Vulnerability assessment of structures along river channels in Oyo metropolis, Oyo State, Nigeria

Odedare Kayode Oyeniyi¹, Amusa Idowu Adigun², Aweda Titus Olusina³ and Gbiri Isaac Adelakun⁴

¹, ² & ³ Department of Geographic Information Systems, Federal School of Surveying, Oyo, Nigeria
⁴ Department of Surveying and Geoinformatics, Federal School of Surveying, Oyo, Nigeria

¹-⁴E-mail Address: odedarekayode@gmail.com, idowuamusa3@gmail.com, aweda.ulusina@gmail.com, gbiriisaac@yahoo.com

ABSTRACT

This study makes use of Remote Sensing and Geographic Information System techniques to assess the vulnerability of structures along river channels in Oyo metropolis. The vulnerable rates were classified into High, Medium and Low using 30m, 45m and 60m buffer distances from the middle of the river channels while network analysis was also carried out to attend to any emergency operation. To achieve this feat, a geospatial database was designed and created with various analyses carried out on the entities extracted from the satellite image of the study area. Such analyses include, buffering to categorize the vulnerable zones into the various classes, network analyst menu of ArcGIS 10.2.2 was employed to find the best route from the Fire Service Station to the point of accident and also an alternative route in case of a barrier or barriers on the best route. This showed that a total of 881 buildings will be affected in any instance of flooding that is within 60m from the middle of the river channels in the study area. 399 buildings fall in high vulnerable zone accounting for 45.29% of the buildings examined for vulnerability in the study area, 245 buildings fall within the moderately vulnerable zone accounting for 27.81% and 237 buildings fall within low vulnerable zone at 26.90%. The best route from the Fire Service Station to the point of accident is gotten to be 2.3 Km while the alternative route is 2.7 Km when a barrier is placed on the best route during rescue mission indicating 0.4 Km difference between the two routes. Maps, tables and a chart were produced for various results.

Keywords: Vulnerability, Assessment, metropolis, flood and hazards
1. INTRODUCTION

The various processes which the earth is being subjected to constantly either natural or man-made have made it to be susceptible to hazards of various kinds which may include flood, drought, landslide and erosion amongst others; these interferences have posed serious threats not only to life and property, but have been a setback to development and natural environment. Recent floods around the country in particular and the world in general are of great concern and require urgent intervention efforts from governments and other non-governmental organisations around the world. This work intends to map structures that are vulnerable to floods in Oyo metropolis and proffer suggestions on the way to avert imminent danger that can result from the encroachment into the flood plains in the study area. Flooding is a potential disaster that is mostly terrain dependent and most widely distributed natural risks to life and properties. Flooding is associated with the existence of river in a place. In the tropical regions of the world, flooding manifest most during the mid-rainy season when the absorptive capacity of rivers and stream are exceeded. Thus, the excess water often overflows their banks in adjacent lands which in most cases cause damage to lives and property (houses, urban infrastructure, roads, and culverts etc.) as well as disruption of the land-use and economic activities.

[1] defined vulnerability as the degree of loss to a given set of ‘at risk’ element that is likely to result from the occurrence of a given phenomenon. Under flood vulnerability, elements considered to be at risk are population, property and economic activities. Flood vulnerability is used to identify the set of features that gave rise to its susceptibility. Here, human interference played a prominent role in the mechanism for risk. Floods are the major disasters affecting many countries in the world annually. It is an inevitable natural phenomenon occurring from time to time in all rivers and drainage systems, which not only damages the lives, natural resources and environment, but also causes loss of economy and health.

[2] were of the opinion that floods in Nigeria have done more harm without any notice of benefits. They observed that in the last 30 years, Nigerian cities have experienced great physical development, in terms of building, manufacturing industries and others without any appreciable infrastructures such as drainages, roads and canals to support them. These have made floods to be a very serious challenge that plague many Nigerian cities. Geographical Information System and Remote Sensing techniques were adopted in their work to arrive at a flood vulnerability map.

The impact of floods has been increased due to a number of factors, with rising sea levels and increased development on a floodplain [3]. Recurring flood losses handicapped the economic development of both advanced and the third world countries. A flood is a large quantity of water covering what is usually dry land, as a result of a river or sea flowing over its usual limits, the breaking of dams, a tidal wave or a strong wind drive waves inland. In Nigeria, flooding is a common experience in all parts of the country. The causes are mainly from three major factors namely: Heavy downpours, overflow of drainage channels or due to refuse dumping in the channels and emergency release of water from dams. The first two factors are common in the study area because there is no dam that is functional that can cause flooding as the time of this study. Erelu dam is outside the metropolis in the northwestern part of the city. Flooding cannot be completely avoided, but damages from severe flooding can be reduced if effective preventing scheme is implemented.
This can be achieved if sufficient information for flood forecasting is acquired in both time and quality. Man’s environment is naturally vulnerable to degradation and disruption through his daily activities, increase in population and the attendant pressure imposed on it by the people. The problem cannot be eliminated but can be managed because it is terrain based and water from rainfall will always find its way to low lying areas as collection of pool water. The actions and inactions of man in terms of how it manages its physical environment in terms of spatial planning, physical development control and policies as well as the employment of appropriate technology go a long way to dictate the sustainability of the carrying capacity of the urban environment.

The study area is Oyo Township and founded as the capital of the old Oyo Kingdom in the 1830s and known to its people as 'New Oyo' (Oyo Atiba) to distinguish it from the former capital to the north, 'Old Oyo' (Oyo-Ile) which had been deserted as a result of rumors of war. Its inhabitants are mostly of the Yoruba people and its ceremonial ruler is the Alaafin of Oyo who is the Permanent Chairman of Council of Obas in Oyo State. It is bounded in the north by Igboho, northwest by Ago-Are and northeast by Ogbomosho, southwest by Iseyin, southeast by Awe and in the south by Ibadan. The geographical location of Oyo town lies between latitudes 7° 27' 48.30" and 8° 40' 47.40" north of the Equator and between longitudes 3° 52' 31.35" and 4° 9' 38.23" east of the Greenwich Meridian. According to [4] saddled with the conduct of population census in Nigeria, Oyo town has a population of 429,784 people during the 2006 population census. Oyo metropolis has three local governments: Oyo West, Oyo East and Atiba. It is located in the southwestern geo-political zone of Nigeria. Oyo town has a rugged terrain which range between 850m to 1050m above the mean sea level. Farming, trading and garri processing activities are predominant works in Oyo Township. Some markets where economic activities take place in Oyo periodically include Ajegunle market, Irepo market, Sabo market and Obada International market which came on board early in 2017. There are also tertiary educational institutions in Oyo town; they include Ajayi Crowder University, Federal School of Surveying founded in 1908, Emmanuel Alayande College of Education, Wolex Polytechnic etc.

Geographic Information Systems according to [5] help to analyse and understand more about processes and phenomena in the real world. It involves the process of representing key aspects of the real world digitally inside a computer. These representations are made up of spatial data, stored in memory in the form of bits and bytes, on a media such as the hard drive of a computer. This digital representation can then be subjected to various analytical functions in the GIS, and the output can be visualized in various ways. The application at hand is subjected to various analyses such as buffering and networking to produce outputs in maps and charts as required.

Remote sensing is the measurement of physical, chemical, and biological properties of objects without direct contact [6]. The term remote sensing subsumes the fields of satellite remote sensing and aerial photography. From the GIS perspective, [6] submitted that resolution is a key physical characteristic of remote sensing systems. There are three aspects to resolution: spatial, spectral, and temporal. All sensors need to trade off spatial, spectral, and temporal properties because of storage, processing, and bandwidth considerations. Spatial resolution refers to the size of object that can be resolved and the most usual measure is the pixel size. Satellite remote sensing systems typically provide data with pixel sizes in the range 0.5 m - 1 km.
Figure 1. Composite map of Oyo Metropolis
The resolution of cameras used for capturing aerial photographs usually ranges from 0.1 m – 5 m. Image (scene) sizes vary quite widely between sensors - typical ranges include 900 by 900 to 3000 by 3000 pixels. The total coverage of remote sensing images is usually in the range 9 by 9 to 200 by 200 km [6]. The resolution of the image used for this study is 1.0m from Ikonos. [7] in their article on application of drone for environmental management in urban spaces in which Oyo Metropolis is not an exception discussed potential applications of drones for use in environmental monitoring and management of urban spaces as well as the potential risks. Applications better suited to an Internet of Things approach include those in which frequently repeated or continuous measurements are needed from a location proximal to existing infrastructure. This is required in areas where the rivers encroach into the dwelling areas and needed to be monitored for security alerts as at when necessary [7]. [8] were of the opinion that the degradation of the environment has led to climate change, ozone depletion, global warming, and many other drastic changes. All the effects of environmental degradation listed threaten the health of community members by causing air pollution, extreme heat, infectious diseases, drought, flooding, and extreme weather. The way the drainages are blocked in the study area is a pointer to the fact that water will find its course in any event of accumulation in the river channels as a result of which flooding will occur at a slightest rainfall above the normal.

[9] opined that Geographic Information System analysis is the process whereby data in a database are integrated and manipulated in such a way that it would provide answers to generic questions of location, condition, trend, routing pattern, etc. The spatial data acquired are also structured for intelligent use.

2. MATERIALS AND METHOD

The entities for the study were extracted from the 1.0m resolution image of the study area from the Office of Surveyor-General of the Federation, Abuja. This was done by head-on digitizing where entities like the study area boundary, roads, rivers, water bodies, buildings were extracted and tables populated with attribute information gotten from oral interviews were added. Ground truthing was carried out on the image to ascertain and authenticate some features on the image.

The vector data model was adopted for this study. This has advantages over the raster data model as stated in the work of [10] where he stated the advantages to include more compact structure than the raster model, provision of efficient encoding of topology in cases of network analysis as shown in this work and the vector data is better suited to support graphics. The model also has its shortcomings because it is a more complex data structure than a simple raster amongst other disadvantages as listed by [10]. The attribute data collected from the oral interviews were linked with the geospatial data from the vectorization of the imagery using relational database system. The product formed the basis for the geospatial analyses carried out on the entities in the study area. Database was designed and created for the entities in the study area that are relevant to the application at hand. The entities are the study area boundary, the rivers, the water body, roads and contours. It is on these tables that various attribute information about the entities were attached to allow the various analyses carried out. Thus, [11] proposed and investigated the relation between the amount of input data, as well as the effort (or cost) of data acquisition and the quality of the model results.
This came to bear in the study area by considering the amount of input data and the efforts cum cost of data acquisition and not only the quality of the results but the seriousness attached to the results when it gets to the decision makers across the levels of government considering the sensitive nature of the devastating effects of flooding in the study area.

3. SPATIAL ANALYSES

Proximity analysis and network analysis were carried out during the course of this study. The proximity analysis was to classify the floodable zones into three, namely: High, Medium and Low while the Network analysis was carried out to take care of the Best (shortest) route and the alternative route in case of emergency situation that can result from flooding of the area during rescue operations.

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Proximity according to [10] is a measure of the distance between the features. It is commonly measured in units of length but can be measured in other units such as travel time or noise level. In lieu of this, buffer zone were created around the rivers in the study area. Buffer zone according to Aronoff is an area of a specified width drawn around one or more map elements. The rivers in the study area were buffered at distances of 30 m, 45 m and 60 m to show the buildings that are in the buffered zone. The physical experience in the study area over the years have prompted the use of at least 30 m from the rivers’ or streams’ channels as

Figure 2. Selection by Location to show buildings within 30m Buffer of Rivers

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the minimum buffer distance as against the standard 20m distance as found in the [12] Planning Standards. The select by location tool in ArcGIS 10.2.2 was used to query the attribute table created to extract those buildings within the distances of 30m, 45m and 60m from the rivers’ channels as shown in figures 2, 5 and 8 respectively. The results were formatted into maps as shown in figures 4, 7 and 10 respectively below. Figures 3, 6 and 9 show the results as generated from the software with the buildings falling within the buffered distances in blue colour along the rivers’ channels. Table 1 indicates the distribution of buildings vulnerable to flooding according to the buffered distances of 30 m, 45 m and 60 m.

Table 1. Table of the buildings vulnerable to flooding

<table>
<thead>
<tr>
<th>SN</th>
<th>Buffer Zone</th>
<th>Vulnerable Rate</th>
<th>No of affected Buildings</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0-30 m</td>
<td>High</td>
<td>399</td>
<td>45.29</td>
</tr>
<tr>
<td>2</td>
<td>30-45 m</td>
<td>Moderate</td>
<td>245</td>
<td>27.81</td>
</tr>
<tr>
<td>3</td>
<td>45-60 m</td>
<td>Low</td>
<td>237</td>
<td>26.90</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>881</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: Authors’ Work, 2017

Figure 3. Result of buildings within 30m Buffer of Rivers
Figure 4. Map of Buildings Within 30 m buffer of Rivers
Figure 5. Selection by Location to show buildings within 45 m Buffer of Rivers

Figure 6. Result of buildings within 45 m Buffer of Rivers
Figure 7. Map of buildings within 45m Buffer of Rivers
Figure 8. Selection by Location to show buildings within 60 m Buffer of Rivers

Figure 9. Result of buildings within 60 m Buffer of Rivers
Figure 10. Result of buildings within 60m Buffer of Rivers
3. 2. Network Analysis

Network analysis according to [10] is used to optimize transportation routing, such as a bus routes and emergency vehicle dispatching. This procedure he believes take into account the length of each transportation segments and factors that affect the speed of travel or the quantity of materials that can be carried. Network analysis is performed in case of emergency that require the attention of the Fire fighters in case there is collapsed building caused by flooding. It is also possible and useful to create topology for linear features as concluded by [13]. Line topology requires knowledge of connectivity (which lines touch which other lines). Topologic linear data layers must have a node where lines touch each other, and the Chain node table relates the line segments or arcs to their beginning and ending nodes. The value of this kind of topology is principally in network analysis as demonstrated in this study. These are some common functions you can perform if your data layer has linear topology as pointed out by [13]:

i) Find the shortest path between two locations;
ii) Location-allocation;
iii) Find an alternate route; and
iv) Create an optimum route to multiple nodes.

The first and the third options were carried out in the course of this study. The shortest path between two locations is referred to as Best route in this study. The second and the fourth options are for salesmen, marketers and similar professionals for efficient distribution of their goods.
Figure 12. Best route from Fire Service Station to the Accident scene

Figure 13. Direction window of Best route from Fire Service Station to the Accident scene
Figure 14. Map of Best route from Fire Service Station to the Accident scene
Figure 15. Alternative route from Fire Service Station to the Accident scene

Figure 16. Direction window of alternative route from Fire Service Station to the Accident scene
Figure 17. Map of alternative route from Fire Service Station to the Accident scene
Table 2. Comparison of the Best and Alternative Routes

<table>
<thead>
<tr>
<th>Route</th>
<th>Best Route</th>
<th>Alternative Route</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire Service Station to Accident Point</td>
<td>2.3 Km</td>
<td>2.7 Km</td>
<td>0.4 Km</td>
</tr>
</tbody>
</table>

Source: Authors’ Work, 2017

4. DISCUSSION OF RESULTS

The factors liable for the deviations in flood magnitude and flood severity class over time could be related to the climate change [14-17]. A total of 881 buildings were examined for vulnerability assessment in Oyo metropolis. The study classified the vulnerability rates into three (3) namely High, Medium and low with buffer distances of 30m, 45m and 60m respectively. The high rate are the most prone to danger associated with flooding while, moderate is on the average and the least affected are the ones in the low category. The moderate and the low vulnerable zones were done to serve as information for early warning signals in case the flooding in the area goes beyond the high vulnerable zone so that evacuation process can be put in place. 399 buildings fall in high vulnerable zone accounting for 45.29% of the buildings examined for vulnerability in the study area, 245 buildings fall within the moderately vulnerable zone accounting for 27.81% and 237 buildings fall within low vulnerable zone taking 26.90% of the 881 total buildings that were examined for vulnerability. The summary is shown in Table 1 and the maps displayed in Figures 4, 7 and 10 with the bar chart shown in Figure 11.

Building collapse is a very rampant case in the floodable areas within the study area because most buildings are either from mud or built with substandard materials. This the reason for undergoing the network analysis to see the option of best route and the alternative route in case of emergencies resulting from building collapse from the fire service station to the scene of accident. The best route covered 2.3 Km while the alternative route covered 2.7 Km when a barrier is placed on the best route during rescue mission indicating 0.4 Km difference between the two routes. The result of the best route, the direction window and the map of the best route are shown in Figures 12, 13 and 14 respectively while for the alternative routes are shown in Figures 15, 16 and 17 respectively. The summary of the difference between the best and the alternative routes is shown in Table 2.

5. CONCLUSION

Geographic Information System capabilities explored for this research confirmed the appropriateness of the tool for the study and revealed that flood is inevitable but could be prevented and the attendant likely damages to life and property minimized. This could be achieved through effective spatial planning, management and mitigation measures and by giving information to residents and building developers. It is hoped that result of this research would serve as an eye opener to Development Control Agencies of Government at the local, state and federal levels on the need to pay special attention to areas where there are rivers,
streams and rivulets because they are progressive in nature in terms of their scope, expansion and destructive tendencies.

6. RECOMMENDATIONS

From the experience, observations and the interactions with the residents during the course of this study, it is expedient to recommend the following:

1. The intervention of the government will involve slum/sprawl clearance and rehabilitation of the affected flood prone areas because of its deplorable conditions. This process will therefore require aggressive public enlightenment and participation of the people in order for them to properly understand the details and implications of the result of flood vulnerability study which affect them. This will assist to smoothen the implication processes and reduce likely obstacles to be encountered from the affected people.

2. The Government should as a matter of urgency enforce restrictions to all forms of construction activities within the flood vulnerable zones while a comprehensive urban renewal programme is undertaken by her to renew physical development activities in the study area. Such renewal programme will involve a redesign, clearance, rehabilitation and sustainability action. This is a holistic and best practice approach to urban planning of slum and sprawl areas as it is the case in this flood prone areas.

3. Construction of approvable buildings within any of the flood prone zones should be subjected to meet certain minimum engineering design and construction standards in order to avert future structural failure of houses due to the nature of the flood plain soil substructure.

4. One of the reasons identified as causes of flood in the study area was lack of channelization of the river courses. It is therefore recommended that the river paths should be properly dredged and constructed with reinforced embankment. A regular maintenance of the river way should be carried out and appropriate side drains should be constructed on the roads within the study area.

References


(Received 30 July 2017; accepted 18 August 2017)