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GIS as a Tool in Analyzing Flood Occurrence and Its Impact on Ikere Ekiti, Ekiti State Nigeria

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Abstract

Flood is any flow of water, which overflows the natural or artificial banks of a body of water. Flooding is one of the fundamental environmental challenges that results from interaction between man and his environment. In Nigeria, Flooding is one of the most common environmental hazards and there is increasing vulnerability of populations and infrastructure to flooding and flood related hazards. This study used GIS as a tool to analyze the cause and the impact of flooding in the study area. The study used both primary and secondary data, through a questionnaire, geographic information system and remote sensing. The result showed that the nature of the basin in the study area resulted to the high volume of water in the major river (River Osun) during raining season, which resulted to overflow across its bank. Fieldwork shows that the river overflows its bank at 500 meters to the north and the south and the GIS analysis shows that over 1000 houses get affected at any point of flooding occurrences, hence the width of the river is less than 8 meters and the depth on the average in less than 10 meter over the bridge of the River Osun. The study recommends methods by which flooding could be controlled in the study area through regular dredging, effective waste management and drainage control.

Keywords

Flood, Flooding, GIS, GIS Analysis, Raining Season, Nigeria

1. Introduction

Flooding is a wide-spread phnomenon which has been defined by many scholars and organizations. [1] defined flooding as a condition that exists when the water discharge of a river or stream cannot be accommodated within the margin of its normal channels so that excess water overflows and spreads over adjoining land.

[2] defined flooding as the occurrence of excessive volume of water in areas not usually water logged or as the accumulation of a large volume of water in an area where it is impossible for the water to percolate or flow away. Flooding is one of the most common environmental hazards in Nigeria [3].

In Nigeria, there is increasing vulnerability of populations and infrastructure to flooding and flood related hazards. Although flooding is one of many hazards occurring in human environment, its effects are significant both in terms of discomfort, destruction of lives, properties and pollution. The severity of flooding has been reckoned with, by the level of damage done [4].

There are various types of flooding, and different causes of flooding have been identified—some natural, others man-made. [5] distinguished between river flooding, coastal flooding and urban flooding as the major types of flooding. River flooding occurs where a river bursts or overtops its banks and inundates the areas around it. This is more common than coastal flooding.

Coastal flooding results when heavy storms or extreme weather conditions combined with high tides cause sea levels to rise above normal and force seawater to the land and cause coastal flooding. Urban flooding happens in a relatively short period of time and can inundate an area with several metres of water. As areas become "urbanized" or go through the process of urbanization, there are increased flood risks that result due to human activities such as deforestation, building without plan and so on. The main problem with urban flooding is the fact that they occur in highly populated areas.

Floods normally occur when more rainfall than the soil and vegetation can absorb. That is, excess rainwater runs off the land in greater quantities than rivers, streams, ponds and wetlands can contain. Such heavy rains periodically cause rivers or streams to overflow their banks spilling onto the surrounding floodplains [6] [7]. In an urbanizing environment like Ikere-Ekiti metropolis, the infiltration capacity is further reduced by the replacement of ground cover with impervious urban surfaces, which gives rise to overland flow as a means of disposing excess rainwater.

This is otherwise known as urban flood. In other words, urban flood is conceived as overland flow of urban streets sufficient enough to cause significant property damage, traffic obstructions, nuisance, and health hazards [8] [9] [10]. Other causes of river flood and urban flood according to [11] include land use pattern of the area and bad planning as well as natural factors like dam braking and volcanic activities.

[12] defined the environment as the total of the places and the surroundings in which we live, work and interact with other people in our cultural religious, political and socio-economic activities for self-fulfilment and the advancement of our communities, societies and nations which must not be left uncared for. [13] noted that the environmental is itself, the point, in which one is found at a time, the surroundings, the more distant places, other earth is components, conditions, prospects and problems which accounts for its flourishing or otherwise.

[14] Observed that, it is audient from research that residents contribute great-

ly to flood problems of their area and their act jeopardizes the environment which attracts many people for economics, social and recreational facilities. These activities are characterized by streams or river channels paved surfaces, poor solid waste disposed techniques, ineffective town planning laws and poor environmental management strategy.

These activities however, have not occurred without some backlash on the environment. Such human activities that contribute to the continuous environmental deterioration and counter-response sometimes manifest in the form of nature-based resistance and resurgence such as flooding. The result or implication of human activities leads to a closer proximity, or encroachment, on natural climatic phenomenon, including: flooding, erosion, wildfires, hurricanes, tornadoes, volcanic eruptions, earthquakes, tsunamis and any other natural phenomenon [15]

2. Methodology

2.1. The Study Area

Ikere-Ekiti, the study area is a traditional Nigeria town that existed long before the advent of British Colonial rule in Nigeria. The town is located within Ekiti State in the South-western part of Nigeria (**Figure 1**). It is located between latitude 7˚28'0" and latitude 7˚38'0", longitude 5˚10'0" and longitude 5˚20'0" and it is situated at an elevation of 381 meters above sea level. Ikere is bounded in the north by Ado-Ekiti, in the south by Akure North local government, and in the east and west by Ise/Orun and Ekiti South-west local governments respectively. The last National Population Census puts the total population of Ikere local government at 147,355 with a projected population of 202,500 in 2016.

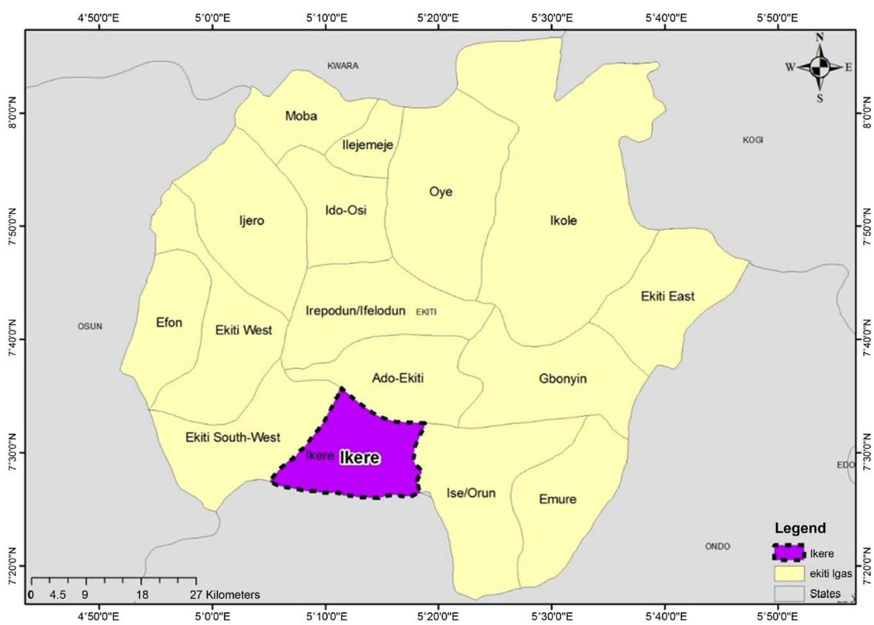

Figure 1. Map of Ekiti showing Ikere Ekiti. (Source: Geographic Information System/ArcMap 10.4.)

Ikere Ekiti experiences a tropical climate with distinct wet and dry seasons which can be better described as Koppen's "A" Climate [16]. The wet and dry seasons are associated with the prevalence of the most maritime South westerly monsoon winds from the Atlantic Ocean and the dry continental north easterly harmattan winds from the Sahara deserts respectively. The rainy season span from April-October while the dry season (November-March).

Temperature is almost uniform throughout the year with very little deviation from the mean annual of 27˚C. February and March are the hottest months with mean temperature of 28˚C and 27˚C respectively while June with temperature of 25˚C is the coolest. The mean annual total rainfall is 1367 mm with a low coefficient of variation of about 10%. Rainfall is highly seasonal with well-marked wet and dry seasons and double maxima as a result of the "little dry season" (August Break); experienced in August [17].

An important feature of the town is the large number of hills it possesses, notably the Olosunta, Ugele hills, and Orole inselberg. The hills are steep-sided and make much of the area susceptible to the risk of soil erosion. Predominantly the people are farmers cultivating both cash and food crops. The cash crops are mainly for export while the food crops are cultivated on subsistence level. Some of the rocks that are granitic in nature are also used for construction activities.

2.2. Method of Data Collection

The methodology adopted has three stages of map preparation, attribute data generation, GIS data input and analysis (**Figure 2**). The study focused on Odo-Osun, and the basin around the river, most especially from the hills, Ikere Ekiti, Ekiti State Nigeria.

2.2.1. Stage I

Preparation of Base Map to prepare the base map for Ikere-Ekiti, Remote Sensing and GIS techniques were employed. To obtain reasonable precision in the mapping process, a 10m resolution imagery of Ikere-Ekiti was obtained from global land cover, USGS and ASA PLANET software for different year for the exact Ikere-Ekiti using path and roll of p191 and r55, and was imported as raster images into the ArcGIS 10.4 software environment which was already geo-reference from the source.

2.2.2. Stage II

This stage involves using GPS; using phone GPS locator application, to locate the existing river and pick the co-ordinate *i.e.* longitude and latitude of the previous flooded areas in IKERE. However this will be computed on the excel application and later save as MS-DOS data; which will allow the ArcMap 10.4 for Desktop software for interpretation. Hence this process on the arcmap include adding of the MS-DOS text data through add X and Y data in the layer options tools.

2.2.3. Stage III

Generation of attribute data and database creation

After the importation of the images from the SASPLANET through add data tool or through the catalog window. Different shapefile was created to add different information as database, point shapefile for structures, line shapefile for river and polygon shapefile for boundaries. Vectorization or digitization; which is moving around the feature for vector generation. However the sub stage three; I combined the different ladsats downloaded which involve lansat 1, 2, 3 for built-up area or ladsat 1, 2, 4 respectively. I used composite band tool in the Arctools box of Arcmap 10.4 (Arctools box ------ → Data Management tools ------ → Rasta ------ → Rasta Processing -------- → Composite bands and on the window I added the rasta imageries and clicked on the processing tools for action. And the end result was a single combined image.

2.2.4. Stage IV

At this point I analyzed the rasta image using image classification and raster calculator and symbolized the difference features for geographical classification.

2.2.5. Stage V

This stage involves importing of DEM (Digital Elevation Model) raster format to ArcMap 10.4 for Desktop for raster analysis and interpretation. This process will be used for Hydrological analysis. Which will create basin, flow lengths, sinks, fills, stream lengths, stream flows etc. as shown in Figure 2.

2.3. Method of Data Analysis

When delineating watersheds or defining stream networks, there are series of steps involved. Some steps are required, while others are optional depending on the characteristics of the input data. Flow across a surface will always be in the steepest downslope direction. Once the direction of flow out of each cell is known, it is possible to determine which and how many cells flow into any given

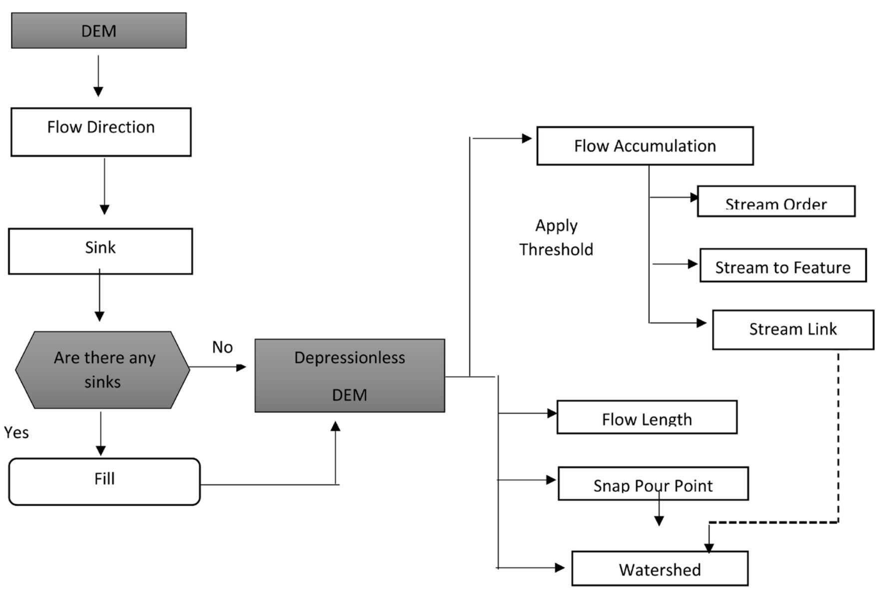

Figure 2. Hydrological modeling flowchart. (Source: ArcMap 10.4, Author field survey.)

cell. This information can be used to define watershed boundaries and stream networks. The flowchart (Figure 2) shows the process of extracting hydrologic information, such as watershed boundaries and stream networks, from a digital elevation model (DEM).

3. Results

The digital images (Figure 3) analyzed the action and vulnerability of Ikere area to flooding. Evidences from the survey show that the area of Ikere community regularly suffer from the overflowing of the Osun river whenever there is occurrence of rainfall that rise beyond 1cm and rained for more than one hour. However the presence of Iselberg of rocks that ranges from 300 m to 580 m above the sea level all contributed to the type of rainfall in the area which is orographic in nature. Also, the report from the satellite imagery proved and showed the ever increasing rise of the Osun River.

The analysis from GIS shows that the river Osun overflowed its bank to the left *i.e.* south and right which is north at the wider level of 450 m to the north and about 500 m to the left. However this increases the level of flood prone houses in the border to about 1500 houses at once. Hence the image bellow explains the different pattern of water basin and flow in Ekiti.

Figure 4 explained the different pattern of river and stream in Ekiti State. The pattern followed majorly dendritic and Trellis pattern which is the major basin and the colour differentiate the different type and level of the drainage basin in different part of Ekiti. Hence the deep purple indicate the oblige drainage basin and the lighter part to the other colour shows the elongated, hence the elongated

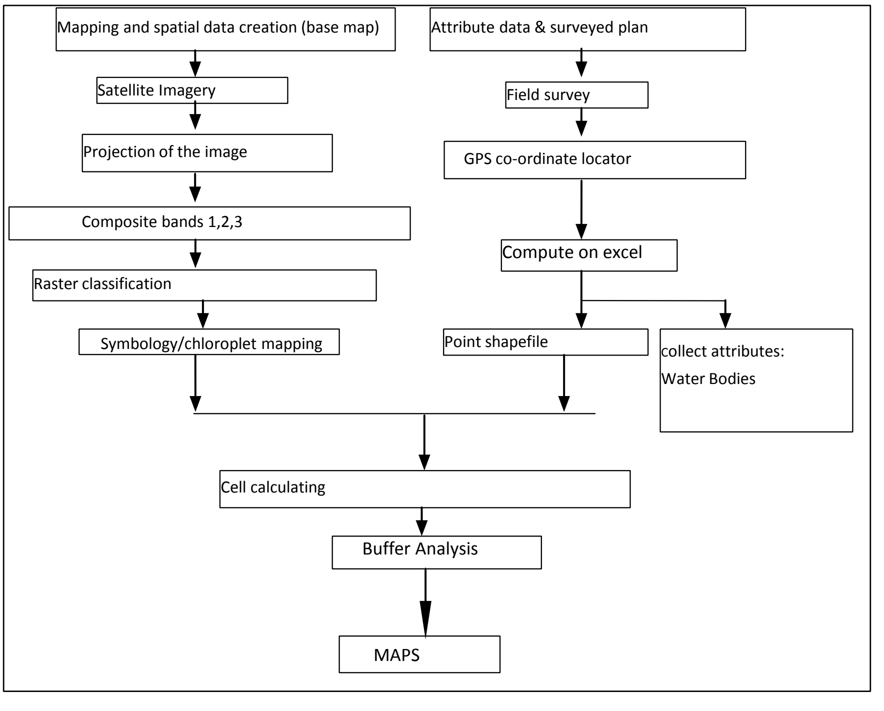

Figure 3. The methodology flowchart. (Source: Author Field survey.)

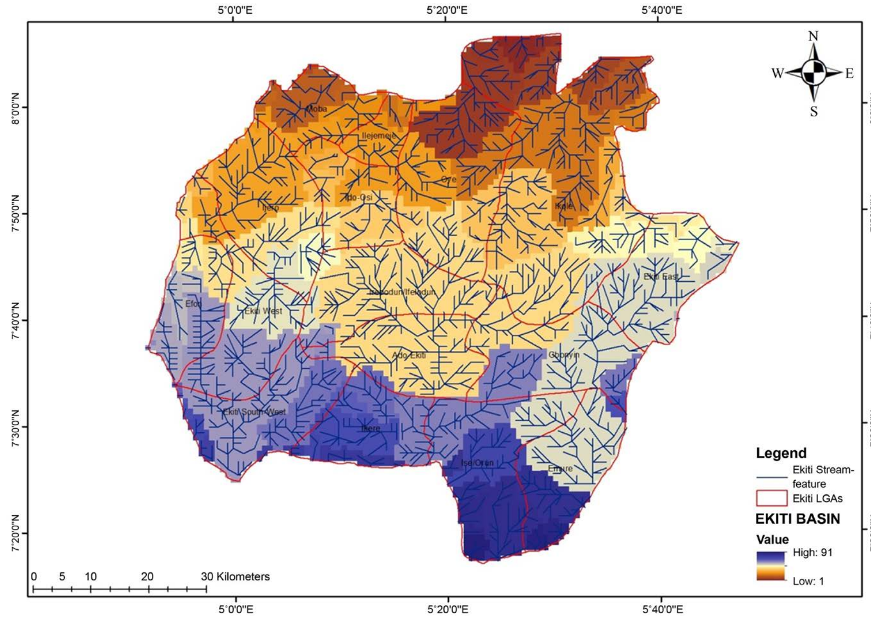

Figure 4. Ekiti State river basin. (Source: GIS 2017, ArcMap 10.4/Author field survey.)

basin are less vulnerable to flooding and however the deeper area is more liable to erosion.

Figure 5 explained the drainage pattern in Ikere-Ekiti. The areas with deep coloration (blue) are more liable to flooding. However the rising of the river is faster than the elongated basin. The Isenberg or outcrop of rocks contributed to the faster rate of movement of the fluvial actions in the area. This contributed to the high level of erosion in Ikere Ekiti.

Figure 6 explained the stream pattern in Ikere Ekiti which are majorly Trellis and Dendritic in nature. The flow of the stream follows different pattern and this contributed to high volume of water that flows into the major river (River Osun) in Ikere Ekiti.

Figure 7 shows the Flow length of the rivers and the streams in Ikere Ekiti. The flow length is ranked from 0 to 0.514928 kilometers and the majority of the flows in Ikere have a very short flow length. This leads to the high rise in the water level in the rivers in the study area during heavy rains.

However without external anthropogenic factors the nature of Ikere geological arrangement have high propensity to cause flood whenever there is rainfall in the area. The deep blue areas of **Figure 6** have a lesser length which shows they have high risk of flooding and erosion. The red colour has long length and gives the chance of prolonged possibility of flooding in the area.

Figure 8 shows the water shed type and pattern in Ikere Ekiti. It depicts the oblige watershed which is considered to be high and have maximum probability to flood when there is heavy rainfall. The rivers overflow their banks which results to flooding the whole area. The image ranges from one level of colour to another. The pink is highest which is of 2210 capacity in water accumulation and it has high risk of erosion and flooding. This is the direct opposite of the elongated

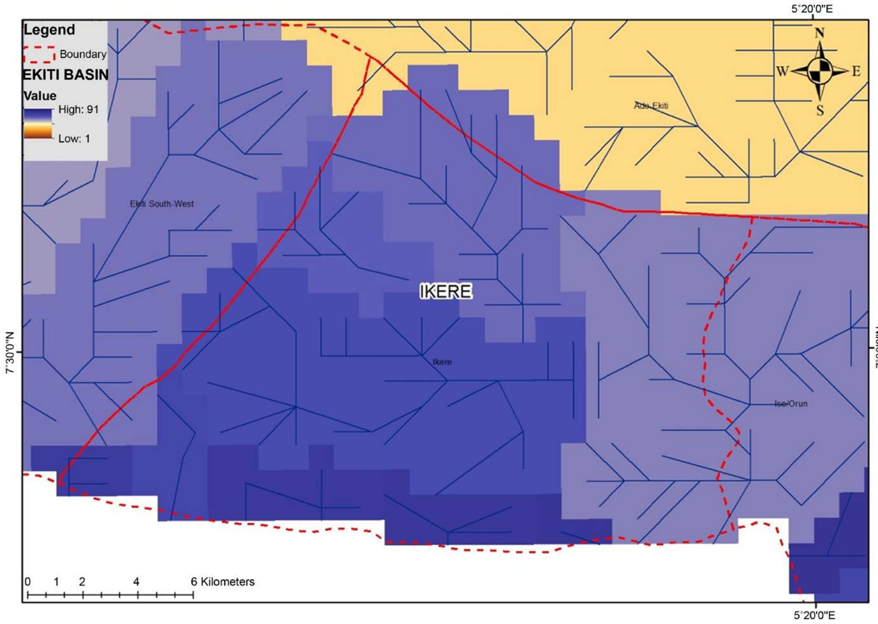

Figure 5. Drainage pattern in Ikere-Ekiti. (Source: GIS 2017, ArcMap 10.4/Author field survey.)

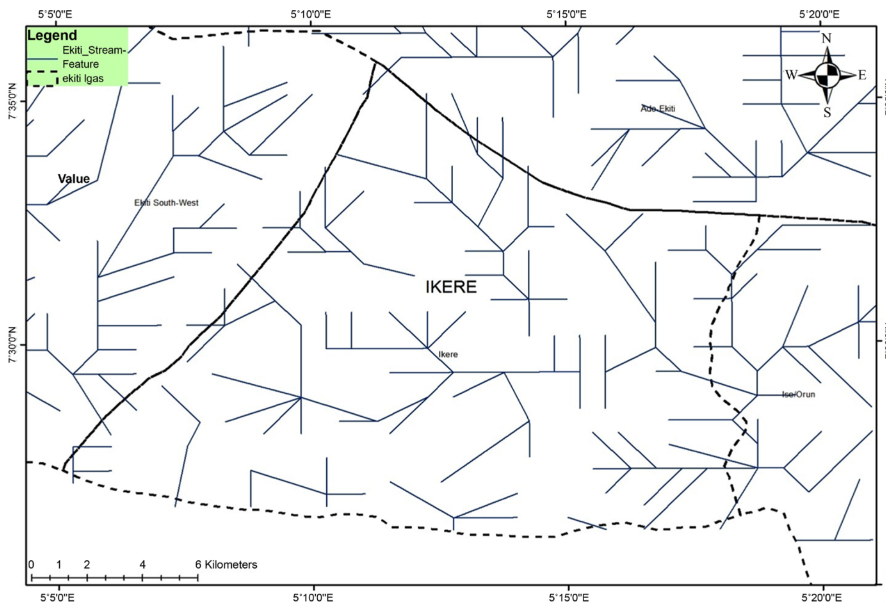

Figure 6. Stream pattern in Ikere-Ekiti. (Source: GIS 2017, ArcMap 10.4/Author field survey.)

one with volume as low as 1 - 1100 compared to the 1101 - 2210 of the oblige. The highest and majority of the water shed in Ikere are of high level and they are as a result of the rugged level of the topography of the area.

Figure 9 shows the Digital Elevation Model of Ikere Ekiti, which shows the elevation and the topographical pattern of the area; hence the variation in the colour and the level of the class mark shows variation in the altitude of the area. The lowest point is the light blue area with altitude 340 m - 367 m and the highest

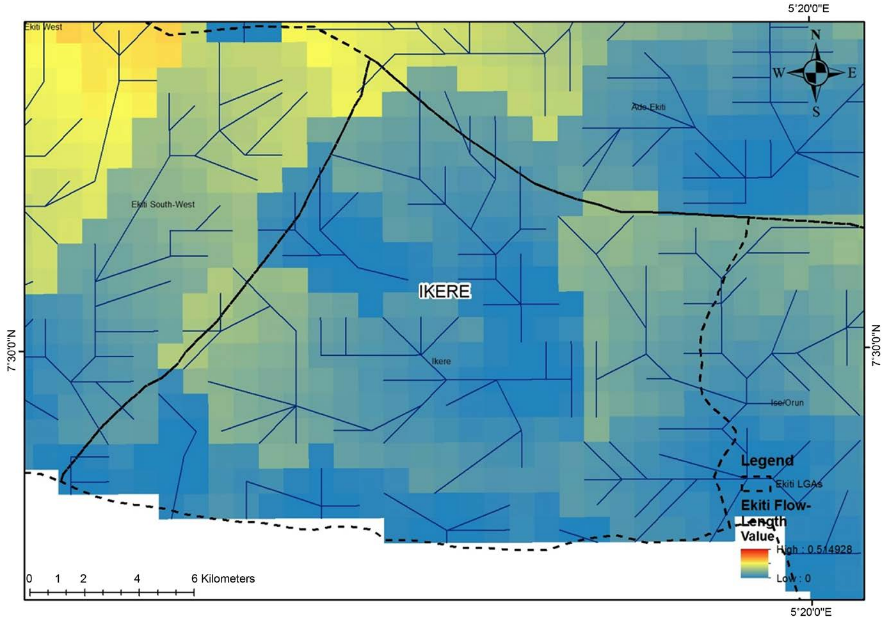

Figure 7. River flow length in Ikere-Ekiti. (Source: GIS 2017, ArcMap 10.4/Author field survey.)

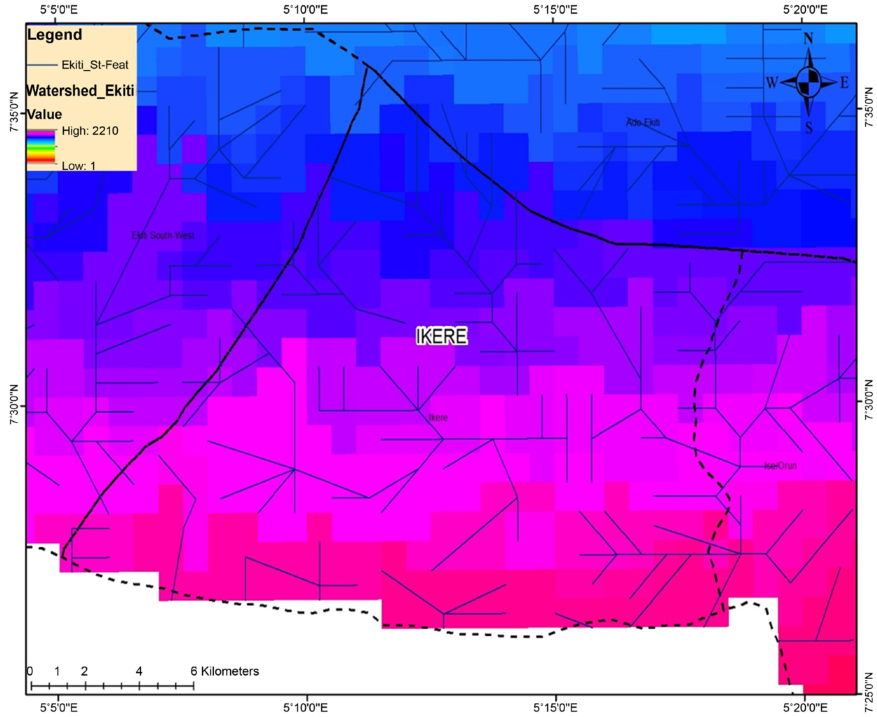

Figure 8. Water shed in Ikere-Ekiti. (Source: GIS 2017, ArcMap 10.4/Author field survey.)

point is of the ashes colour with altitude 529 m - 557 m while the red line indicates the flow of the streams in ikere Ekiti along the valley. This shows that the streams and the river flows across the low area in Ikere and the upland serves as the riverbasins that contributed to the volume of water in the rivers most especially river Osun.

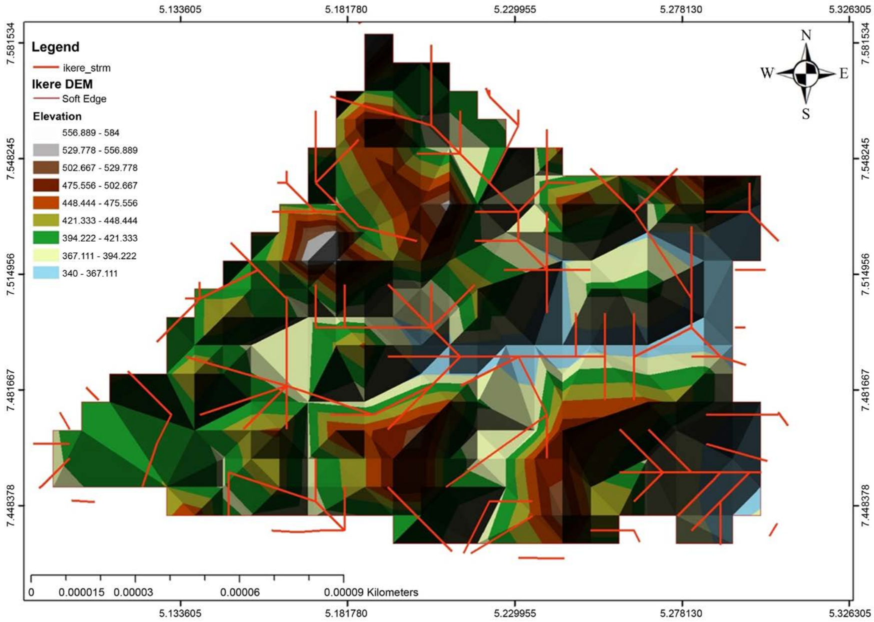

Figure 9. Digital elevation model. (Source: GIS 2017, ArcMap 10.4/Author field survey.)

Figure 10 shows the length of the rivers in Ikere Ekiti. The image contains the flow length and the directions of flows and the numbers show the order of the rivers in the area. However the red line is the boundary of Ikere with other towns, hence the whitish colour area shows the area connected to the longest direction and the deep black shows the lowest order.

Figure 11 shows the digital illustration of flooding in Ikere Ekiti. The red line shows the flow of Osun river, which flows directly into Ikere from Ilawe and the outflow from the area. Also, the blue line shows the basin from the mountain and other little uplands which contributed immensely to the volume of water into osun river, which flood the area when the influx goes beyond the beyond capability of the river. The continuous yellow belt indicates the floodable area of 500 meters away from Osun river, and it shows the maximum extent the river can cover at a time.

Figure 12 shows the buffer analysis of the relative extent at which the impact of the flooding for Oke Osun and Isale Osun area of Ikere-Ekiti. The buffer analysis shows the impact of the flooding from Osun River in Ikere-Ekiti. The analysis shows the extent to which the water will cover in any moment of flooding in Ikere-Ekiti. The analysis shows that of any prolonged orographic and conventional rainfall that last heavily for an hour will force the area to experience flooding away from the area surrounding the Osun river.

The elevation of the river is lower than the respective altitude of the surrounding area. The impact is estimated to flood more than 1000 houses at the hotspot of the occurrence; hence areas more than 450 meters away from the river to the north will be flooded and more than 500 meters away from the river to south will experience flooding. This occurs due to the variation in the altitude of the area surrounding Osun river.

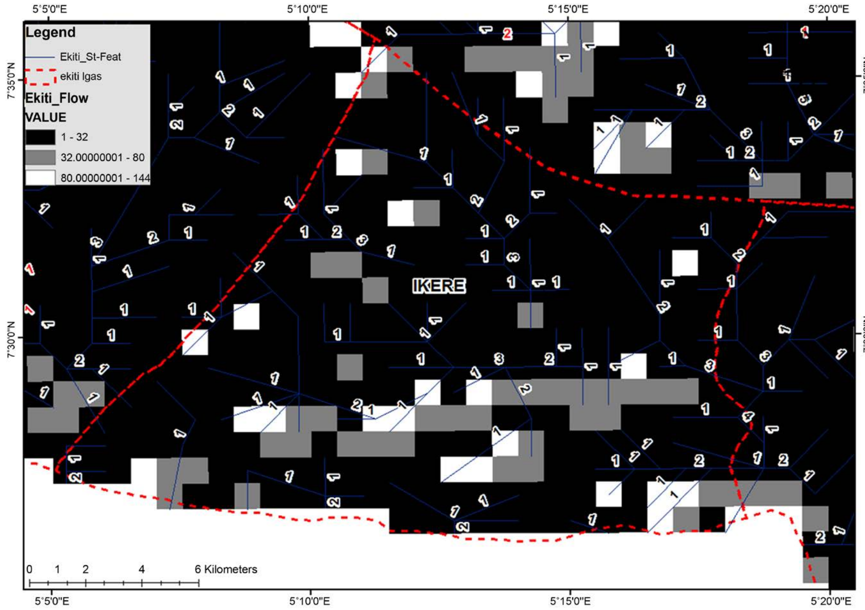

Figure 10. Length of the rivers in Ikere-Ekiti. (Source: GIS 2017/Author field survey.)

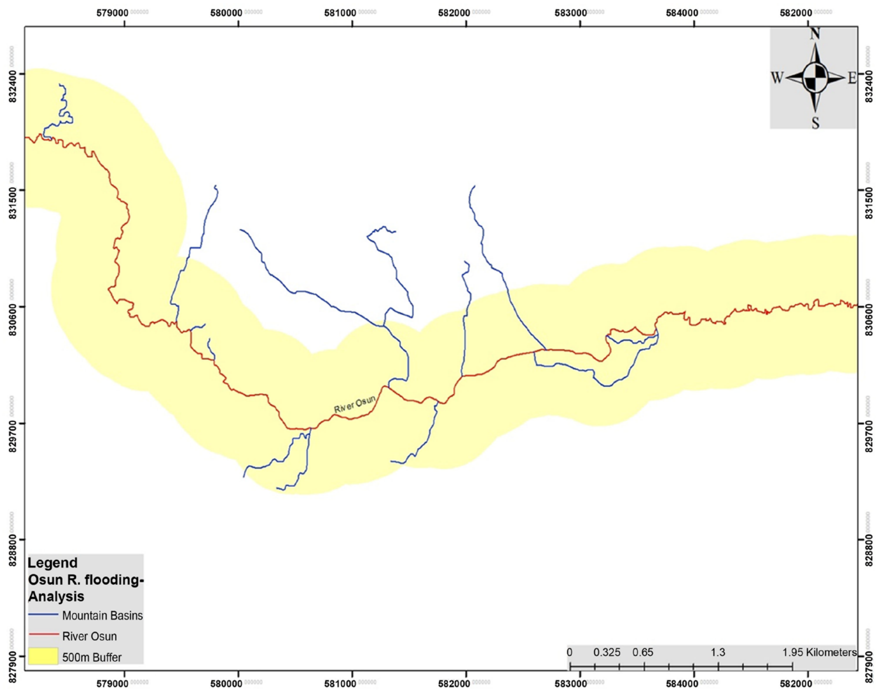

Figure 11. Digital illustration of flooding in Ikere-Ekiti. (Source: GIS 2017, ArcMap 10.4/Author field survey.)

Figure 13 shows the pictorial representation of the Osun River and the elevation relative to the sounding areas.

4. Conclusion

From the data analysis, it can be said that Geographic Information System will aid the control of flooding and methods of preventing flooding in the study area.

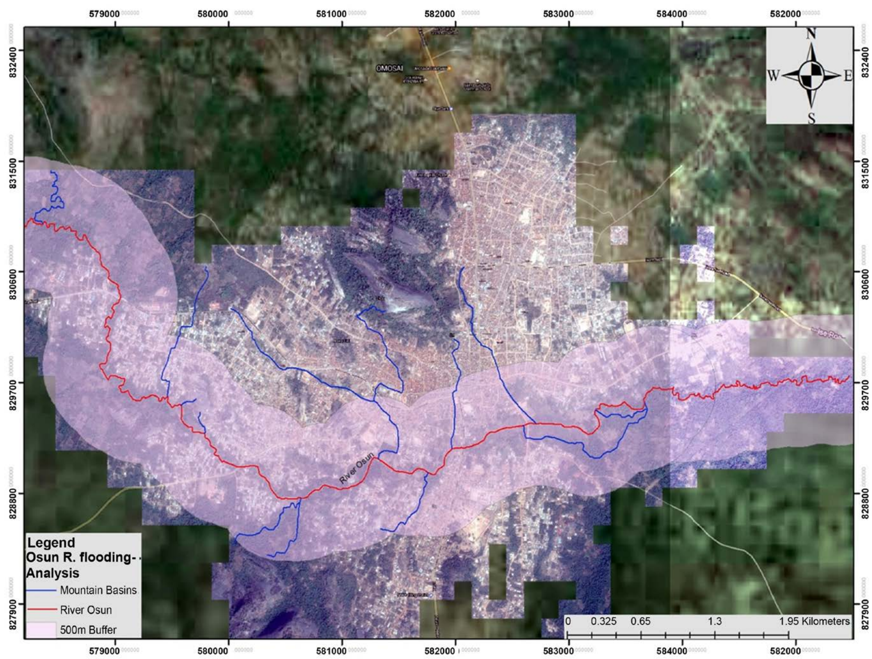

Figure 12. Buffer analysis of River Osun. (Source: GIS 2017, ArcMap 10.4/Author field survey.)

Figure 13. Pictorial view of Osun River. (Source: Author Field Survey, 2017.)

Flooding is inevitable due to human activities and topography of the area. However, it is equally possible to mitigate the effect if proper measures are taken.

Recommendations

From the findings of the study, the following are recommended:

- Geographic Information System should be used as a major tool in analyzing geographical phenomenon including flooding, because of the cost effectiveness and time savings.
- Planners and water resources expert should be equipped with adequate

technological knowhow majorly in the area of Geographical Information System for the sake of easy data collection, analyzing, interpretations and predictions.

- Strong measures and enforcement of orders in the allocation of land water resources management should be undertaken.
- Citizens should be encouraged to set up buildings away from the river bank so that erosion can be controlled.
- Laws should be made to prohibit the indiscriminate dumping of refuse along the river valleys to prevent obstruction to the smooth flow of the river.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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