Application of Location Based Service for flood Vulnerability Assessment of Part of Minna, Niger State, Nigeria

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Abstract

Flood disaster has been a global emergency issue, the cause may be traced to both natural and man-influenced factors, the alarming increase in global warming has an underlying effect on glacial melting, sea level rise etc. these, coupled with the effect of human activities such construction along flood plain, deposit of waste in rivers etc. have pose a threat not only lives but putting properties into danger. In order to alleviate the effect of this flooding, emergency agencies and individual must be informed about the status of such emergency. Flood vulnerability status is thus a reliable solution to such problem. How will individual get current vulnerability status of their current location? The research revolves around creation of an android application capable of indicating the vulnerability to flooding of points within the study area. Data source include administrative map, Digital Elevation Model and Landsat Imagery with band 6, 7 and 8. ArcGIS software was used to produce the flood vulnerability information and database for the study area. Different elevation ranges; (very low, low, moderate, high and very high) were classified to determine the flood vulnerability status. The android application was developed using Android studio application. The location based service in the mobile device help to correlate the longitude and latitude information of points within the study area with the database to determine the vulnerability status of an area to flooding on average scale. It also stores such details. The result shows that the study area is a relatively low terrain and is more vulnerable to flooding; with very low and low terrain having a percentage of 18 and 36% respectively. The result also show that only 11% of the study area are built up with vegetation and farmland having a percentage of 18% and 22% respectively. Although it was discovered that the flood vulnerability assessment can only be done within the study area, updating can be done to enable it work for other area.

***Keywords:** Android application, Location based service, flood vulnerability, landuse/land cover and Digital Elevation Model (DEM)*

1.0 INTRODUCTION

Apart from the 1936 flood disaster in Nigeria, Aliyu (2018) identified certain flood disaster which include; the disaster that ravage Ibadan (1985, 1987, 1990), Oshogbo (1992, 1996 and 2002), Yobe (2000), Akure (1996, 2000, 2002, 2004, and 2006), Abia Adamawa and Akwa Ibom in 2001, coastal cities such as Lagos, Port Harcourt, Calabar and Warri experience annual flooding during raining season. Cases of collapse of buildings and flood incidents have been in occurrence over the past few years and even this year within the study area (Aliyu Bashar, 2018). This incidence has posed a threat to lives and properties of which these people and properties are located in areas with high flood vulnerability and as such a need for an easy to understand and easy to use source of vulnerability information of an area to flooding.

Location based services (LBS) can be defined as computer applications (especially mobile computing applications) that deliver information tailored to the location and context of the device and the user (Raper *et al.,* 2015). Recent years have witnessed rapid advances in its enabling technology, such as mobile devices and telecommunication (Burak and Sharon, 2015). Secondly, there has been an increasing demand in expanding location-based services (LBS) from outdoors to indoors, and from navigation systems and mobile guides to more diverse applications (e.g. healthcare, transportation, and gaming) (Raper *et al.,* 2015). Thirdly, new interface technologies (e.g. more powerful smartphones, smart watches, digital glasses, and augmented reality (AR) devices) have emerged. Moreso, there has been an increasing smartness of our environments and cities (e.g. with different kinds of sensors) (Ratti and Claudel, 2016). Finally, more and more location based services (LBS) are entering into the general public's daily lives, which greatly influence how people interact with each other and their behaviors in different environments

The first location based services (LBS) appeared in the early 1990s (e.g. active badge), location based service (LBS) became a fast-developing research field only in the early 2000s, mainly due to the discontinuation of the selective availability. Selective availability was an intentional degradation of public Global Positioning System (GPS) signals implemented by the U.S. Government for national security reasons. View all notes of Global Positioning System (GPS) by the U.S. President Bill Clinton in May 2000. This discontinuation has made GPS more responsive to civil and commercial users worldwide (Ladan, 2016). Since that time, more and more GPS-based applications have appeared, resulting in a strong interest in location based services (LBS) from both academics and industry. This has paved way for geospatial approach in general emergency management and control. Andi et al.(2017) use geospatial approach for flood vulnerability mapping, Ladan (2016) show that Satellite Remote Sensing can be applied in Terrain Analysis and Flood Plain Delineation, this can also be seen in other research that have identified flood, landslide and seismic effect as a tool for hazard assessment (Bathrello *et al.,* 2016), for flood assessment (Ouma and Tateishi, 2014; Andi *et al.,* 2017) incorporate Analytical Hierarchy Proces(AHP) and GIS to predict flood vulnerability using rainfall, elevation, drainage , land , soil and slope as parameter, Siddayao *et al.,* (2014) use population density and distance from river bank as parameters, while Kazakis et al. (2015) evaluate flood hazard by adding flow accumulation, distance from channel stream and totally covered stream and hydro-lithological formation. Klein (2014) Develop a method which uses android application to address the vulnerability to climate change and climate. The ability of an android device to detect small or large variations in height details of an environment as they affect flood vulnerability of such an environment is of paramount essence and not commonly available to the general public. Although maps were generated from their various researches, much effort has not been put in place to automate such result and create a spatio-temporal vulnerability map which will be made readily available to individuals during on-site decision making. Recent flooding in the study area and the need to procure a lasting solution has also geared this research work as many buildings and structure experience collapse since no prior assessment was done before engaging in construction and development. Klein (2014) stated that flood vulnerability information is a very vital information in engineering and construction operations.

The study deal with the determination of flood hazard status of specific positions in an area, using a smart approach which is through the use of android application. The objective is to identify flood hazard zone, by creating a database for flood risk area, and also developing an android application which will enable decision and policy makers to have a first-hand information of the vulnerability status of specified location on their mobile devices. The parameters used for flood vulnerability were landuse/landcover map, slope and elevation data.

2.0 STUDY AREA

The study area is an area of 10km buffer zone around Federal University of Technology Minna, Gidan Kwano Campus, Niger State. Niger State is a state in Central Nigeria and the largest state in the country. The state capital is Minna. Minna is a city in Middle Belt Nigeria, located between latitude 9° 36′ 50″ N and longitude 6° 33′ 25″ E and it is situated at elevation 243 meters above sea level.. It consists of two major ethnic groups: The Nupe and the Gbagyi.. Its headquarters are in the town of Maikunkele. It has an area of 1,592 km² (The Concice Britannica, 2019). Some of the socioeconomic activities carried out within the research area include black smiting, weaving, pottery and furniture making. The research area is within Bosso local government Area, Minna Niger State. The study area varies between latitude 9°50' N-9°20' N and longitude 6°10'E-6°40'E. Figure 1.0 shows the map of the research area.

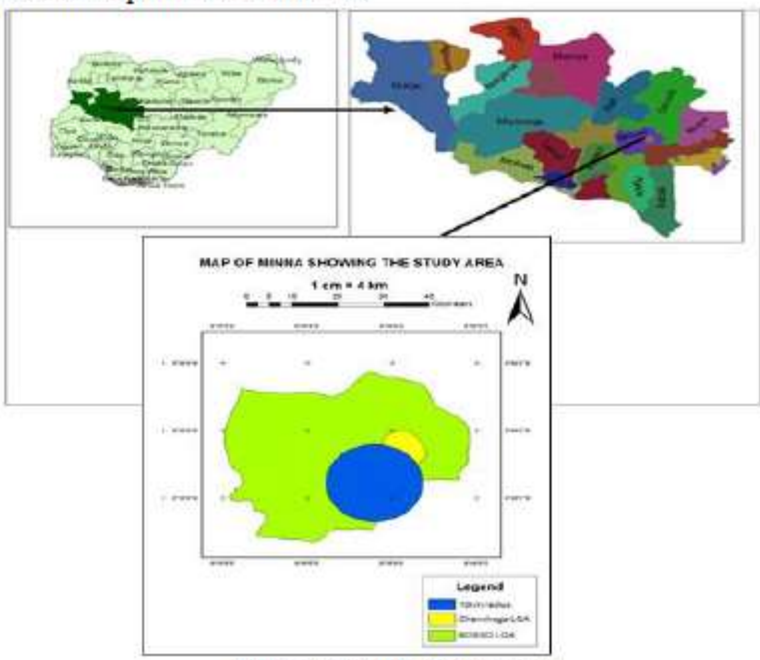

Figure 1.0: Map of study area

3.0 Materials and methods

Vulnerability maps can be utilized in all steps of disaster management; prevention, mitigation, preparedness, operation, relief, recovery and lesson learnt (Andi *et al.,* 2017). The risk faced in the recent years have cause various kind of losses. In order to build sustainable cities and environment, individual must have first-hand information of the vulnerability status of their environment. The overall description of method for application of location based service for flood vulnerability assessment is explained in figure 3.0, Landuse/Landcover map was generated from the Landsat imagery using Maximum Likelihood classification, Arithmetic overlay was done between the DE M and Landuse/Landcover map to generate the Flood Risk Map, using raster calculator. The map generated was thus incorporated with the developed android application, using the local scale formulated by (Fekete *et al.,* 2010), the vulnerability scale of an area can be determined through the application and its status reported.

3.1 Data source and acquisition

The data source can be categorized into primary and secondary data source, Primary data include the coordinates of controls within the study area, the UTM coordinates of these controls were collected from the department of Surveying and Geo-informatics, Federal University of Technology Minna, Niger State and are shown in the table 3.0, they were used for Geo-referencing.

Table 3.0 Control Points and their coordinates

CONTROL POINTS	LATITUDE	LONGITUDE
GPS 01	9.535576	6.454623
FUTSVG 01	9.529549	6.465483
CSN 128P	9.549321	6.473994

Secondary data source include; Administrative map of Minna obtained from the department of Geography, Federal University of Technology Minna, Digital Elevation Model SRTM 1 arc seconds downloaded from United State Geological Survey (USGS), shapefiles, satellite imageries

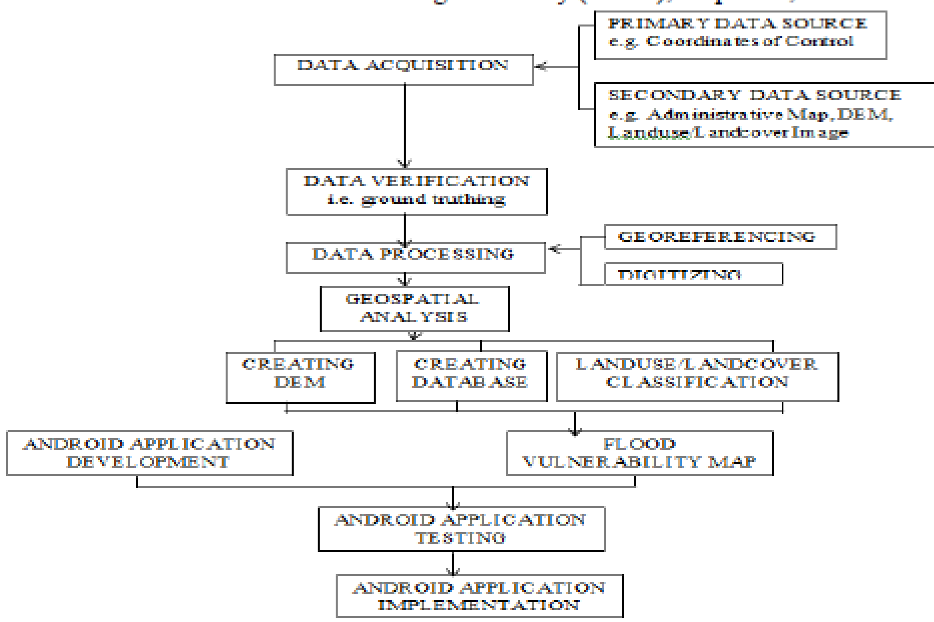

Figure 3.0: The methodology flow chart for the research

3.2 Data processing

The data processing can be broadly grouped into three stages, which include; generating the DEM of the study area, generating the Land use/land cover and finally incorporating the two map together to generate the Flood vulnerability map. The extracted DEM image of the study area was processed and filled, using the 'Symbology' feature in the ArcGIS, the different height ranges from very low areas to very high areas were obtained and the necessary color convention was given to show these range of height differences.

3.2.1 DEM and landuse/landcover analysis

The shape file for the administrative boundary of Minna from which the DEM image, Land cover/land use images for Minna metropolis were selected and extracted. With reference to Google earth for better accuracy, the training sites of the features within the study areas were selected and a Maximum likelihood classification was carried out on the composite image of the Land use/land cover bands.

To depict areas vulnerable to flood activities more efficiently an overlay process is required. This overlay was done using the principle of the "Arithmetic overlay" process, which involves raster addition. Using the "Raster calculator" tool in the ArcGIS the Land use and Land cover image was added to the DEM image of the area to give a new flood risk map of the area, via a simple arithmetic operation, that is:

Land use Land cover image + DEM image = Flood Risk map/overlay map

From the attribute Table (Table 3.1) of the risk regions of the study area, the area of each region of height differences was calculated and the percentage covered by each region determined. To obtain the coordinates covered by each region, the risk map was converted to point feature, to give the latitude, longitude and elevations of points within the regions of each height difference. These coordinates serve as database for the android application building. Conversion of areas of different elevation data details to Shapefiles, such shapefile polygon features were then converted to point files, generating the latitude, longitude and elevation of such points and adding to the database for each class of low, high and moderate elevations, as classified using the ArcGIS software for range of elevations.

3.2.2 Elevation Scaling

Fekete *et al.* (2010) identify two main scale used in flood vulnerability assessment, which include sub-national and local scale, the specification for local scale was used as shown in Table 3.1, as the radius of study area is 10km.

Table 3.1 Attribute table of vulnerable regions (Fekete, 2010)

Class	Elevation Range(m)	Number of points
Very low	157.000-215.000	63,222
Low	216.000-237.000	132,533
Moderate	238.000-262.000	100,981
High	263.000-298.000	42,096
Very High	299.000-404.000	26,192

The application was built using Android studio software with Java programming language, the location-based service on android allows the determination of location of a point which is turn incorporated with the flood risk database. The application thus provides two specific information which include; the location of user and the flood vulnerability status of such location.

3.3 Image processing

The study adopted the concept of Geo-referencing and digitizing

The internal coordinate system of a map or aerial photo image was related to a ground system of geographic coordinates (USGS, 2019). The ground coordinates in UTM Northings and Eastings were converted to latitudes and longitudes (in decimal degrees), and used to geo-reference the satellite imagery. The ground coordinates were entered into Excel and the coordinates of the control point and were imported into the ArcGIS environment. Certain features which include boundaries of local government areas within Niger State, buildings, water features and vegetation areas were vectorized from the acquired raster imagery into point, line and polygon features.

3.4 Data analysis

Database management is discussed in this Section

A database is an organized collection of data, generally stored and accessed electronically from a computer system (*Beynon-Davies, 2017*). It can be updated and scope of coverage increased over time, as this will continue to assist in the process of querying for any desired information from the set of data under the database. In creation of the database for the application, the latitudes, longitudes and elevation of points over the 10km radius were the most crucial and required information, these sets of information were grouped into separate files within the database in the order of: database for very low elevation points, database for low elevation points, database for moderate elevation points, database for high elevation points, database for very high elevation points (figure 3.0). By correlating these information in the database with the information from the mobile device (latitude and longitude) the application is capable of ascertaining to which class of data such points belong. Figure 3.0 shows the flow chart used for the data analysis.

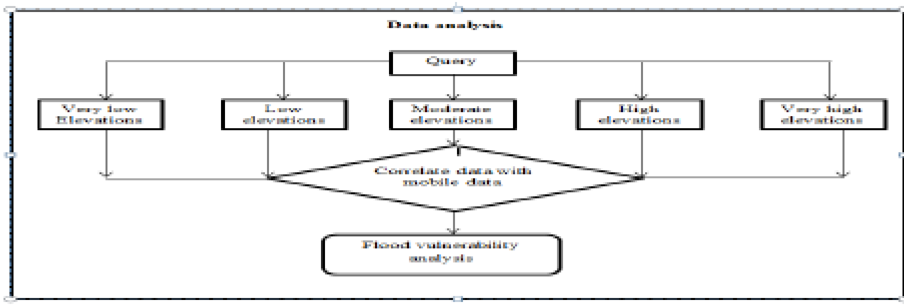

Figure 3.0: Flow chart for the data analysis

3.5 Application operation

The application simply operates and displays data by reading the information provided by location service of the android device and correlating it with the data in the database. It matches the longitude and the latitude from the device with the longitude and latitude of the database and uses this information to ascertain which class of elevation this information falls, after ascertaining that, it displays the elevation information and tells if the elevation is low, moderate or high. Using this information, it tells the user if the area is vulnerable or not.

4.0 RESULTS AND DISCUSSION

This section analyses and displays the result obtained from the study, by depicting information's on achievement made at various stages.

4.1 Classification of features

The landuse/landcover satellite image of the study area was used in the carrying out a supervised, maximum likelihood classification of features within the study area, using the ArcGIS software. The various landuses and land covers within the study area were depicted and the percentage covered by each landuse computed and displayed (Figure 4.1). The classification process comprises of the composite image of bands 6, 7 and 8 of Landsat image of the area and the result of the various features displayed using different color conventions (Figure 4.4).

4.2 Elevation analysis using the digital elevation model (DEM) of the study area

The SRTM DEM of the study was used in the elevation analyses and categorization of the range of elevations used in ascertaining points of low elevation, which are usually prone to flood activities and points of high elevation which are usually less prone to flood activities (Figure 4.2). It can be seen from the map in Figure 4.2 that the maximum elevation of point within the study area at this stage is 390m, and the lowest elevation point is 156m. This information prior to the overlay with the landuse/landcover shows the elevation characteristics of the bare earth surface.

4.3 Overlay analysis

In order to depict and acquire the elevation properties of the earth surface as it stands in the real world, an overlay operation comprising of the Arithmetic overlay of the SRTM digital elevation model and the landuse/landcover satellite image was carried out using the arithmetic overlay model (Figure 4.3). The maximum elevation point in the resulting raster image is 404m and the lowest elevation point is 157m as seen in Figure 4.3. The increase in elevation (Figure 4.3) after overlay indicates the presence of features both natural and artificial been overlaid on the initial DEM (Figure 4.2) of the area.

Elevation Classification is as discussed below:

Using the "Symbology" feature in the ArcGIS environment, the area was divided into five classes of elevations as shown in Table 4.1. The lower the elevation of points within an area, the higher the level of vulnerability of such area to flooding. From the elevation details of the various raster classes, the regions more susceptible to flood action are regions of very low elevation points and regions of low elevation points with a combined percentage area of about 57%, which is more than half of the study area (Table 4.1). Regions of moderate elevations are less liable to flooding except in situations of heavy rainfall and poor drainage within such regions. Regions of high and very high elevations are safer zones with less probability of flood actions, occupying a combined percentage of about 18% of the study area (Table 4.1). This shows that not up to a quarter of the study area are less vulnerable to flood actions. Based on this information of the elevation details the vulnerability assessment of the study area was carried out.

Various color conventions for the ranges of elevations after overlaying the SRTM DEM of the area with the landuse/land cover image of the area are used to show the different elevation classes (Figure 4.4). It can be seen that there is a potential increase in the elevations of points of low, moderate, and high elevations and a decrease in the elevations of points of very low and very high elevations (Table 4.1) before and after overlay.

Table 4.1: Table of the percentage and elevation values of the various elevation classes

ELEVATON CLASS	% BEFORE OVERLAY	% AFTER OVERLAY	ELEVATION VALUE AFTER OVERLAY
VERY LOW	22.28486176	19.09764628	157.000000-215.000000
LOW	32.89719578	37.01185584	216.000000-237.000000
MODERATE	25.6824721	26.13062629	238.000000-262.000000
HIGH	9.567735178	10.84955671	263.000000-298.000000
VERY HIGH	9.567735178	6.910314876	299.000000-404.000000

4.4 Database creation

In order to create a group of points within the various elevation classes, each class of elevation were converted to polygon feature and then subsequently each polygon feature of the various class of elevation converted to group of point features with each point comprising of the latitude and longitude information of the point. Points with the lowest of elevations were masked out of the overlay map and a polygon shape file of the raster class created to enable conversion of the class to a point shape file (Figure 4.5). This enables the coordinate characteristics and the elevation details of points within the raster class represented to be obtained and stored in the database used by the application. This process was repeated subsequently for elevation classes of low (Figure 4.6), moderate (Figure 4.7), high (Figure 4.8) and very high elevations (Figure 4.9).

The database created consist of the longitudes, latitudes and elevations of points within the study area (Table 4.2), these data sums up to tens of thousands of generated points, of which the application correlates the real time coordinates of points with the points on the database to ascertain which class of vulnerability the elevation using its coordinate value falls in. The dataset (Table 4.2) were added to the raw folder of the project structure, after converting the Excel file to JSON (Java Script Object Notation). JSON uses human readable text to transmit data objects consisting of attributes-value pairs and array data types or any other serializable value (Doug, 2019).

Table 4.2 Sample data used in creating the database for the application

Longitude	Latitude	Elevations
6.468622	9.441785	186
6.452681	9.443929	186
6.44358	9.443863	186
6.459522	9.44172	197
6.457247	9.441703	213

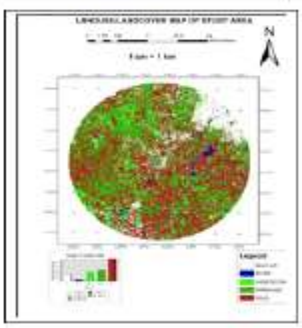

Figure 4.1: Map of the LULC of the study

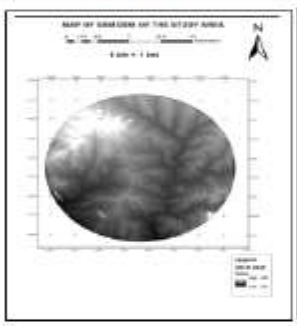

Figure 4.2: Map of SRTM DEM of the study

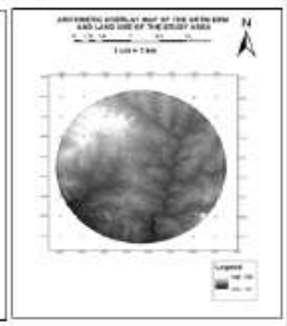

Figure 4.3: Overlay map of the SRTM DEM and LULC image of the study area

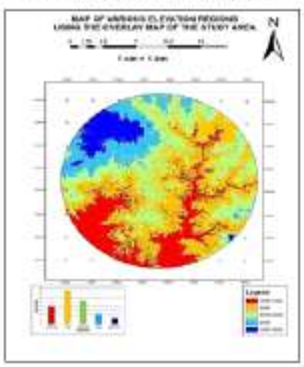

Figure 4.4: Map of the various elevation differences after overlay of the study area

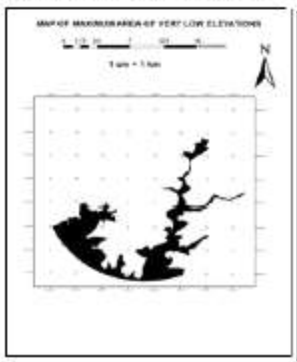

Figure 4.5: Map of maximum areas of very low elevation used for database creation.

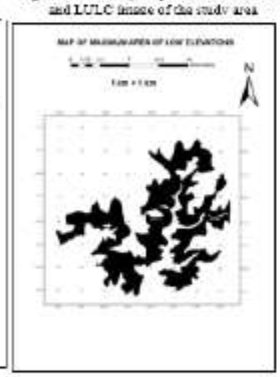

Figure 4.6 Map of maximum areas of low elevation used for database creation

4.5 Display result

The android application with the aid of the location based service reads in the latitude and longitude information of the position occupied by the mobile device and then searches for the class of elevation within the database to which this positional information belongs and then displays the vulnerability information on a point-based system. Using this information, result of multiple points within an area can be derived, and if in a land parcel more than 70% of the boundary points falls within the first two categories of elevation as shown in Table 4.3. It is safe to say such an area is highly vulnerable to flood activities; using this principle the vulnerability of any area can be identified. Although this is not the most accurate means of depicting flood vulnerability information but is adequate to guide variety of users in identifying the vulnerability of an area to flooding.

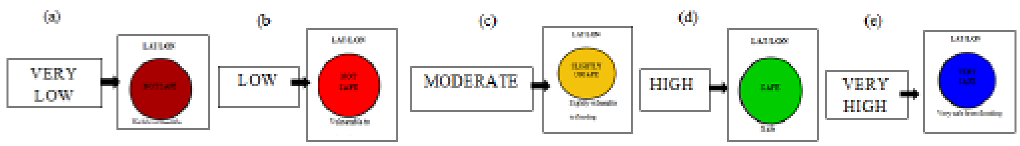

Figure 4.6b: The various categories of elevation in application display

4.6 Operational information

The operational information about the application is shown in figure 4.0

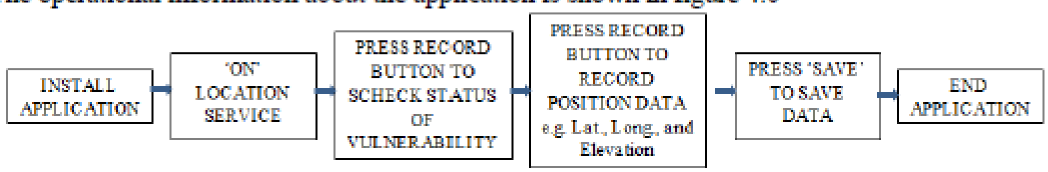

Figure 4.0 Operational information of the app

You can access the saved file from your File manager on your mobile device memory. When the application is operated outside the 10km radius of the study area, it displays 'NO DATA' (Figure 4.11), with additional information below the display panels.

4.7 Application validation/updating

The application can be validated and updated with a new database added to the JavaScript of either of the same area or of another area. It should be noted that as the volume of data increase in the database, this will result to a slower operation of the application and lagging in some android devices with lower memory space. To solve this problem an online database can be created and a program added to the program script of the app to enable the app access this online resource/database, more also another database format like MySQL can be used in the database management. The need for an external management source of the database is to enable a faster operation of the application. The interface can be updated and edited via coding of the app script.

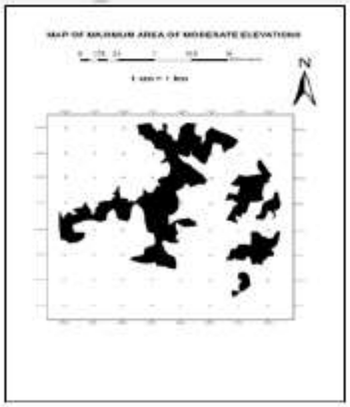

Figure 4.7: Map of maximum areas of moderate elevation used for database

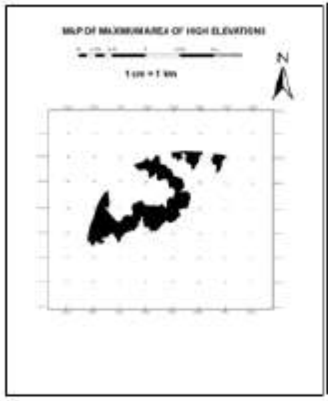

Figure 4.8: Map of maximum areas of high elevation used for database

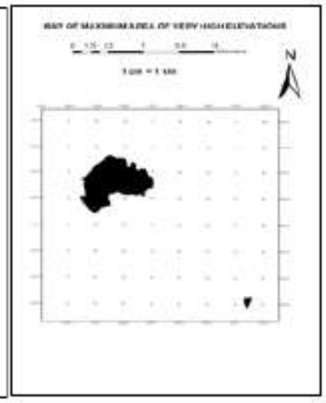

Figure 4.9: Map of maximum areas of very high elevation used for database

Figure 4.11: Display information of the application outside study area

Figure 4.12: The pop up information for location service of the device

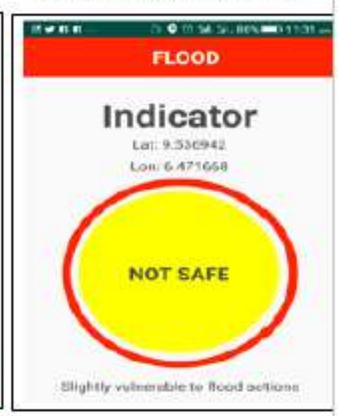

Figure 4.13: The vulnerability information to flooding at a position

5.0 Conclusion and Recommendation

We can only minimize the impact of flooding as a natural disaster we cannot totally remove it. Assessing the vulnerability is not just enough as information is only limited to researcher and archives of such field of learning. The study opines to assess and incorporate such assessment into an android application to make it readily available to anyone as a form of first-hand information to know the vulnerability status of their current location. The assessment shows that the study area is a relatively low terrain and is more vulnerable to flooding; with 'very low' and 'low' terrain having a percentage of 18 and 36% respectively, while moderate, high and very high has 26, 12 and 8% respectively. The result also show that only 11% of the study area are built up with vegetation and farmland having a percentage of 18% and 22% respectively, hills and rivers have a percentage of 45 and 4% respectively. The result also indicated that while the application was tested, it worked perfectly for points within the physical cope of the study area, but had a limitation outside the scope. Updating, validating and enlarging the physical scope of the work more than our study area will be suggested for further research. The Analytical Hierarchy Process (AHP) procedure used by (Andi *et al.,* 2017) can be implemented to help GIS and Remote Sensing preserve up-to-date information at low cost and good visualization.

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