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Risk Analysis of Arable land to Flooding: A Case Study of Yenagoa and Environs, Bayelsa State, Southern Nigeria

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Abstract

This study assesses the threat of arable land to flood events within parts of southern Nigeria; this is due to the impact the recent flood events of 2012 had on different aspect of the environment, including farm and crop lands. It therefore becomes necessary to determine the level of vulnerability in this locality, especially within the floodplains. This approach will combine various spatial layers in a multi-criteria decision model such as forest areas arable lands, built up areas, and rivers; and subsequently adding weights to these layers. The analysis of DEM indicates that over 70% of the Bayelsa State is located within the floodplain (below 40meters). Also, that arable lands make up approximately 15% of the land cover types. The proportion of arable land likely to be flooded and their spatial pattern is mostly concentrated in the south east and north east of the study area; with over 85Km^2 or 38% of these arable lands at risk to flooding. This model indicates that over a quarter of the food production areas are at risk of been inundated and hence threatens the food security of the communities. Therefore, adaptive measures are vital for the sustenance of the food production capacity.

Keywords: Floodplains, DEM, multi-criteria decision analysis, spatial pattern.

Introduction

Many countries are already dealing with climate change impacts resulting from irregular, unpredictable rainfall patterns, increased incidence of storms and prolonged droughts. In the assessment of the global economic cost of extreme weather and flood catastrophes it was determined that their impacts to be severe especially to the poorest nations. From 1971 to 1995, floods affected more than 1.5 billion people, or 100 million a year; of those, 318,000 people were killed and more than 81 million left homeless[1]. Additionally, the number of major flood disasters has risen relentlessly over recent time. In Nigeria, the incidence of flooding have been on the increase in the last decade, there have been precisely four (4) major flood events between 2010 and 2013.Consequently, within this period mechanisms have been set-up to deal with the response phase of flooding and coordinated by the National Emergency Management Agency (NEMA) through the International Charter on Space and Major Disaster (ICSMD). This mechanism has been activated by the authorized user (NEMA) on behalf of Nigeria in 2010, 2011 and 2012 for floods in Sokoto (Charter Call 324 and 326), Ibadan (Charter Call 370), and Adamawa (Charter Call 407), Kogi (Charter Call 415), Bayelsa (Charter Call 416), respectively[2]. The results from these activations have enhanced the ability of NEMA to respond to disasters swiftly and efficiently. Moreover, these activations complemented the Nigerian satellite infrastructures, Nigeria sat-1, Nigeria Sat-2 and Nigeria Sat-X.

Due to the increasing intensity and frequency of flooding globally, attempts have been made to investigate the natural and human causes of flood and flood related disasters. This has been achieved through flood risk assessment, which identifies the level of flood risk to properties or sites. Furthermore, several researches have attempted to determine risk of flood to various phenomenon; A study mapped flood risk vulnerability pattern in flood plain of the Kankai River, Nepal using a combination of flood simulation model, remote sensing data and socio-economic data[3]. Another study also used social survey and focal group discussion in analysing the impact of flood on farmlands in Cross River state, Nigeria[4]. However, a resourceful attempt was taken to derive flood hazard index map of vulnerability levels by incorporating population density, flood frequency, transportation network, access to drinking water and the availability of high ground in mapping maximum risk zones[5].

It has been reckoned that the rapid growth of the world's population has escalated both the frequency and severity of the natural disasters[6]. Flood disaster has a very special place in natural hazards. Floods are the costliest natural hazard in the world and account for 31 per cent of economic losses resulting from natural catastrophes. IFRC reported that communities within the African continent are vulnerable to unfamiliar hazard and cannot cope with the shocks resulting from such events, leading to more people seeking humanitarian assistance. The report also noted that average number of emergences in the African continent has almost tripled since the mid-1980s to about 25million in 2005[7]. This is also directly related to their sources of livelihood, including farmland, A study affirmed that one of the causes of severity of flooding is rapid urbanization without corresponding infrastructural restructuring to accommodate services and other auxiliary activities such as farmlands[8].

The idea of acceptable risk for different regions/countries may be influenced by a single spectacular accident or incident like 1953 flood disaster in the Netherlands; tsunami disaster2004 in Asia, Katrina in New Orleans, USA 2005; Damrey Typhoon in Vietnam 2005 and large flooding in Bangladesh 2007. These unwanted events could be starting/ turning points of any new safety policy establishment for countries around the world[9].

A related study noted that flood related problems (including destruction to farmlands) and many other applications proved that these problems could be solved through planning studies and detailed projects about flood prone areas. Determining the flood vulnerable areas is important for decision makers for planning and management activities[10]. In this case the determination of arable farmlands that are most vulnerable to flooding will involve Geographical Information System (GIS) that may provide more and better information about decision making situations. Furthermore, GIS allows the decision maker to identify a list meeting a predefined set of criteria with the overlay process[11] and the multi-criteria decision analysis within GIS may be used to develop and evaluate alternative plans that may facilitate the identification of farmlands most at risk in an event of flooding[12].

This study is a backdrop of the flooding that affected a large portion of Nigeria, in 2012 especially southern Nigeria, and seeks to demonstrate the relevance of GIS[13-15] techniques in assessing the food security risk[16] within Bayelsa state.

Material and Methods

This study area is in Bayelsa State, southern Nigeria (see figure-1). It is located between latitude $4^0$48’46.85” N - $5^0$6’ 30.28”N and longitude $6^0$11’ 5.18”E – 6^0 2657.69”E and consist of three local government area namely; Yenagoa, Ogbia and Kolokuma LGAs. The major language spoken is Ijaw language. The physical setting of the state consist mainly of riverine and estuarine, it is located within the lower delta plain believed to have been formed during the Holocene of the quaternary period by the accumulation of sedimentary deposits. The climate is tropical i.e. wet and the dry season. The amount of rainfall is adequate for all-year-round crop production. The mean monthly temperature range is from 25°C to 31°C. The hottest months are December to April. The Relative humidity is high in the state throughout the year and decreases slightly in the dry season.

Data Characteristics: In order to effectively accomplish risk analysis of arable farmland to flooding, remotely sensed data was used to determine the floodplain and land cover types. These data are:

Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER) images: The ASTER Global Digital Elevation Model covering the study area was used. It was obtained from the United States Geological Survey (USGS) service website with one image scene consisting of 4,100 x 4,200 lines and a spatial resolution of 30m over a swath width of 60 x 60 kilometres, acquired in 2003. This data was useful in modelling the terrain and subsequent determination of floodplain of the study area.

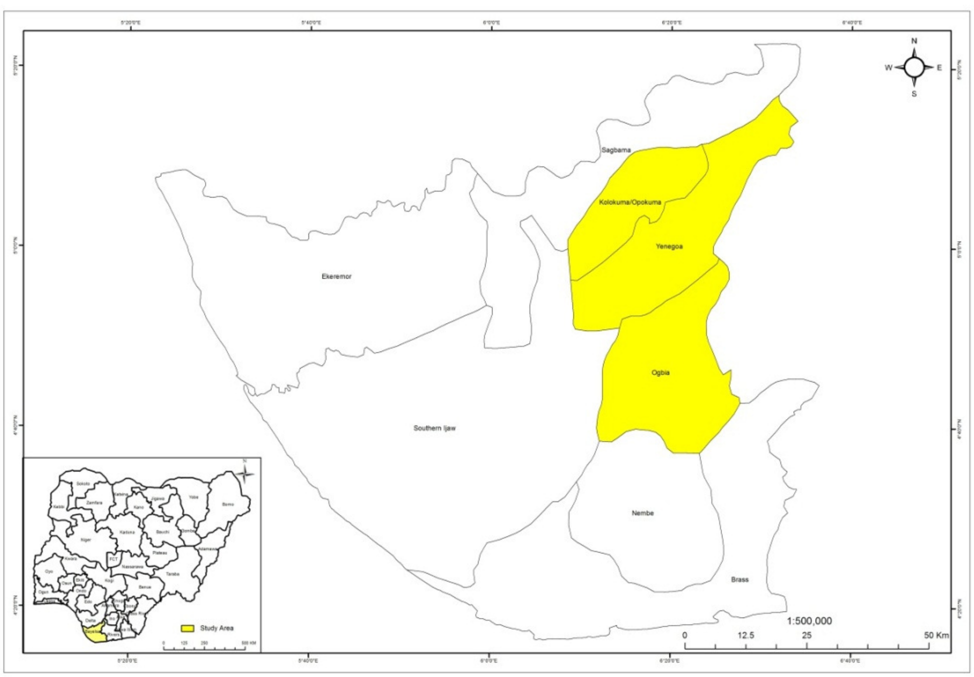

Figure-1
Map of Study Area (Inset: Map of Nigeria)

SPOT –XS image: SPOT multispectral image acquired in 2012 and covering the study area was used for land cover analysis. The image had a spatial resolution of 2.5m and consisted of three (3) spectral bands namely; green wavelength (0.50-0.59µm), red wavelength (0.61-0.68µm) and near infrared wavelength (0.79-0.89µm).

Terra SAR-X image: This is advanced radar (X Band) which was acquired on the 12th of October, 2012 with a spatial resolution of 3.5m. The mode of acquisition is the HH polarization due to its suitability for detecting flooded surfaces and was used to identify the areas flooded during the 2012 floods that affected most parts of Nigeria. This was used for verification of the flood risk zone, defined with the datasets mentioned earlier.

Data Processing and Analysis: Multi-criteria analysis and weighted overlay technique was used for the identification of the different layers extracted from the data discussed in results and discussion. In order to achieve this task, different land cover types were extracted from the SPOT-XS images using the FORMECU (1995) classification scheme. As a result four (4) feature classes were identified namely; water body, built up areas/bare land, forest and farmlands.

Subsequently, floodplain within the study area was defined using a digital elevation model (DEM). This was then overlaid over the land cover types to determine the proportion of farmlands that falls within these areas. The process of neighbourhood function analysis was implemented to further identify the farmlands at risk to destruction in an event of flooded. However, due to time constraint and security issues within the Niger Delta area, the results were verified using advanced RADAR images, that captured flooded areas in October, 2012.

Results and Discussion

Characterization of the Area: The topography within the study area is generally low lying; the processed digital elevation model revealed that the topography ranged from 10 to 50meters above mean sea level. As a result large proportion of the study area falls within the floodplain (areas less than 30 meters), especially the urban centers (figure-2); thereby increasing the vulnerability of these areas to flooding.

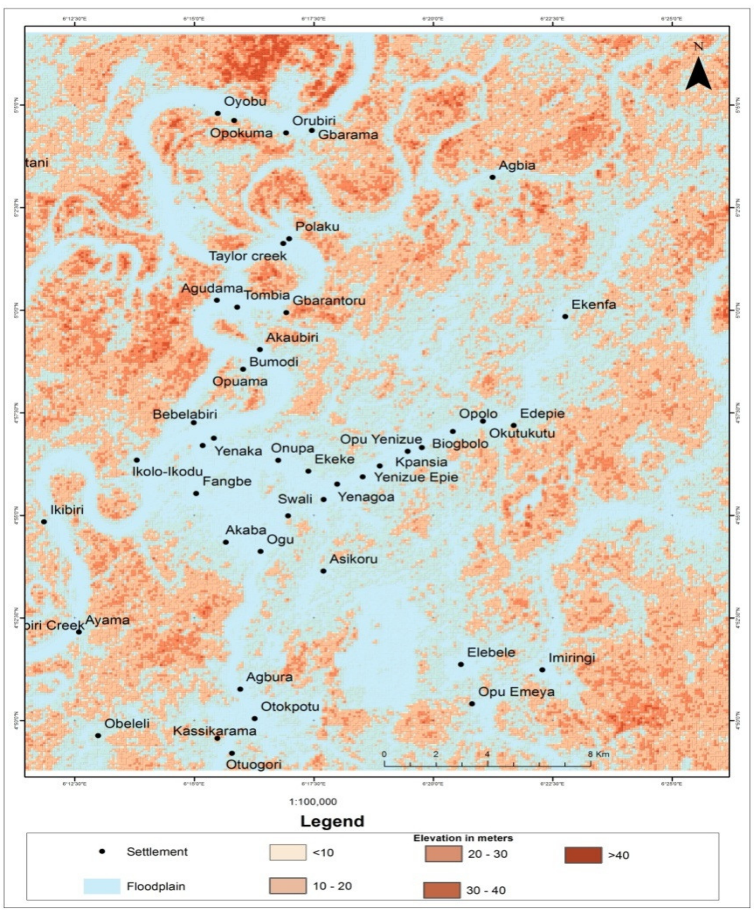

Figure-2
Digital Elevation Model showing Floodplain

Further analysis shows that forest areas made up the largest proportion in land cover types (69%), while farmlands consisting of cultivated lands, scattered grassland etc make up 15% of the land cover types, built up areas (12%) and water body (4%). A spatial distribution of the land cover types s depicted in figure-3 and table-1 below.

Table-1
Proportion of LULC types within the study area

Name	**Area (Sq. Km)**	**(%)**
Water body	35.30	3.89
Forest	627.91	69.15
Mixed Farmland	138.37	15.24
Built up Area	106.50	11.73
Total	908.08	100

Proportion of Arable Land and Risk Analysis: Using weighted overlay technique the proportion of arable farmland in the floodplain is 85.20 km^2 representing about 38% of the farmlands. This translate to a quarter of the farmland at risk of been inundated during any flood event. Figure 4a.of arable lands at risk of flooding, this further indicates that arable lands located south of Yenagoa are most vulnerable to flooding. This includes: Elebele, Obu Emeya, Imiringi and Asikoru communities, while to the north of Yenagoa; Ogu, Ekenta and Abgia communities were mostly affected. These are results were verified using flooded areas identified during 2012 flood events within the area, this revealed a 60% positive correlation between areas at risk to flooding and areas flooded (figure 4b).

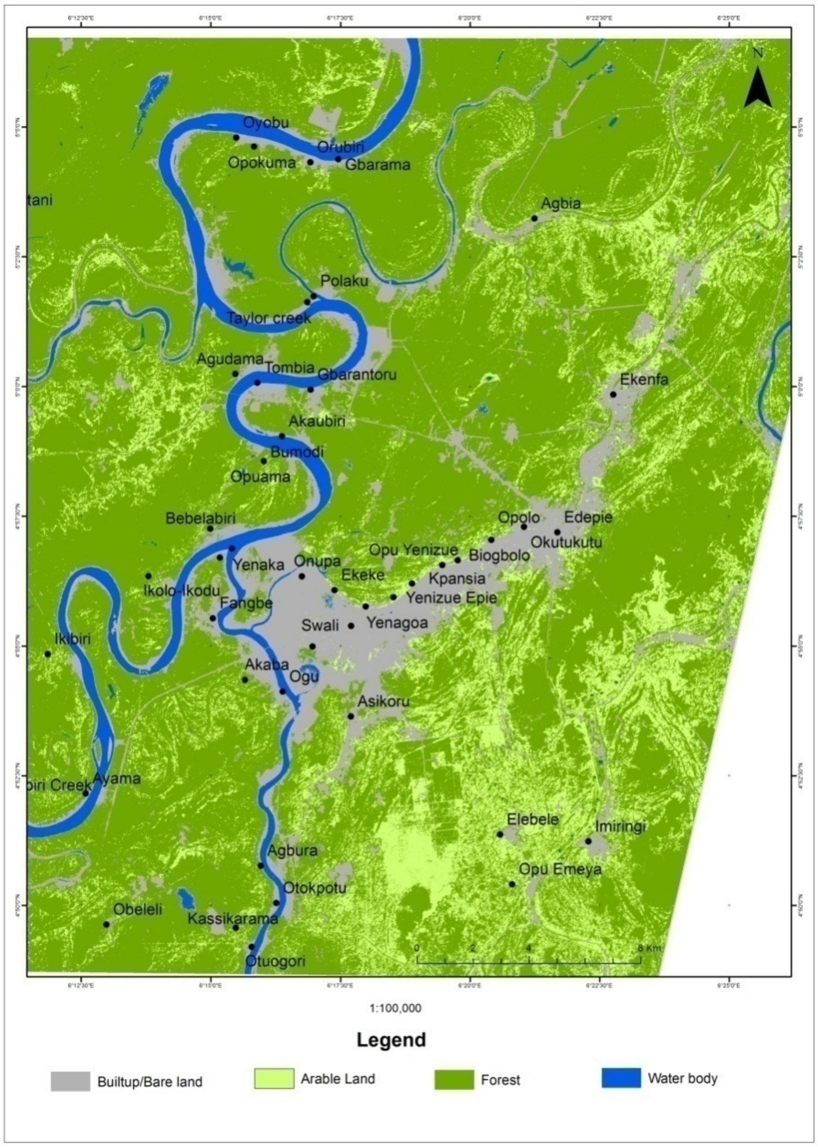

Figure-3
Land Use Land Cover types of the study area

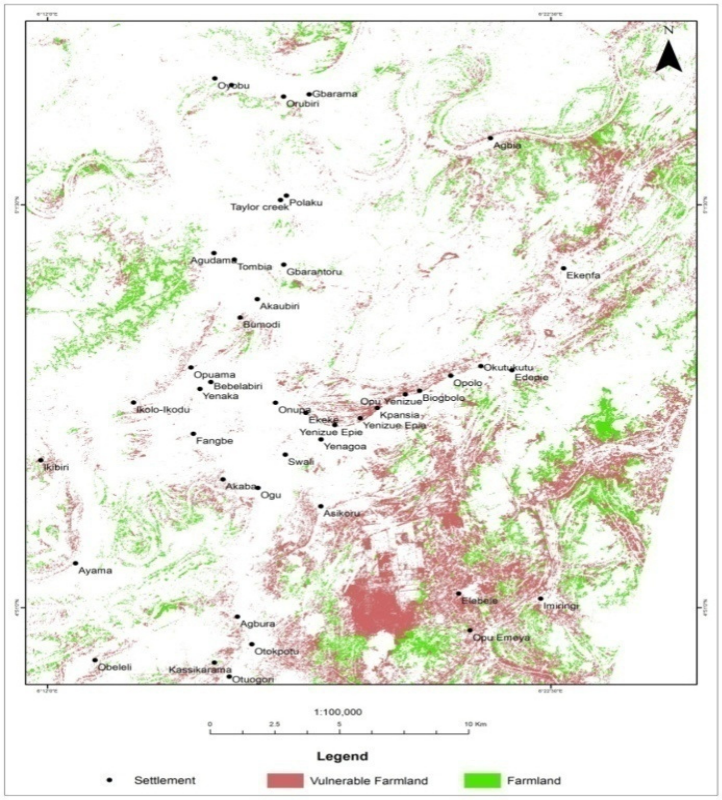

Figure-4a
Arable lands at risk, Extracted from Terra SAR-X images

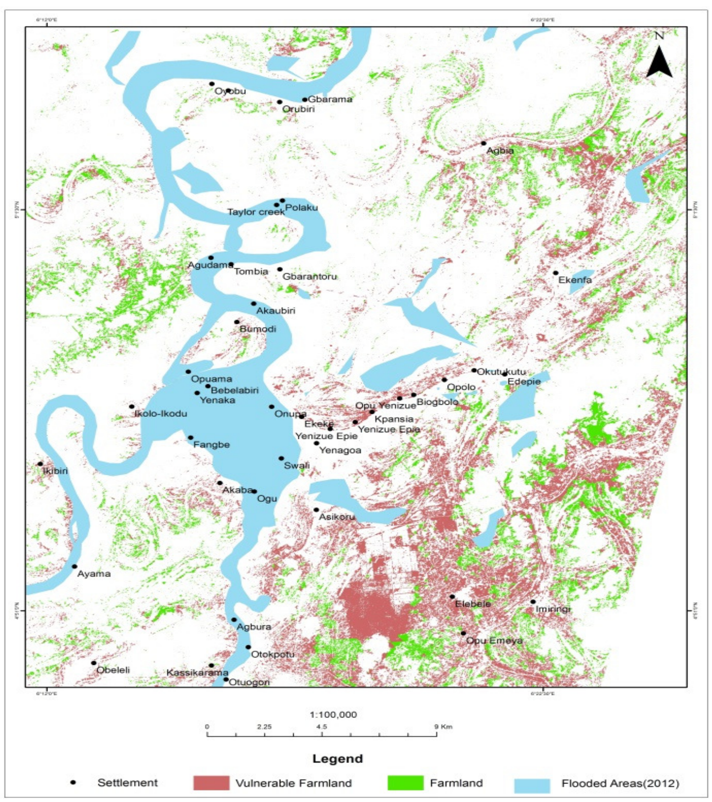

Figure-4b
Arable lands at risk and flooded areas, Extracted from Terra SAR-X images

Conclusion

The current political administration attributes the unsatisfactory state of agriculture to its subsistence-orientation, hence its national agricultural policy are to attain food security, increase production and productivity, generate employment and income; and expand exports and reduce food imports. This ultimately lays the foundation for risk analysis and assessment of the food production capacity within the nation, by measuring the impact of various variables most notable is climate change.

This study evaluated the risk of arable lands within parts of southern Nigeria and determined that over arable lands make up 15% of the entire land cover types, behind only forest areas (69%). Furthermore, about 38% of these arable lands (0r 85km^2) are found within the floodplain (or risk zone) making them most vulnerable to flooding and thereby jeopardizing over a quarter of the food supply (Oil Palm, Cocoa, Cassava) that comes from these region.

It is therefore important to create adaptive measures for sustaining the food production capacity of these communities (or region) by developing a robust network of dykes to enable the channeling of excessive water and the education of local farmers on modern adaptive products (such as Geographic Information System) and techniques (Remote Sensing) to cultivated farming in the face of climate change.

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