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ANALYSIS OF TOPOGRAPHICAL CONTRIBUTION OF FLOODING IN OWERRI URBAN IMO STATE USING GIS AND REMOTE SENSING TECHNIQUES

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ABSTRACT: Flooding poses a significant environmental challenge in Owerri Urban, Imo State, Nigeria, exacerbated by rapid urbanization, inadequate infrastructure, and heavy rainfall. This study examines the topographical contributions to flooding in Owerri using Geographic Information Systems (GIS) and remote sensing techniques. By analysing Digital Elevation Models (DEM), slope gradients, hill shade, aspect, and contour maps, the study identifies key areas prone to flooding. The findings reveal that flat or gently sloping areas, particularly those with a slope gradient of 0° to 40°, are most susceptible to run-off accumulation and flood events. The study further highlights the role of flat or gently sloping areas (0° to 40° slope gradient) in contributing to flood risk.", especially at the bases of slopes, where runoff from higher elevations accumulates. These insights underscore the critical role of topography in flood risk assessment and provide a foundation for developing targeted flood mitigation strategies. The study recommends the construction of a comprehensive drainage network, the integration of flood risk maps into urban planning, and the enforcement of land use regulations to reduce flooding in Owerri Urban. The use of GIS and remote sensing in this analysis demonstrates their effectiveness in enhancing urban resilience to environmental hazards.

Keywords: Flooding, Topography, GIS, DEM, Remote Sensing, Urban Resilience

INTRODUCTION

Flooding is characterized by the accumulation of water on the land surface for extended periods after heavy rainfall. It becomes a global concern when rainfall exceeds normal levels for a region, leading to substantial damage to lives, and properties, traffic disruptions, nuisances, and health hazards (Adeleke, 2015). Floods are one of the most severe geophysical events, posing significant hazards to humans (Gillespie et al., 2017). They affect various human activities such as agriculture and transportation (Ademora, 2014). Flooding has increasingly become a common environmental hazard in many Nigerian towns, including Owerri. Some of the factors such as high intensity rainfall, paved surfaces, high run-off from higher ground, and lack of good drainage etc. contribute to flooding, resulting in river floods, flash floods, urban floods, and coastal floods.

Flood-inducing processes include intense precipitation, snowmelt, dam breaks, or water releases from dams. In tropical and subtropical regions, severe flood hazards result from heavy thunderstorms, torrential monsoon rains, hurricanes, cyclones, and tidal waves. These events, increasingly linked to global warming and climate change, are becoming annual occurrences (Karagiozi, 2011). Owerri has experienced increased flooding incidents in recent years. For example, on September 10, 2016, no fewer than 30 buildings in the densely populated Works Layout in Amakohia were submerged following heavy rain. Flood risks in Owerri's urban areas are exacerbated by population growth, housing expansion, increased paved surfaces, inappropriate waste disposal, and other factors that contribute to high runoff intensity leading to flooding in lowland areas (Iro, 2024). Urban flash floods caused by torrential rainfall are the most common in Owerri, affecting people more than any other natural disaster annually. The impacts of floods include structural damage, erosion, loss of life and property, and disruption of social and economic activities (Akinyemi & Akinyemi, 2016).

Floods are a significant environmental issue, posing threats to human life and hindering economic activities by damaging cultivable land and property. The increasing flood damage in recent decades is attributed to changes in land use patterns driven by population growth, leading to more housing, paved surfaces, loss of vegetation, and excavation activities. These human activities significantly impact climate change, global warming, and rising sea levels. Consequently, both the frequency and intensity of floods are increasing. Addressing flood risk management using Geographic Information Systems (GIS) and remote sensing is crucial. Owerri's disaster profile is dominated by flood events, which cause property damage, disrupt movement, and affect economic and social activities. Effective flood risk assessment and adaptation are essential for ensuring the safety and sustainability of human lives and properties. In Owerri, flooding has become a regular annual occurrence, with rainfall being the primary source. Recent floods have resulted in property losses, traffic obstructions, and highlighted the need for flood risk assessment and adaptation strategies. Identifying flood-prone areas is vital for protecting lives and property. Addressing environmental factors using GIS and remote sensing is increasingly important, especially in areas like Ahiajoku centre, where no similar studies have been conducted.

GIS plays a critical role in disaster analysis and management, particularly in life-saving measures, and has been extensively used in developed countries for the past two decades. Advancements in remote sensing (RS) and GIS technologies aid in real-time monitoring, early warning systems, and rapid damage assessment of flood and drought disasters (Long et al., 2014). GIS assists floodplain managers in identifying flood-prone areas by storing and analysing geographical information, which can be graphically displayed for assessment. By overlaying different geographical layers, areas at risk of flooding can be identified and targeted for mitigation or stricter floodplain management practices. Remote sensing is effective in flood management through detailed mapping for hazard assessment and developing broader views of flood situations within river basins to identify areas at greatest risk and needing immediate assistance. Remote sensing and GIS techniques have successfully been applied in flood inundation mapping, floodplain zoning, and river morphological studies.

This study represents a pioneering effort in analysing the contribution of topography to flooding in Owerri Urban using GIS and remote sensing techniques. While previous research, such as the works by Anyadiegwu et al. (2021), Chibo and Okeke (2012), Okorie et al. (2022), and Akamuga et al. (2022), has primarily focused on the anthropogenic factors influencing flooding in Owerri, this study will employ advanced technology to model the topographical aspects of the flooding issue. By examining the impact of the study area's relief, this research aims to uncover the role of topography in exacerbating flood events in Owerri Urban.

Study Area

Owerri, the capital city of Imo State Figure 1, is located in the southeastern region of Nigeria. Known for its vibrant culture and economic activities, Owerri has experienced rapid urbanization over the past few decades. This urban expansion has brought both development and challenges, particularly in managing environmental issues such as flooding.

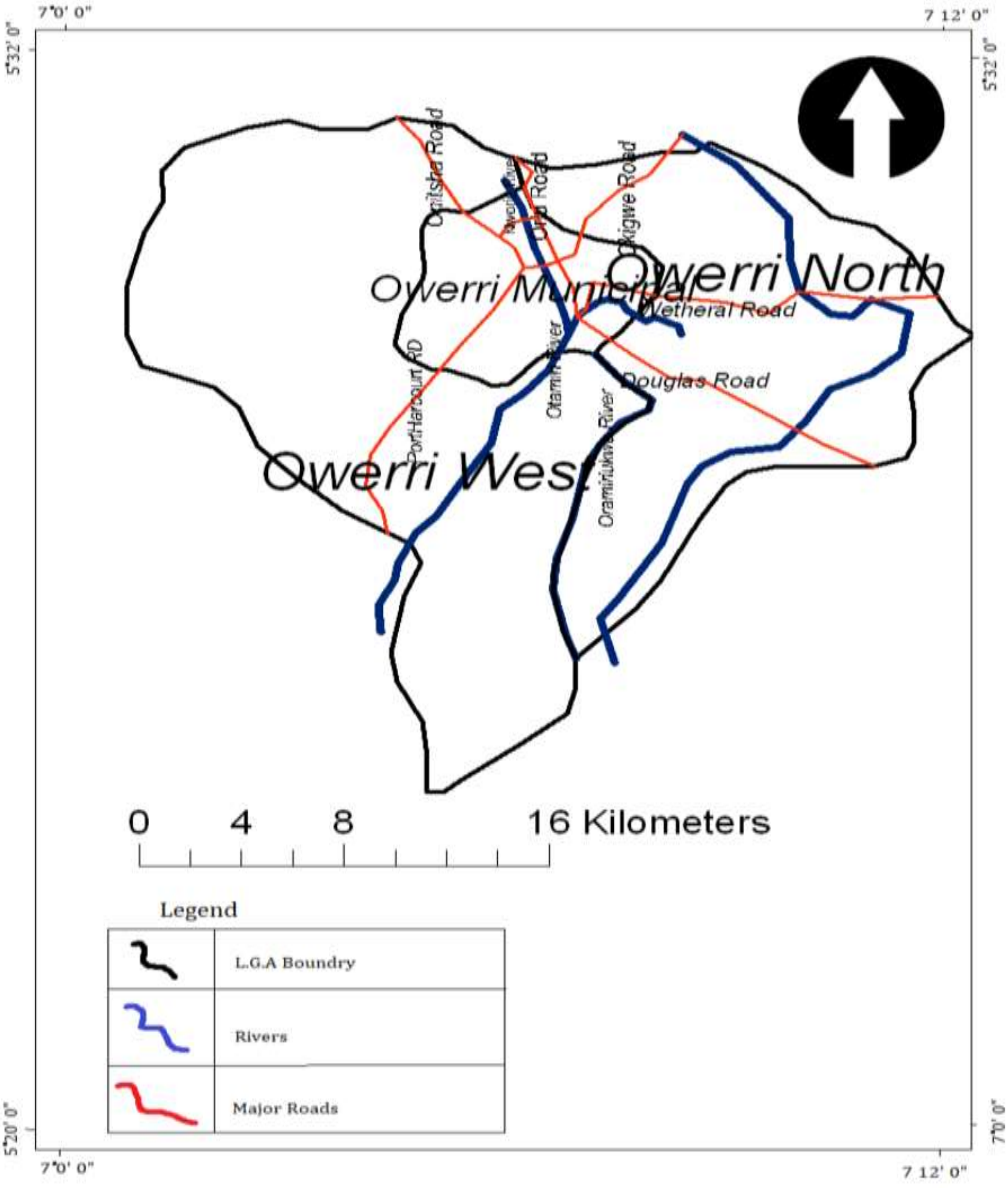

Figure 1: Owerri Urban with rivers and major Roads

Geographic and Climatic Features

The city covers an area of approximately 104 square kilometres and is situated on a relatively flat terrain with a gentle slope towards the Otamiri River, which traverses the city. The elevation of Owerri ranges from 50 to 150 meters above sea level, contributing to its vulnerability to surface water accumulation and flooding. The climate in Owerri is characterized by a tropical wet and dry climate, with a distinct rainy season from April to October and a dry season from November to March (Emetuma et al. 2023). The average annual rainfall is about 2,500 millimetres, with the heaviest rains occurring between June and September (Axim, 2016). The high rainfall intensity, coupled with poor drainage systems, exacerbates the city's flooding problems.

Socio-Economic Profile

Owerri is a bustling urban centre with a population estimated at over 1,000,000 people National Population Commission, 2020). The city's economy is diverse, encompassing commerce, industry, education, and healthcare. It hosts several educational institutions, including the Federal University of Technology, Owerri (FUTO), and Imo State University (IMSU). These institutions attract a large number of students, further boosting the city's population and economic activities. The commercial activities in Owerri are centred around major markets such as Eke Ukwu Owerri and Relief Market. Additionally, the city has numerous small and medium-sized enterprises (SMEs) that contribute to its economic growth. However, rapid urbanization has outpaced the development of infrastructure, leading to challenges such as inadequate waste management, traffic congestion, and increased flood risk.

Environmental Challenges

One of the most pressing environmental issues in Owerri is flooding. The combination of heavy rainfall, flat topography, and insufficient drainage systems leads to frequent and severe flooding events. These floods cause significant damage to properties, disrupt transportation, and pose health risks due to waterborne diseases. The urban flash floods in Owerri are often exacerbated by clogged drainage channels, resulting from indiscriminate waste disposal and poor urban planning. In recent years, the city has witnessed several severe flooding incidents. For instance, on September 10, 2016, heavy rainfall led to the submersion of over 30 buildings in the Amakohia area, highlighting the urgent need for effective flood management strategies (Iro, 2024). The frequent flooding has also led to soil erosion, further deteriorating the city's infrastructure and contributing to the loss of agricultural land in the surrounding areas.

Owerri Urban in Imo State, Nigeria, is a rapidly growing city facing significant environmental challenges, particularly flooding. The combination of heavy rainfall, flat terrain, and inadequate infrastructure necessitates the use of advanced technologies like GIS and remote sensing to manage and mitigate flood risks. By leveraging these tools, Owerri can develop sustainable urban planning strategies that enhance its resilience to environmental hazards and support its continued growth and development.

METHODOLOGY

Flooding in Owerri Urban has been variously studied but were all focused on the anthropological contribution of flooding in the area. research work such as (Iro, 2020 and

Muianga, 2004) all centered on human contribution without looking at the topography. This study adopts remote sensing methodology in processing the satellite data. This involves Digital Elevation Model (DEM) study area analysis, Landsat imagery and coordinate points from the field to relate with what is in the satellite images.

SRTM (DEM) for Topographical Outlook of the Study Area

To obtain the structure and contribution of topography to flood in the study area, SRTM (USGS DEM) image was used. This study used newly released 30m X 30m SRTM data of the study area acquired from the Shuttle Radar Topography Mission Dataset Figure 2 (Iro, 2020). This dataset was chosen to get a recent topographical outlook of the study area to enable qualitative and quantitative analysis of the flood sites. It can be observed that no other method can study the contribution of topography in the study of flooding effectively than using GIS and Remote Sensing (Iro, 2020) This is because it involves the use of satellite imagery which can give the result of the analysis of topography instantly. While other old methods will require longer and time-consuming processes to accomplish the same goal.

The processes

1. The DEM (Digital Elevation Model) imagery called SRTM (Shuttle Radar Topography Mission) was downloaded and cropped to the area of interest Figure 2. The elevation values range from low = 30m to high = 144m.
2. The imagery was preprocessed in ArcGIS 10.8 version to remove artifacts and fill the Gaps
3. ArcGIS Management Tools such as Slope, Contour, Slope Aspect, and Hillshade were used to run the analysis and model the contribution of the topography to flooding in the study area
4. One of the most important factors affecting flooding is topography (Iro and Acholonu, 2020). Digital elevation models (DEMs) have been commonly used in geographic information systems (GIS) for representing topography and for extracting topographical and hydrological features for various applications, including flood and its studies (Iro 2020). Topography is a crucial surface characteristic in flood modelling, and studies use a digital elevation model (DEM) to derive the topographical characteristics of a study area (Iro, 2021).

In the landscape, the topography determines the behaviour of the surface runoff, the phase of the hydrologic cycle that is most directly associated to runoff requires a rigorous and effective analysis throughout its entire extension. This is made possible with the use of digital elevation models (DEM) (Lillesand, 2008). The analyses developed using a DEM allow visualisation of the model in planar geometric projection. From Owerri DEM, greyscale images, shaded images and thematic images, the conducting of profile analyses, and generating derivative maps, such as steepness and exposure maps, drainage maps, contour maps, slope maps, and aspect maps were all generated for analysis. Very importantly, elevation points were generated from the Owerri DEM.

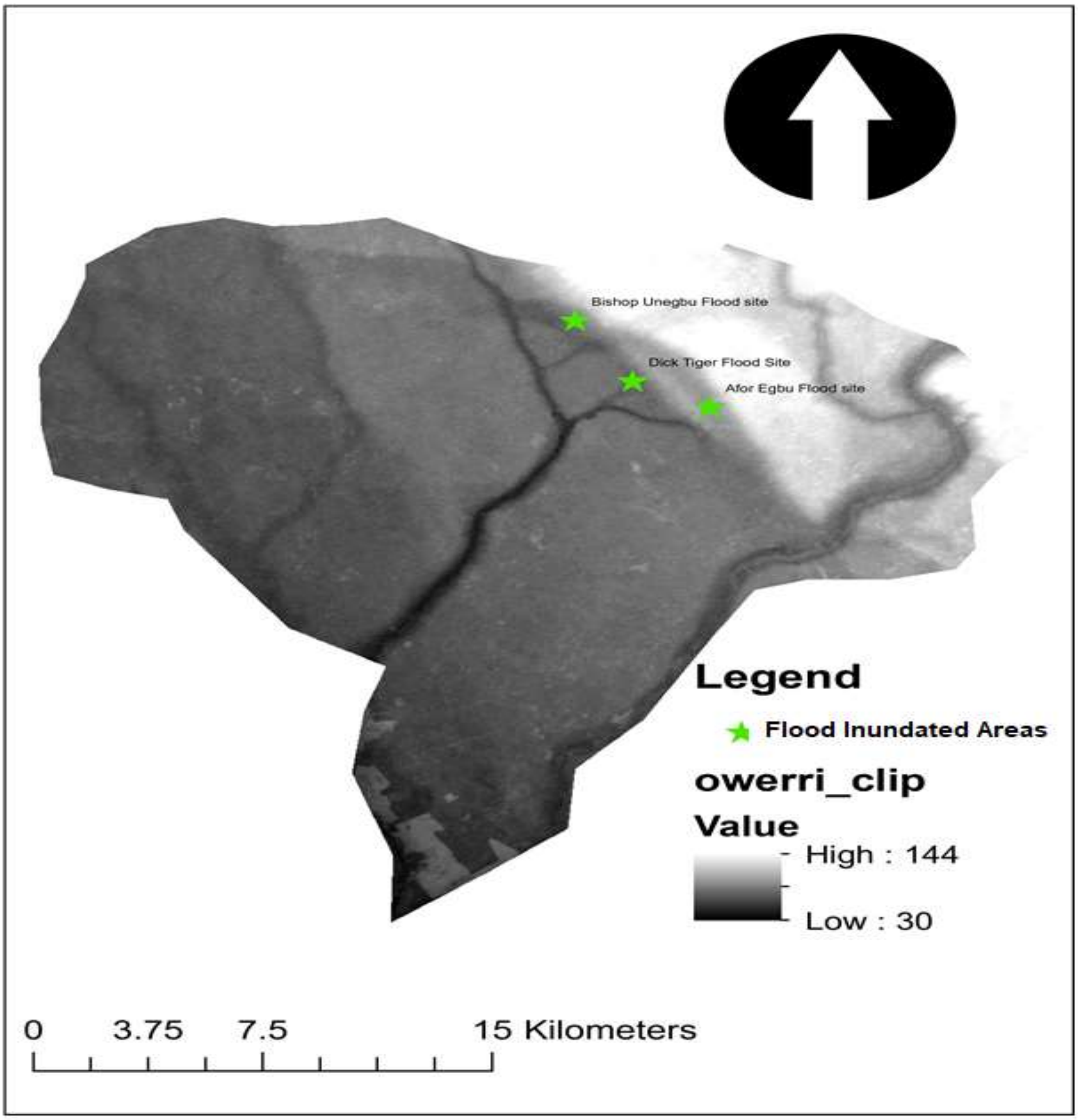

Figure 2: An SRTM DEM image of the study area, cropped to Area of Interest (USGS 2021)

DATA ANALYSIS AND RESULT PRESENTATION

Slope

The slope gradient is one of the most important factors affecting flooding (Qing-quan et al., 2001). Iro (2021) also emphasizes the importance of slope by showing that the studied flood sites are located at the base of slopes that have $0^0 - 20^0$ and 21^0 to 40^0 Figure 3. Iro (2020), observed that in the simplest terms, land located on steep inclines is more vulnerable to water runoff than flat land and flat land is where the inundated flood is mostly located.

In terms of degrees, Figure 3 shows that areas with 0 - 40^0 are mostly found in low-lying areas, flood plains, flat areas, and areas liable to flooding. The analysis of slope and overlay of flood inundated points have revealed that floods mainly percolate in areas with 0^0 to 40^0. It can be observed from the slope analysis that areas above 40^0 and above are areas where runoff are generated and devastate areas below it. This is observed from the 3 flood inundated points which are located on the bases of higher ground where the elevation is low, and the runoff water inundate the area. From the overlay of slope map and cadastral map of Owerri Urban, it can be observed that parts of Amakohia, Egbu and Trans Egbu areas, Riverbanks and Ihieagwa areas etc.

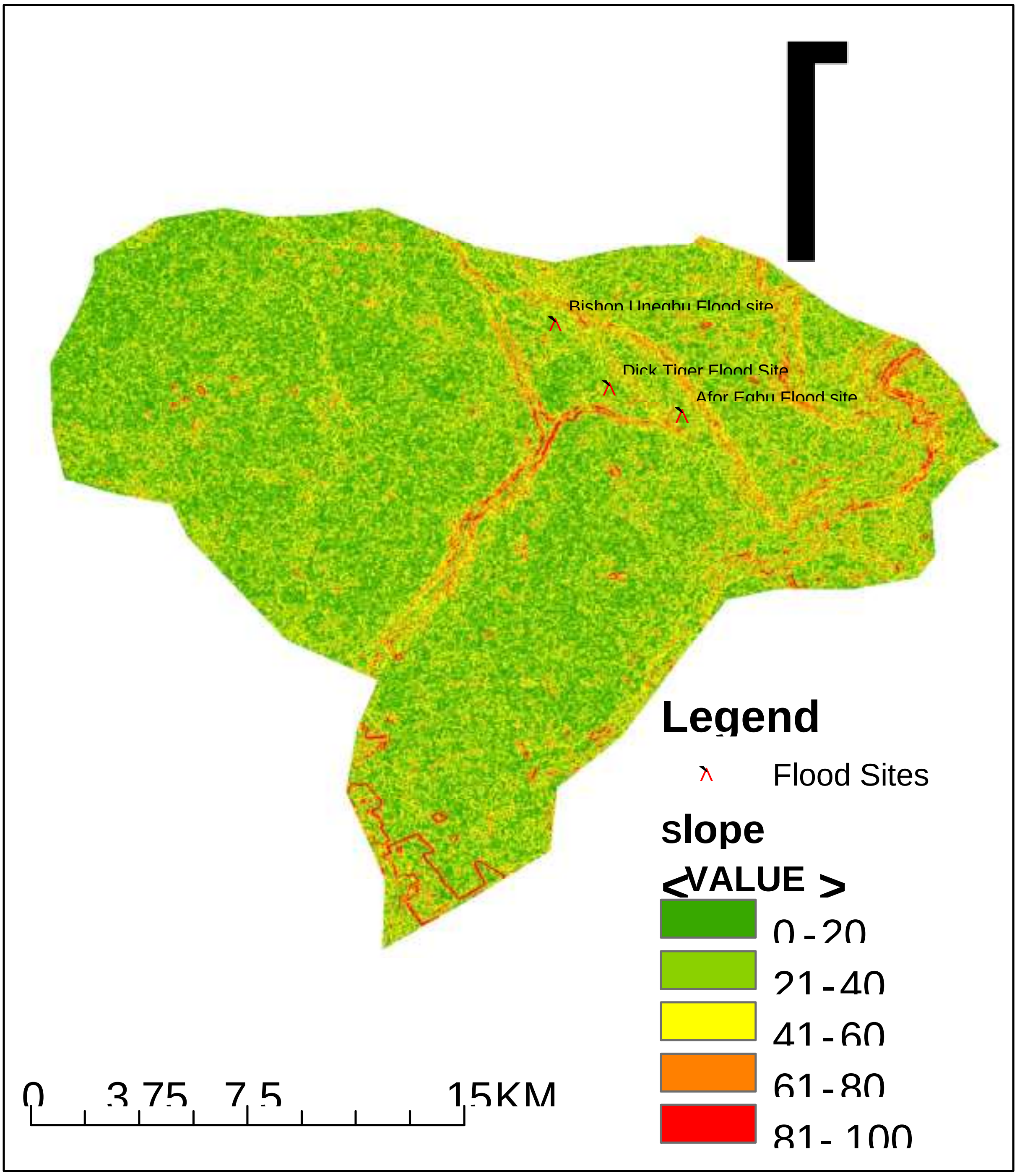

Figure 3: Maximum slope map of the study area shown as a degree gradient (flat areas have 0 – 40, 41 - 60^0 gentle slope, and 61^0 and greater are higher).

Hillshade

It provides relief, based on elevation variations within the landscape. It provides a clearer picture of the topography on flat, hills, sunken areas, and canyons. The overlay of the three inundated flood sites **Figure 4** reveals that they are located in a flat area.

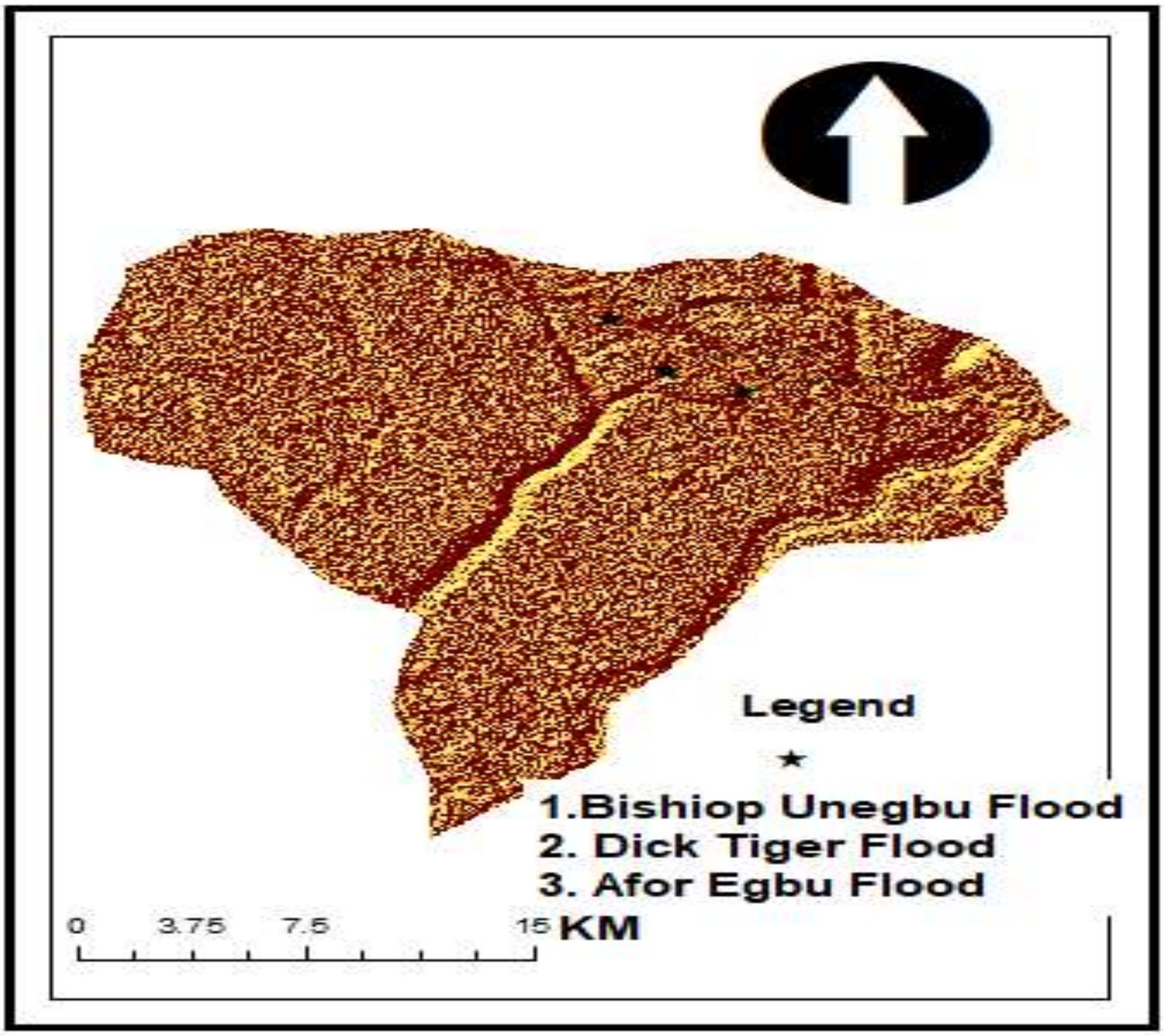

Figure 4: Hillshade map overlayed by the flood inundated points. Sunken areas are rivers and water bodies

Slope Aspect

Further analysis of topography was conducted via analysis of flood generation and locations in respect to the slope aspect. Boudou et al. (2016), Marque and Forkuo, (2011), maintained that slope orientation affects flood and gully development which depends on the side that is receiving rainfall more which determines the amount of runoff. The aspect map of the study area, Figure 5, was classified into ten classes, defined as flat, N, NE, E, SE, S, SW, W, NW. On this basis, the aspect classes of Owerri highlight a fairly homogeneous distribution. Slopes facing from North to North-west slightly predominate when compared with South, southeast, and south-west while the value of -1 is used to identify flat surfaces such as flood plains, fluvial terraces, river courses, and hill plains. All the flood-inundated areas of the study area were located in areas with a value of -1 which represent a flat area as can be observed from the overlaid flood-inundated points. These areas include flood plains, areas liable to flooding which include parts of Egbu, Trans Egbu, Amakohia, river Nworie and Otamiri rivers, etc.

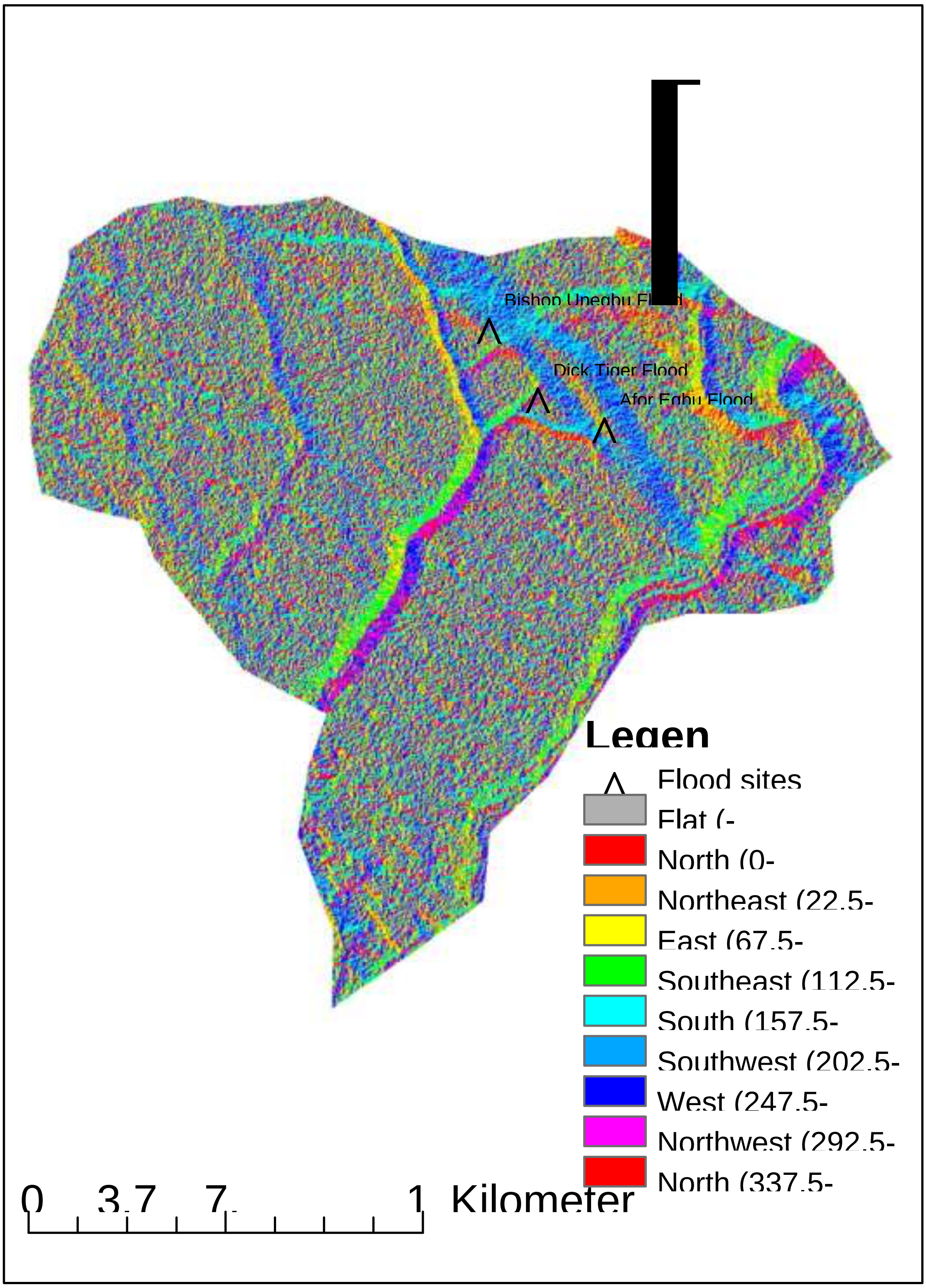

Figure 5: Aspect map overlayed by the flood inundated points. Flat, N (0 -22.5), NE (22.5 – 67.5), E (67.5 – 112.5), SE (112.5 – 157.5), S (157.5 – 202.5), SW (202.5 – 247.5), W (247.5 – 292.5), NW (292.5 – 337.5 and N (337.5 - 360)

Contour Map

Gradient represents how much the elevation is changing in each distance. A contour map is generated from the DEM data of the study area. Observing the contour map Figure 6 will show how the areas around the flood inundated points are higher ground above 50m than the areas where the flood inundated points are located that are below 50m. The contour map reveals that areas where the contours are higher are areas where the highest runoffs are generated to form flood at the flat area.

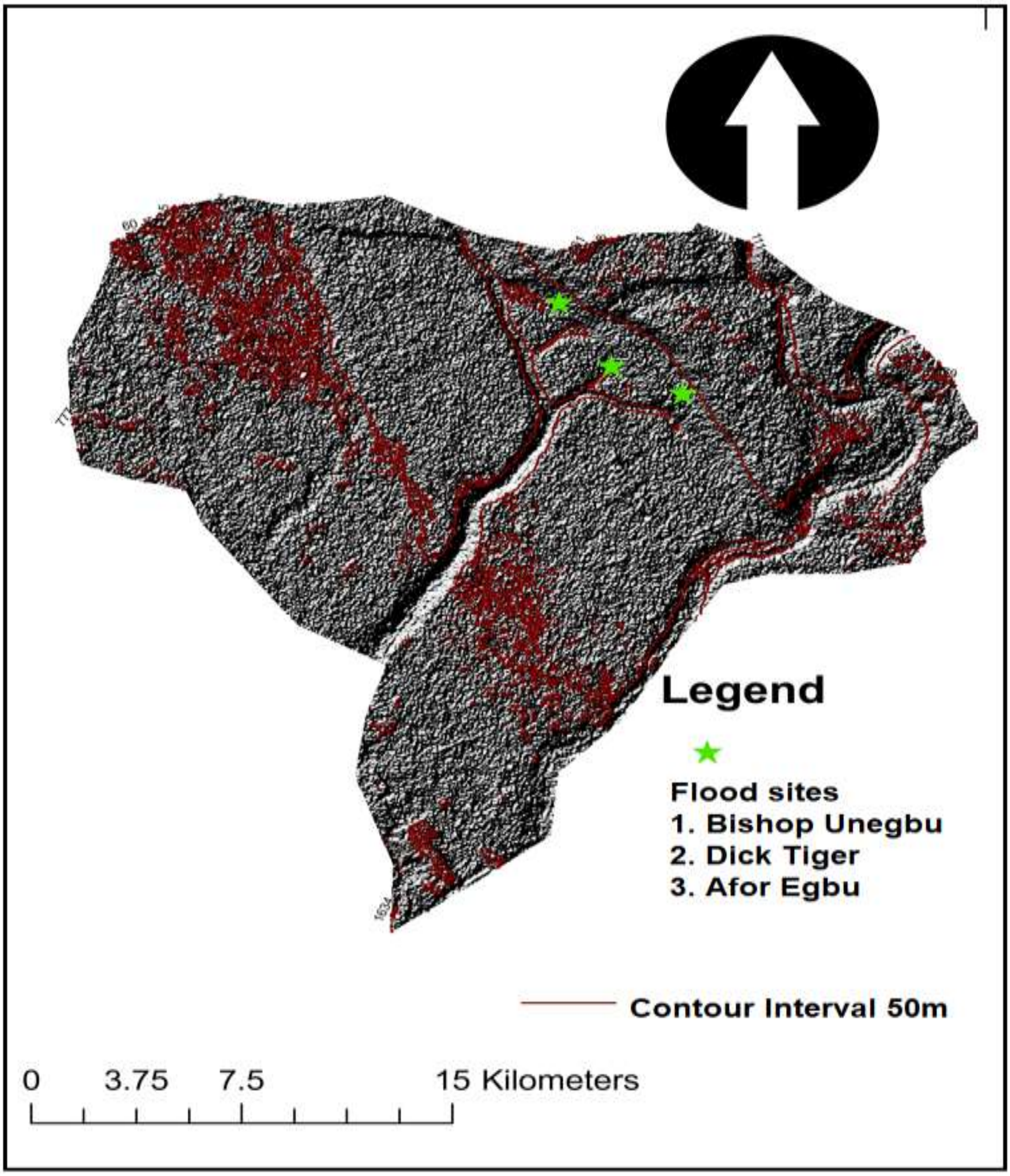

Figure 6: Displayed flood points on the contour and hill-shade maps of the study area with contour interval of 50m

DISCUSSION

The analysis of topographical contributions to flooding in Owerri Urban, Imo State, using GIS and remote sensing techniques, has revealed significant insights into the relationship between the city's physical landscape and its susceptibility to flood events. The findings from the study highlight the critical role that topography plays in influencing flood patterns, with particular emphasis on slope, hillshade, aspect, and contour features.

Topographical Influence on Flooding

The slope analysis demonstrated that areas with a slope gradient between 0° and 40° are predominantly flat or gently sloping and are highly susceptible to water accumulation and flooding. This is consistent with previous studies (Iro, 2021; Qing-quan et al., 2001), which indicate that flat lands or areas with minimal slope are more prone to flooding due to slower runoff and higher infiltration rates. The identification of flood-prone areas at the base of slopes where the elevation is low further underscores the influence of topography on flood risk in Owerri. The hillshade analysis, which provides a visual representation of relief based on elevation variations, confirmed that flood-inundated sites in Owerri are located predominantly in flat areas. This finding is crucial for urban planners and disaster management authorities, as it identifies specific regions where flood mitigation efforts should be concentrated. The aspect analysis, which examined the orientation of slopes to flood occurrences, revealed that flat surfaces and slopes facing from North to North-west are slightly more predominant in the study area. This aspect orientation contributes to the spatial distribution of flood-prone zones, as slopes facing these directions may receive more runoff, leading to localized flooding. Finally, the contour map analysis provided a comprehensive view of the elevation differences across Owerri Urban. The study found that areas where contours indicate higher elevation are the primary sources of runoff, which then accumulates in lower-lying flood plains. This pattern of runoff generation and accumulation aligns with the observed flooding in specific areas such as parts of Egbu, Trans Egbu, and Amakohia, as well as along the banks of the Nworie and Otamiri Rivers.

Conclusion

In contemporary times, the pace of climatic change and rapid urbanization creates a complex Eco- system and puts trust on policymakers concerned with resource management. Therefore, modern techniques that produce accurate results must be used in the management and conservation of natural resources if millennium development goals must be met and sustained. Remote sensing and GIS have proven to be reliable in capturing and management of large volume of data in geographic space. In this study remote sensing and GIS has been combined for the Analysis of Topographical contribution of flooding in Owerri Urban Imo State. Basic quantitative attributes of the Owerri Urban such as drainage density, stream frequency, form factor, circulatory ratio, elongation ratio bifurcation ratio relief ratio, etc. have been mapped in GIS environment in order to understand the topographical, hydrographical and geological processed within the Owerri Urban. The aspect map of the study area was classified into ten classes, defined as: flat, N, NE, E, SE, S, SW, W, N,W. On this basis, the aspect classes of Owerri highlight a fairly homogeneous distribution. Slopes facing from North to North-west slightly predominate when compared with South, South-east and south-west while the value of -1 is used to identify flat surfaces such as flood plains, fluvial terraces, river courses and hill plains. All the flood-inundated areas of the study area were located on areas with value of -1 which represent a flat area as can be observed from the overlaid flood-inundated points. These areas include flood plains, and areas liable to flooding which include parts of Egbu, Trans Egbu, Amakohia, river Nworie and Otamiri Rivers etc.

Recommendations

To effectively address the issue of urban flooding in Owerri, the following measures are recommended, specifically directed towards the Ministry of Environment and Urban Planning, as well as relevant agencies like Urban Planners and the Nigeria Environment Study Team and Civil Engineers: There is an urgent need for construction of a network of underground and open drainage channels to empty the flood into Otamiri and Nworie Rivers. The network should incorporate primary drainage collectors originating from streets as phase (1) drainage channels. These phase 1 channels could be surface U-shape channels but covered with concrete slabs. These primary channels will empty into secondary underground channels phase (2) located in the urban roads. These secondary channels will finally empty into a tertiary (mega) underground drainage channel Phase (3) long established at the urban centre through Okigwe Road circle to Bank Road and into the receiving axis of Nworie River.

1. The Urban planners should incorporate a combined drainage and flood risk map (Figures 4 and 5) as a guide to help in site inspection and plan approval for construction of new buildings. As this would help to determine areas that should be avoided in the location of buildings for specific land use purposes.
2. There is need to make and enforce laws on urban cementation: For example, $\geq$ 30% percentage of a plot of land should be reserved for natural infiltration when building a house by Urban planners. This should be specified and maintained within an urban setting. Provision of retention basins, rain gardens, lawns, and low impact development structures must be encouraged to minimize flooding in Owerri.

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