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MODELLING THE IMPACT OF FLOODING USING GEOGRAPHIC INFORMATION SYSTEM AND REMOTE SENSING

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Abstract- Flooding is one of the most devastating natural disasters in Nigeria. The impact of flooding on human activities cannot be overemphasized. It can threaten human lives, their property, environment and the economy. Different techniques exist to manage and analyze the impact of flooding. Some of these techniques have not been effective in management of flood disaster. Remote sensing technique presents itself as an effective and efficient means of managing flood disaster. In this study, SPOT-10 image was used to perform land cover/ land use classification of the study area. Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER) image of 2010 was used to generate the Digital Elevation Model (DEM). The image focal statistics were generated using the Spatial Analyst/ Neighborhood/Focal Statistics Tool in ArcMap. The contour map was produced using the Spatial Analyst/ Surface/ Contour Tools. The DEM generated from the focal statistics was reclassified into different risk levels based on variation of elevation values. The depression in the DEM was filled and used to create the flow direction map. The flow accumulation map was produced using the flow direction data as input image. The stream network and watershed were equally generated and the stream vectorized. The reclassified DEM, stream network and vectorized land cover classes were integrated and used to analyze the impact of flood on the classes. The result shows that 27.86% of the area studied will be affected at very high risk flood level, 35.63% at high risk, 17.90% at moderate risk, 10.72% at low risk, and 7.89% at no risk flood level. Built up area class will be mostly affected at very high risk flood level while farmland will be affected at high risk flood level. Oshoro, Imhekpeme, and Weppa communities will be affected at very high risk flood inundation while Ivighe, Uneme, Igoide and Iviari communities will be at risk at high risk flood inundation level. It is recommended among others that buildings that fall within the "Very High Risk" area should be identified and occupants possibly relocated to other areas such as the "No Risk" area.

Keyword- Flooding, Remote sensing, GIS, Risk

I. INTRODUCTION

Over the past decades, the pattern of floods across all continents has been changing, becoming more frequent, intense and unpredictable for local communities, particularly as issues of development and poverty have led more people to live in areas vulnerable to flooding [1]. Flood by nature are complex events caused by a range of human vulnerabilities, inappropriate development planning and climate variability [2]. A UN HABITAT Report in 2010 predicted that "more than 25% of Africa's population living within 100km from the coast will be at risk from sea level rise and coastal flooding within the next decade 2010-2020" and recommended immediate adoption of mitigation measures to reduce vulnerability [3]. It has been reported that developing countries like Nigeria will be more vulnerable to climate change due to its economic, climatic and geographic setting [4].

In 2012, Nigeria witnessed the most devastating effect of flooding. The flood event affected about 13 States: Niger, Benue, Edo, Kogi, Anambra, Ebonyi, Ondo, Imo, Bayelsa, Delta, Rivers, Adamawa etc. The flooding was triggered by intentional opening of the Lagdo Dam in Cameroon to release excess rain water caused by climate change from the Dam. This action caused huge socio-economic loss to Nigeria especially residents of Edo State.

Several techniques have been used to map flood hazard and risks. The conventional technique is mostly through the use of information on historical floods, soil maps, aerial photographs, hydrological modeling of the major rivers, use of National Digital Terrain Model (DTM) and water levels [5]. These techniques have not been able to provide sufficient information needed for management of flood disasters.

There is therefore need to develop a more effective and efficient approach of monitoring, mapping and modeling of flood risk and hazards. Remote sensing and GIS provides a useful means of modeling flood disaster. It provides a rapid response data source for mapping of flood disaster. GIS is a powerful tool that enables the integration of spatial data such as land use and land cover, topography, soil, hydrography, geology, utility e.t.c on a common platform. GIS also enables photographs of flood disaster areas to be hyperlinked with spatial database for a more visual understanding and documentation of the disaster area. This potential of GIS, when combined with Remote sensing satellite image provides a very flexible platform for modeling and analysis of any environmental phenomenon and for providing sustainable and profitable solutions to environmental management.

This research seeks to model and analyze the risk and impact of flooding using GIS and satellite remote sensing images.

A. The Study Area

The area selected for this study is located in Edo state, South-south Nigeria. The geographic location is approximately between latitudes 6º34'N and 6º43'N and longitudes 7º04'E and 7º13'E (see fig. 1). Early rainfall occurs usually in January/February with full commencement of rainy season in March and stopping in November of each year. The dry season commences from November and ends in February. Edo state has 8.01% of its terrain covered by upland; 85.74% lowlands and 6.25% as wetlands [2].

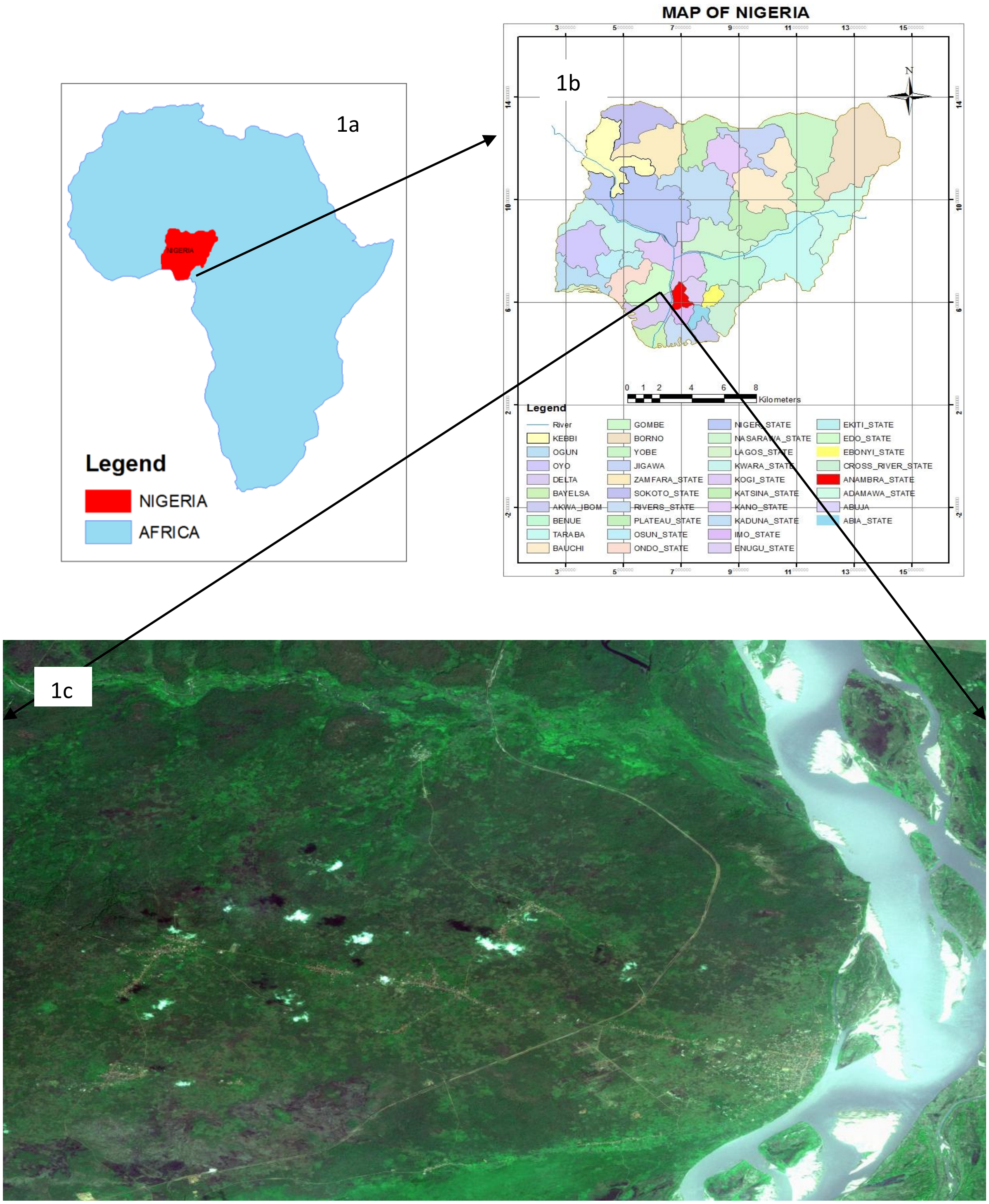

Fig. 1a: Map of Africa Showing Nigeria; Fig1b: Map of Nigeria Showing Edo State and Fig.1c: Image window of the Study Area.

II. MATERIALS AND METHODS

The method employed for the study is illustrated in figure 2.

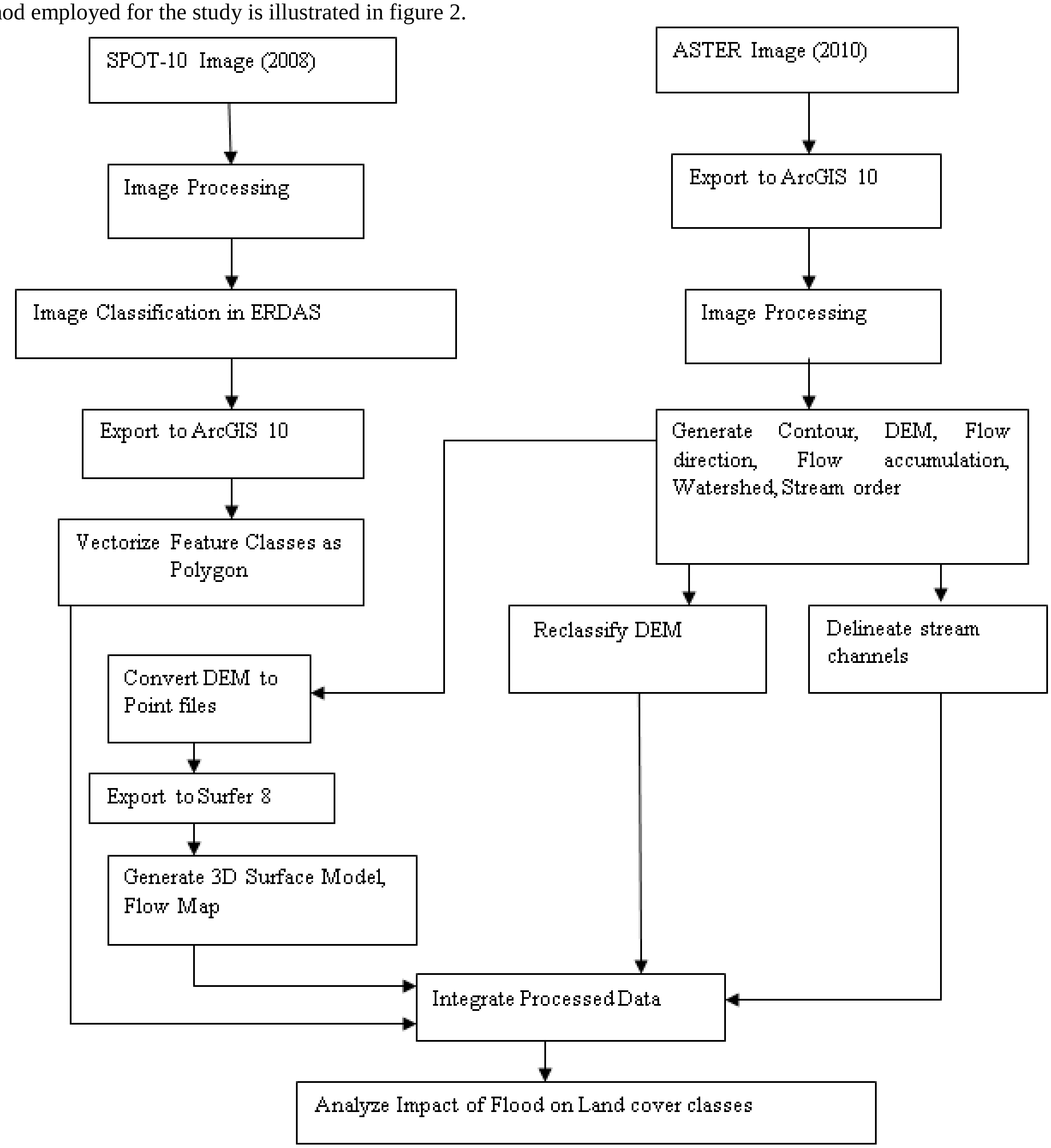

Fig. 2: Work Flow Diagram of the Methodology adopted

The SPOT-10 image which was in geographic coordinate system was exported to ERDAS Imagine 9.2 software. The image which has been processed was checked for line dropout, line banding effect and noise to ensure its usage.

A pre- classification visits to the site was carried out and the following classes were adopted; Water body, Farmland, Built-up Area, Vegetation, Wetland and Open space. To begin the classification proper in ERDAS Imagine, sample set was selected using the Area of Interest (AOI) tool. The signature editor table was opened to add the AOI as a signature. Name and colour were assigned to the AOI class. Feature space layer was created from the signature editor menu bar. Other AOI classes were created and added as signatures. The feature space was masked to image space. Supervised classification method was used to classify the image. The feature space and maximum likelihood were selected as the non-parametric rule and parametric rule respectively.

The classified image was exported to ArcGIS 10 software. The accuracy of the classified image was checked by plotting the coordinates of the remaining ground truth data not used in the classification process into the classified image. The result shows a high correlation and the classes vectorized into polygons.

The ASTER image was exported to ArcGIS 10 environment and the depression in the sink filled. The image focal statistics were generated using the Spatial Analyst/ Neighborhood/Focal Statistics Tool in ArcMap. The contour map was produced using the Spatial Analyst/ Surface/ Contour Tools. The DEM generated from the focal statistics was reclassified into different risk levels based on variation of elevation values. The depression in the DEM was filled and used to create the flow direction map. The flow accumulation map was produced using the flow direction data as input image. The stream network and catchment area were delineated.

The reclassified DEM, stream network and vectorized land cover classes were integrated and used to analyze the impact of flood on the classes.

A. Discussions of results

The classified map was exported to ArcGIS 10 where they were vectorized as polygon. The vectorized feature classes of the study area is shown in figure 3.0

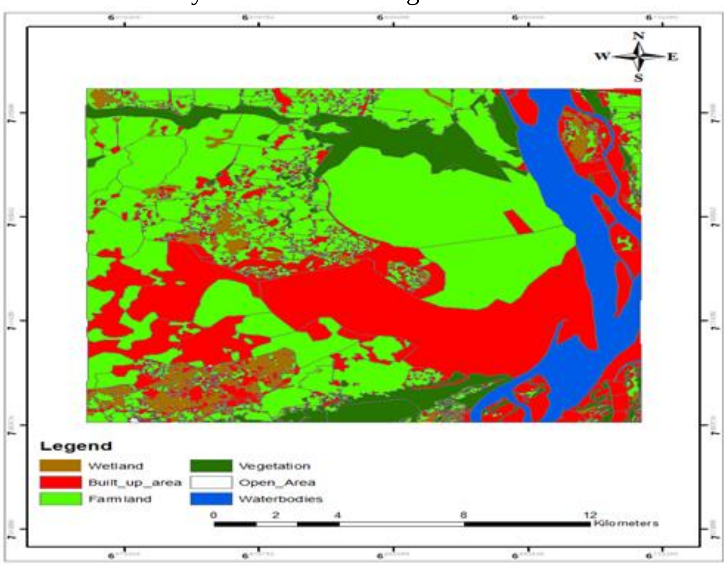

Fig. 3.0: Vectorized feature classes of the study area.

The result shows that most of the study area is occupied by farmland; followed by built-up area. The built up area comprises of buildings and road networks. A high concentration of human activities is represented by built-up areas class in the study area. The implication of this is that if more runoff is generated than the drainage or river channel can accommodate as a result of increased paved surfaces, the water will overtop the drainage channel or river and flows into buildings or floodplain.

The DEM of the study area was reclassified and the result is shown in fig. 3.1

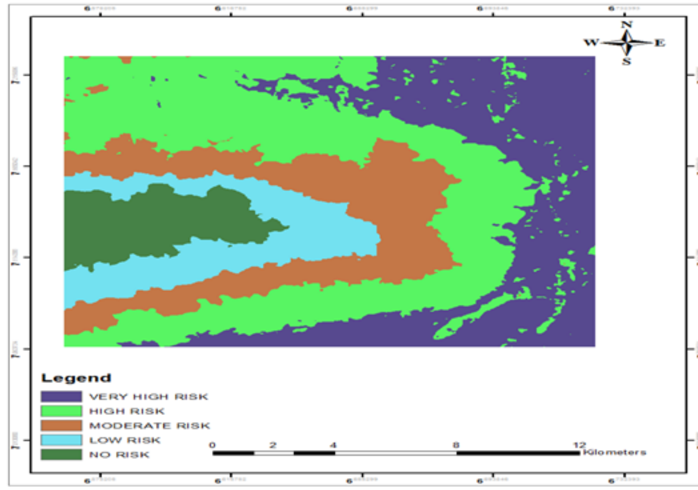

Fig. 3.1: Reclassified DEM of the study area.

The result shows that topography of the area reclassified as 'very high risk' falls mostly on the right hand side of the map and the risk level decreases as we move towards the left hand side of the study area.

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The DEM was used to generate the flow direction map. The flow accumulation map derived from the flow direction data is shown in fig. 3.2

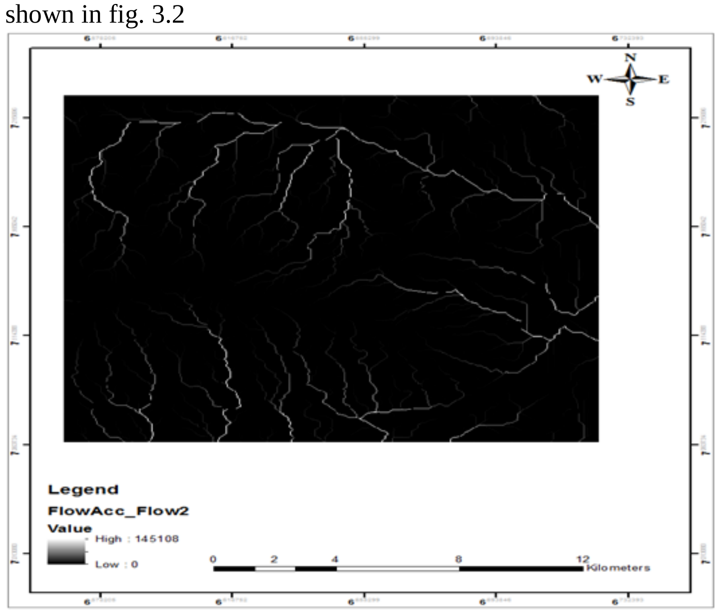

Fig. 3.2: Flow accumulation map of the study area.

Cells having flow accumulation values of zero generally correspond to areas with high elevation values whereas cells with high flow accumulation values shown white in the map correspond to stream courses. The stream courses were extracted from the flow accumulation data and the result is shown in figure 3.3

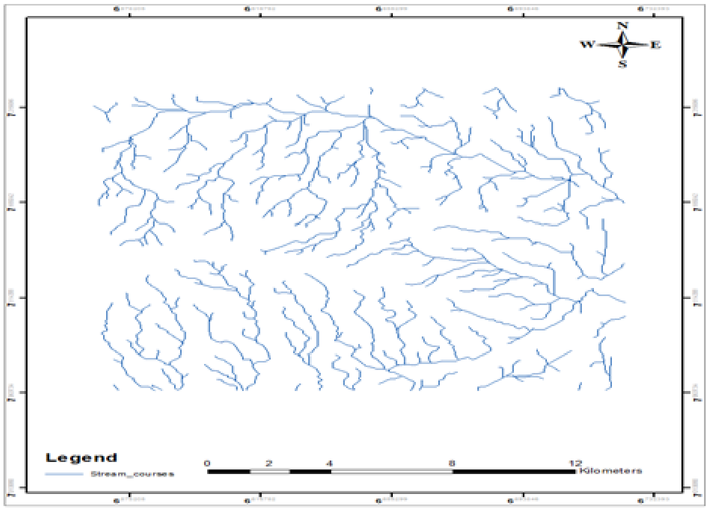

Fig. 3.3: Stream courses within the Study Area

To further appreciate the effectiveness of GIS and remote sensing, the DEM was converted to point feature and the coordinates of the point files generated. The generated coordinates was exported to Surfer 8 software and used to generate the 3D surface model and flow direction map of the study area. This is shown in fig. 3.4 and 3.5 respectively.

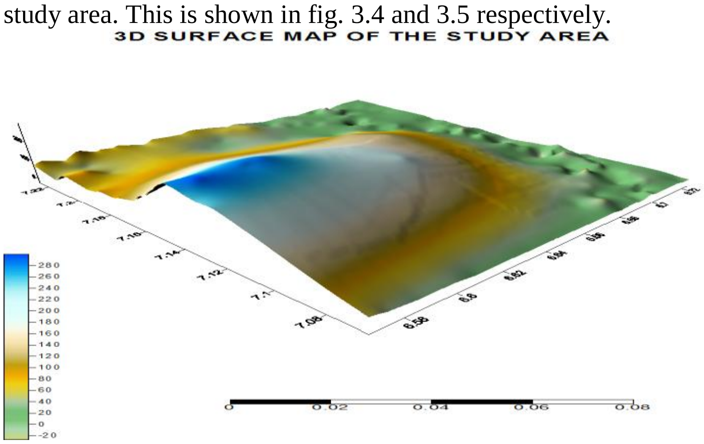

Fig. 3.4: 3D Surface Model of the Study Area

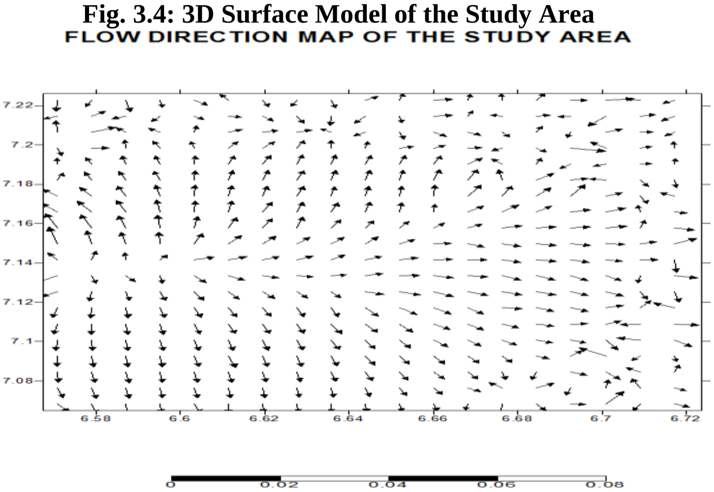

Fig. 3.5: Flow Direction Map of the Study Area

Table 1.0 shows the different risk levels derived from the DEM and their percentage of coverage.

Table 1.0: Flood Risk Level and percentage coverage of the study area.

S/No	Risk	Area (Km^2)	% of the Area
1	Very High Risk	91118	27.86
2	High Risk	116531	35.63
3	Moderate Risk	58539	17.90
4	Low Risk	35078	10.72
5	No Risk	25837	7.89
	Total	**327103**	**100**

The reclassified DEM was vectorized into polygon. The different flood risk levels were integrated with the land cover classes through the intersect tool of the overlay analysis. The essence of this analysis was to know the land cover types that will be affected at different level of flood risk. For example, fig. 3.6 and 3.7 shows the result of intersect analysis between "Very High Risk" and "Built_Up_Area" and "High Risk" and "Farmland" respectively.

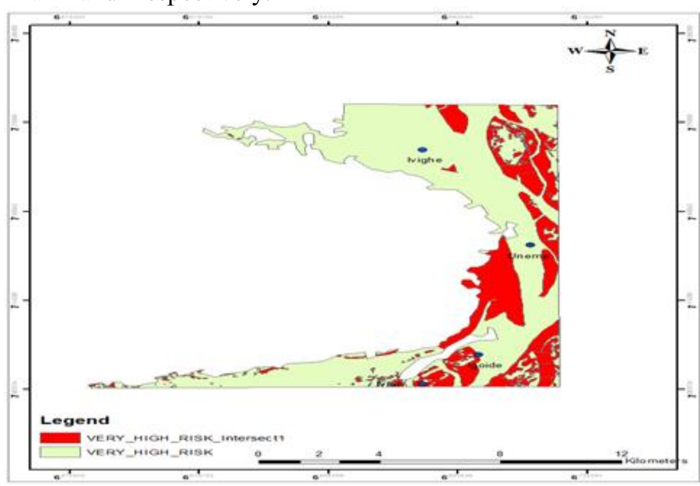

Fig. 3.6: Overlay analysis of "Very High Risk" flood level and "Built_Up_Area" land cover class

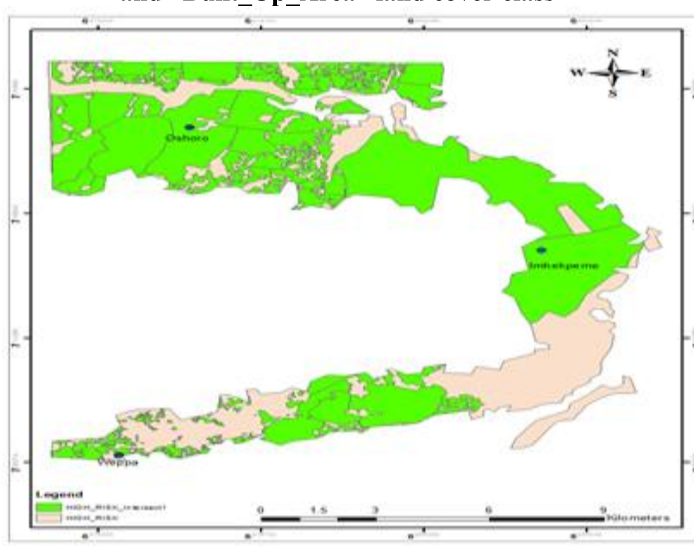

Fig. 3.7: Overlay analysis of "High Risk" flood level and "Farmland" land cover class.

III. CONCLUSION

Satellite images have shown the capabilities to extract relevant information needed to model and manage the impact of flood. ASTER image was used to extract the elevation information while SPOT-10 image was used to generate the land use/ land cover classes. The derived data were integrated through series of analysis in order to determine the land cover classes that will be at risk at varied degree of flood level.

The result revealed the various land cover classes that will be at risk at various categories of flood level. Oshoro, Imhekpeme and Weppa communities will be at risk at very high risk flood inundation while Ivighe, Uneme, Igoide and Iviari will be at risk at high risk flood inundation. Also, the stream network generated shows the location of the stream channels and the classes that may be affected as a result of overflow of water at the stream channels.

IV. RECOMMENDATIONS

Based on the results and analysis obtained, the following recommendations were made:

i. It is recommended that occupiers of buildings that fall within the very high risk flood inundation areas should be identified and possibly relocates the occupants to a higher ground elevation to avoid severe flood disaster.

ii. Presence of high concentration of stream channel in the area makes the area suitable for rice farming and other irrigation farming.

iii. Further research should be carried out in this area using radar satellite and very high resolution imagery such as Terra-SAR and Quickbird image respectively.

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