 2.54 | Moderate | 38.3004 | 0.76 |
| 2.77 | Moderate | 34.2201 | 0.68 |
| **Mean Elevation** | **Flood Risk** | **Area Sq Km** | **%** |
| 3 | Moderate | 73.2881 | 1.45 |
| 3.22 | Moderate | 39.0353 | 0.77 |
| 3.45 | Moderate | 44.732 | 0.89 |
| 3.7 | Moderate | 54.3926 | 1.08 |
| 3.99 | Moderate | 192.9316 | 3.83 |
| 4.15 | Moderate | 40.3336 | 0.8 |
| 4.35 | Moderate | 44.7486 | 0.89 |
| 4.57 | Moderate | 44.8176 | 0.89 |
| 4.79 | Moderate | 41.5171 | 0.82 |
| 4.99 | Moderate | 95.487 | 1.9 |
| 5.25 | Low | 26.6348 | 0.53 |
| 5.77 | Low | 89.4545 | 1.78 |
| 7.63 | Low | 220.8317 | 4.38 |
| 13.76 | Low | 105.9768 | 2.1 |

A summary of the total area under each elevation and flood risk category is shown on table 1.

Fig. 5 Flood Risk Zones of the Study area

Fig 6: Land resources and settlements under very high and high flood risk

From the GIS flood risk analysis, about 1,337.78km$^2$ representing 26.6% of the area falls into the very high flood risk zone. Correspondingly, 1,058km$^2$ (15.6%) and 442.8km$^2$ (9%) of the land area respectively fall under high, moderate, and low flood risk zones. Excluding the areas covered by water bodies (rivers and ocean), about 3,183.45km$^2$ (763039.2 acres) representing about 63% of the total study area falls under 5m elevation.

Furthermore, from the analysis of land resources data generated from the satellite imagery, there are about 293 built up areas (settlements) covering about 37.8km$^2$ (9,350 acres). This is in addition to several hundreds of small villages and fishing camps that are not directly interpretable from the imagery (fig 4). The area also consists of 299km$^2$ of cultivated lands. The rest are water bodies, mangrove, forest, palms and thickets. 88 settlements or 30% of the 293 built up areas with total area of 9.69km$^2$ or 25.6% of the total area of all settlements and 78.1km$^2$ or 26.1% of the total area of farmland within the study area are lying within the very high and high flood risl zone (0.1-2m). The implication is that these feature anc areas are likely always at the risk of inundation by flooc year in and year out.

## Economic and Social implications of Flood problems and Community Adaptive Strategies in the study area

Bruce, (1990) commenting on the probability of sea leve rise as a result of global warming observed that 12-15% o Egypt's arable lands and other densely populated low-lying coastal areas and estuaries are susceptible to devastating inundations due to surges during coastal storms. The socia and economic implications of the seasonal flooding of thi udy area for almost 6 months in the year are rather great. This comes in form of social dislocations, loss of economic activities and livelihood sources and yearly migration from the extremely low-lying to relatively higher grounds. Farmlands, Lakes and ponds (that serve as sources of drinking water), and fishponds and aquacultures are also inundated, resulting in eutrophication of lakes and ponds, and therefore forced shifts in livelihood sources at flood seasons. Important towns such as Forcados, Burutu, Bomadi, and Ekeremor are among the acutely affected built up areas. The last three settlements are administrative headquarters, with each having a population of over 30,000 people. The study area is also part of the oil and gas fields of the Niger Delta with lots of oil and gas infrastructures in place. Though flooding problems in the area may not pose formidable problem to oil exploration and other activities, oil and hazardous chemical spillage, which is a regular pollution problem in the Niger Delta, can be exacerbated by the flood problem. Oil and chemicals travel faster on water than any other medium, and at high tide rapid cleaning response strategies are difficult to implement. Hence the probability of an oil spill being more devastating at flood season is quite high. This always causes social and health problems to the inhabitants.

An important consideration is that the magnitude of flooding problem and terrain of the study area and the Niger Delta in general makes implementing hydraulic or construction based adaptive solutions such as raising/construction of dykes difficult and environmentally non-sustainable. The local inhabitants know so much about themselves and their environment, and this knowledge is being put to use. Over the years flood defense mechanisms has been implemented wholly through their knowledge and perception of the environment. Some of these defense mechanisms include the following:

**Sèasonal economy**

The local people run a type of dual economy that is wholly controlled by seasons. Farming and fishing (plus other coastal resources allied industries such as mat making, gin bottling, boat making, etc) form the main economy. At periods of low flow usually mid November to May, fertile alluvial raised beach ridges and riverbanks are intensively cultivated for vegetables, cereals, seasonal fruits and sometimes yam species. The crop calendar is arranged such that by the approach of the next flood season (high flow), the crops are ready for harvest. At peak flood season, the people shifts to full time fishing and other coastal resource based economic activities. In this case not much threat is posed to their food security.

**Appropriate technologies for local constructions**

Another major defense mechanism employed by the people is the mode, methods and materials of building constructions. Houses are usually or in most cases constructed with thatched palm fronds supported by strong mangrove trunks. These houses are also raised up to about 1m-1.5m above the ground level. At high flood level, paddle canoe becomes the only mobility source to reach these houses.

**Environmental migration**

At high flood when most lakes and fishing ponds are inundated; some inhabitants especially of the extreme low-lying fishing camps and villages often migrate to the relatively higher grounds where new settlements are constructed. Some others, especially the virile young men do migrate to oil and gas construction sites and upland towns and cities such as Warri, Ughelli, Sapele and Port Harcourt in search of daily/monthly paid employment. Many of then migrate back to the swamp and coastal settlements when flood has considerably receded.

**Recommendations for Sustainable Flood management and Conclusions**

The nature of the flooding problems and the difficult and sensitive edaphic components of the Niger Delta may not permit holistic hydraulic or engineering solution to the flood problem. Hence in addition to the various appropriate adaptive responses by the local people, an integrated coastal zone management approach to flooding is required for effective flood management in the study area and the Niger Detla. This should involve integrating the planning of waters of the Niger with its adjoining lands, i.e. planning water and water related land resources or coordinating the planning of the flow resource with that of the landscape element as observed by Falkenmark, (1983). There is therefore the need for detailed sensitivity mapping of the study area and the entire Niger Delta with a view to classify and delineate the areas according to susceptibility and vulnerability to flood risk; as well as the human, social, economic, cultural and ecological values at risk.

There is also the need for land use and resource planning in the study area. This will involve the location of local industries that are dependent on local coastal resources and materials that are abundantly available in the study area. Fish processing, cane weaving, boat making, log/wood processing and gin/distilleries are some of the industries with raw materials locally available in the study area (Fasona & Anosike, 2002). If these industries are set up in parts of the study area that are less sensitive to flood risk, they will provide alternative and viable sources of income and livelihood to the inhabitants and make them less susceptible to the vagaries of seasonal changes.

As part of the integrated coastal zone management planning, more research should be conducted into the feasibility of the proposed dredging of the lower Niger River especially as it relates to flooding reduction. More gauging stations and ocean parameters monitoring stations should be set up around the study area to enhance monitoring and better prediction of flood and flooding problems in the area. Such information if obtained in real time are capable of being converted into sophisticated systems for early warning (EW) information that can be disseminated to the inhabitants as at when necessary. Correspondingly, refuge platforms should be constructed in strategic areas closer to major human habitation. More information and education to the inhabitants on ways of improving local adaptive strategies is also necessary. Finally, creation of a GIS databank that can assist in monitoring of flood and other natural hazard, land use and other planning activities in the study area is necessary.

This study has highlighted the flooding problems and the risk of probable flood hazard resulting from accelerated sea level rise in the western Niger Delta using remote sensing and GIS techniques. The land resources that are seriously at risk have been assessed. Local adaptative strategies currently in place in the study area are examined and recommendations have been suggested for future flood disaster mitigating measures in the area. With the probable increase in climatic variability, and its expected global warming and anticipated accelerated sea level rise, it is clear that there is the urgent need for capacity building towards sustainable adaptative and preventive flood management strategies to save the people and resources of the study area from future catastrophe.

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