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Assessing the Impact of Relief on Dick Tiger Flooding in Owerri Municipal Using GIS and Remote Sensing Techniques

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Abstract: Flooding in urban areas is a recurring environmental challenge, particularly in rapidly developing regions like Owerri Urban. This study assesses the impact of relief on flooding in the Dick Tiger area of Owerri, employing Remote Sensing and GIS techniques. The research aims to model how topographical features, including elevation and slope, contribute to flood risk in this area, which is frequently inundated during heavy rainfall. Digital Elevation Models (DEMs) were used to analyze the terrain, identifying low-lying areas prone to water accumulation. The findings highlight the significance of relief as a critical factor in flood occurrence, with certain slopes and elevation levels correlating strongly with increased flood risk. The study provides a clear visualization of flood-prone zones by overlaying flood data with topographical maps. The research also explores the implications for urban planning, emphasizing the need for incorporating topographical analysis in flood management strategies. This approach could significantly reduce the vulnerability of the Dick Tiger area to flooding. The study's novel application of Remote Sensing and GIS technology in assessing the topographical contributions to urban flooding represents a significant advancement in flood risk management. It also underscores the importance of integrating scientific data into urban planning processes to build more resilient cities. This research serves as a foundational step towards developing more effective flood mitigation strategies in Owerri Urban, with broader applicability to other flood-prone urban centers in Nigeria.

Keywords: Remote Sensing, Flooding, techniques, developing, topographical analysis.

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Background

Many studies have investigated the anthropogenic factors contributing to flooding in Owerri Urban, including those by Iro (2015) and Anyadiegwu et al. (2021). However, this research uniquely focuses on analyzing the physical factors driving flooding in Owerri Urban using remote sensing techniques—an innovative approach in flood research and management within this region. Owerri is experiencing rapid growth in both human and animal populations, alongside an expanding built environment, which has led to a significant increase in paved surfaces. Flooding, resulting in the loss of lives and property, is becoming an increasingly common annual occurrence in Nigeria (Njoku et al., 2017). A combination of natural and human-induced factors including heavy rainfall, favorable relief, soil, and topographic conditions, a growing human population, poor waste management practices, and deep, narrow river valleys makes the country highly susceptible to flood hazards and disasters (Idah et al., 2008).

As noted by Ibe et al. (2002), flooding has led to the loss of numerous lives and properties worth millions of Naira, both directly and indirectly. In many urban areas across the country, particularly in eastern Nigeria, factors such as population growth, landscaping, increased paved surfaces, stream and channel blockages due to poor waste disposal practices, and other human activities around floodplains are considered major contributors to flooding (Iro and Ezedike, 2020). Additionally, the encroachment of flood-prone areas by human settlements and infrastructural developments has heightened the exposure of these regions to flood risks. Impervious surfaces, which result from urban development and include roads, walkways, buildings, and rooftops, are significant contributors to runoff and reduced infiltration. The expansion of impervious surfaces increases vulnerability and enlarges flood-prone areas.

Statement of the Problem

Flooding is a recurrent issue in Owerri Urban, resulting in significant damage to property and loss of lives. While previous studies have focused on the anthropogenic factors contributing to this problem, such as poor waste disposal and urbanization, there has been limited exploration of the physical and topographical factors driving these floods. The Dick Tiger area of Owerri Municipal Figure 1, a region prone to severe flooding, exemplifies the urgent need for a comprehensive analysis of the topographical contributions to flood risk. This research aims to fill this gap by utilizing advanced GIS and Remote Sensing techniques to assess how the relief and topography of the area influence flood patterns. By focusing on the physical terrain such as slope gradients, elevation, contour, and curvature, this study provides a clearer understanding of the underlying topographical factors that exacerbate flooding in Owerri Urban. The findings from this research will not only enhance flood prediction models but also guide urban planning and flood management strategies, ultimately contributing to the mitigation of flood-related disasters in the region.

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Study Area

Figure 1: Google Earth imagery of the site of Dick Tiger flood

Materials and Methods

SRTM (DEM) for Topographical Outlook of the Study Area

SRTM (USGS DEM) image was utilized to obtain the topography's structure and contribution to flooding in the research area. This study made use of recently made public 30m X 30m SRTM data for the research area, which was obtained from the Shuttle Radar Topography Mission Dataset Figure (Iro 2020). This dataset was chosen to provide a recent topographical perspective of the research area to facilitate qualitative and quantitative topographic analysis. The DEM was downloaded and cropped to the area of interest (1.5 X 1.5 Km) around the flooding site Figure 2. The low elevation is 23 metres, and the high elevation is 206 metres. The hill shade, slope gradient, slope aspect, and area contour are all included in the elevation data from the study area. Topography is one of the most significant variables affecting flooding (Iro and Acholonu, 2020). Geographic information systems (GIS) frequently use digital elevation models (DEMs) to depict topography and extract topographical and hydrological features for a variety of purposes, such as studying floods and their effects (Iro 2020). Studies employ a digital elevation model (DEM) to determine the topographical characteristics of a research area since the topography is a key surface characteristic in flood modelling (Iro, 2021).

Surface runoff, the hydrologic cycle phase most closely related to runoff, is influenced by topography in the landscape and must be thoroughly and effectively analysed throughout its full range. Digital elevation models (DEMs) are used to achieve this (Oliveira, 2013). The studies created using a DEM enable: flat geometric projection of the model. Greyscale images, shaded images, themed images, profile studies, and the production of derivative maps for analysis, including steepness and exposure maps, drainage maps, contour maps, slope maps, and aspect maps, were all done from the Owerri DEM. The Owerri North DEM was used to generate elevation points, which is extremely significant.

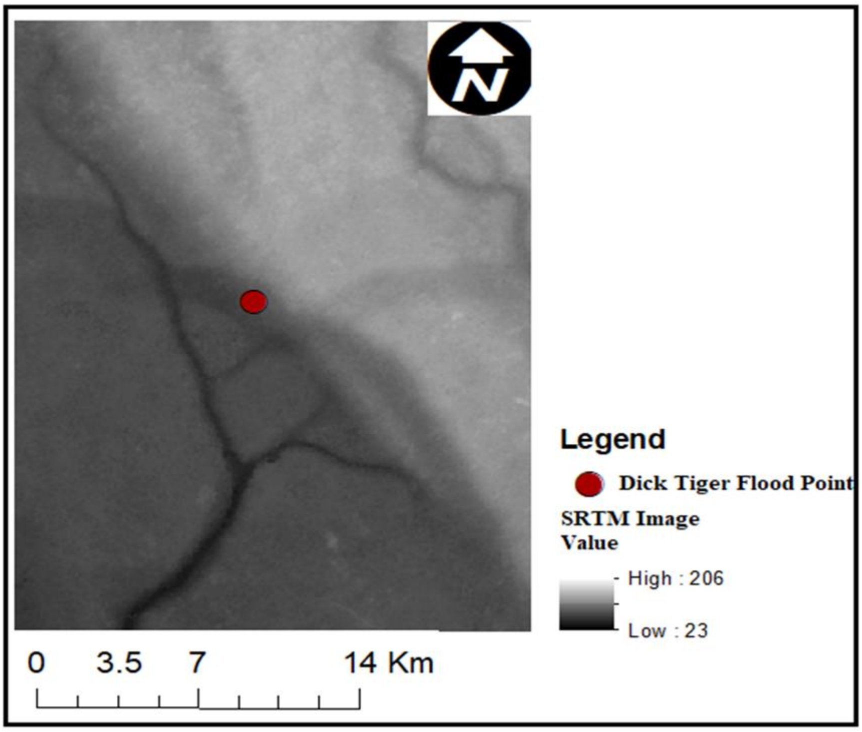

Figure 2: An SRTM Elevation image of the study area, cropped to Area of Interest 1.5 X 1.5 Km^2 (USGS)

Result Analysis and Presentation

Slope

The gradient of the slope is one of the key factors causing floods, (Qing-quan et al. 2001). By demonstrating that the flood spots that are being examined are at the base of slopes that range from 0^0 to 20^0 and 21^0 to 40^0. The significance of the slope is further emphasized in Figure 3 (Iro, 2021). According to Iro (2020), the Dick Tiger flood-inundated area is on level ground, surrounded by high areas, although land on steep inclines is more vulnerable to water runoff. The location of the flooding as depicted from the slope map shows its on the slope range of 0^0 to 20^0 and areas around it are high from 21^0 and above.

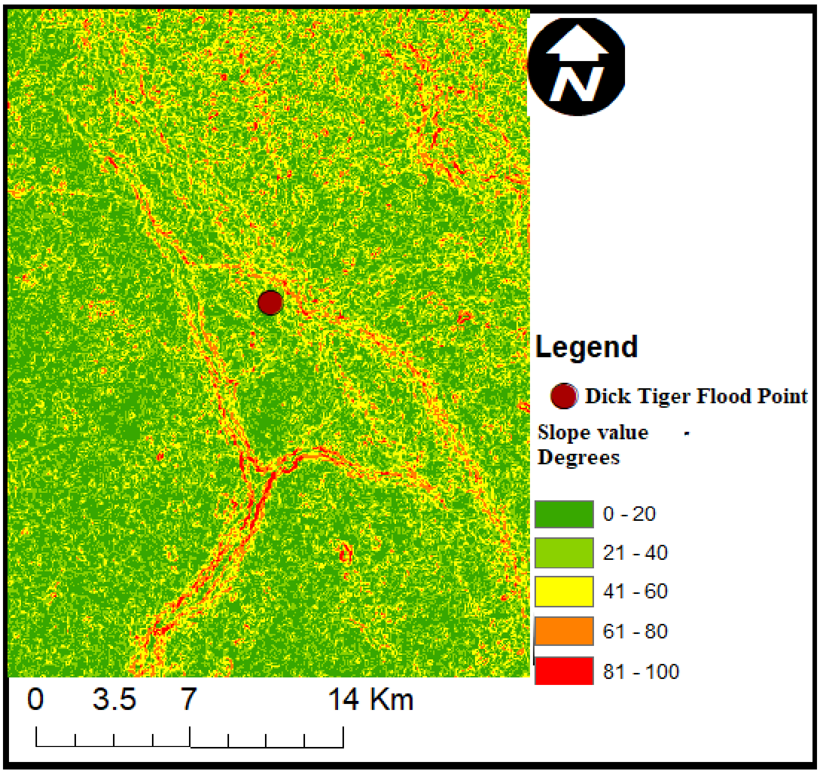

Figure 3: Maximum slope map of the study area shown as a degree gradient (flat areas have 0 – 40, 41 - 60^0 gentle slope, and 61^0 and greater or higher).

Slope Aspect

Additional topographic investigation was carried out by examining the slope aspect. Ten classes were identified from the study area's aspect map Figure 4***:*** flat, N, NE, E, SE, S, SW, W, and NW. Based on this, Owerri North's aspect classes show a rather uniform distribution. When compared to south, south-east, and south-west, slopes facing north to north-west somewhat prevail; flat surfaces such as flood plains, fluvial terraces, river courses, and hill plains are identified by a value of -1. The places with a value of -1, or flat area, are where the flood plains are situated including the Dick Tiger flood but can be viewed properly in GIS/Remote Sensing software.

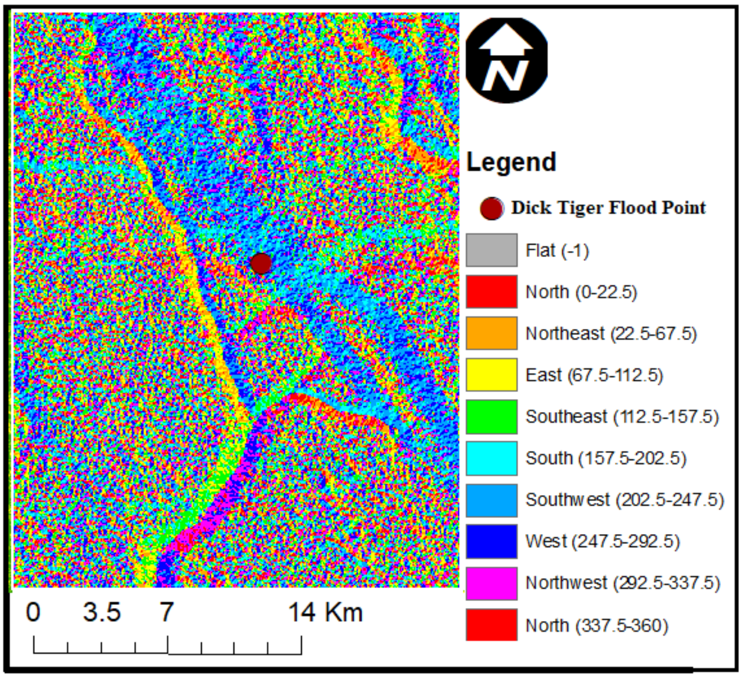

Figure 4: Slope Aspect map: Flat (-1), N (0 -22.5), NE (22.5 – 67.5), E (67.5 – 112.5), SE (112.5 – 157.5), S (157.5 – 202.5), SW (202.5 – 247.5), W (247.5 – 292.5), NW (292.5 – 337.5 and N (337.5 - 360)

Slope Plan Curvature

The curvature is very important in understanding how run-off flows in the study area, which influences flooding. The low values of -1 (x10^6) of plan curvatures define convexity; while high values of 1 (x10^6) plan curvatures characterize concavity of slope curvature. Values of plan curvatures around zero indicate that the surface is flat. The curvature data from across the study region is shown in *Figure 5****.*** As depicted from the figure, the flood site is located on flat area with convexity plan curvature around it which shows that run off flows from different direction to the flood site

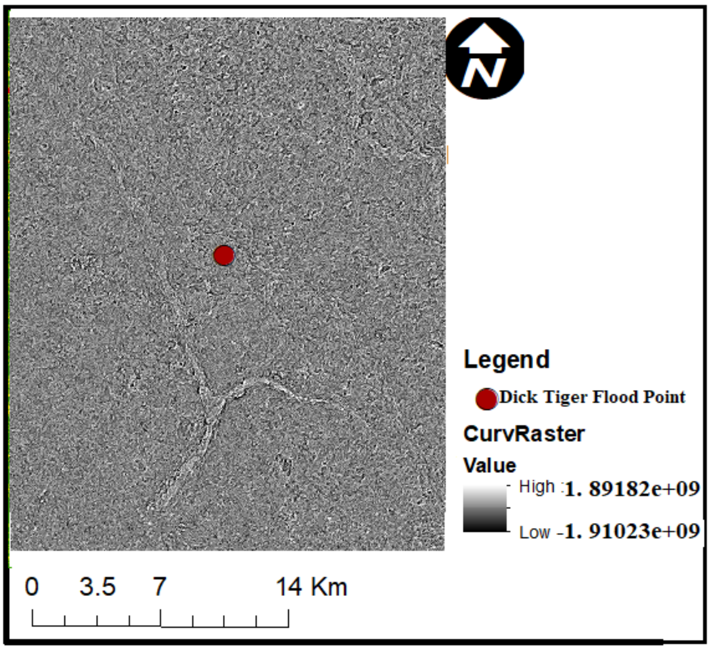

Figure 5: Curvature of the slope of the study area; The low values of -1 (x10^6) of plan curvatures define convexity; while high values of 1 (x10^6) plan curvatures characterize concavity of slope curvature

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 point are higher ground above 60m than the areas where the flood-inundated areas are located that are below 10m. The contour map reveals that areas where the contours are higher 60m and above are areas where the highest runoff is generated to form flood at the flat area (0m - 20m).

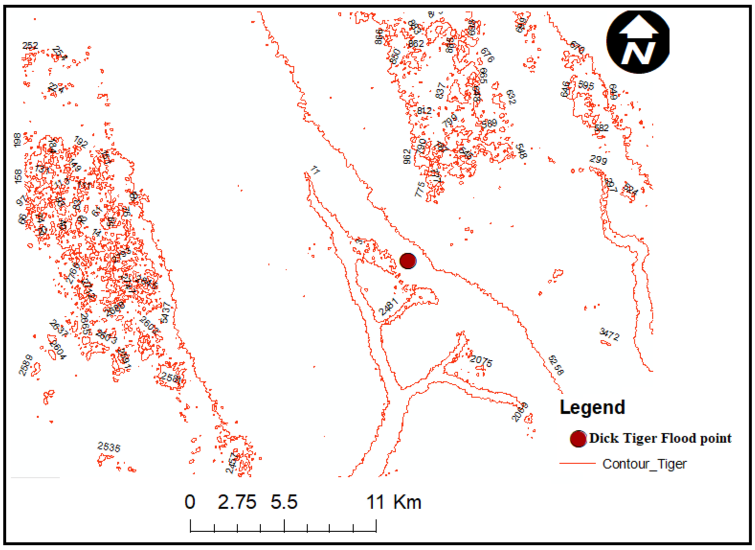

Figure 6: The Dick Tiger Flood point overlayed on the contour map

Discussion

The analysis of the topographical contributions to flooding in the Dick Tiger area of Owerri Municipal reveals significant insights into the flood dynamics of this region. The study successfully mapped the topographical features and their impact on flooding by utilizing Remote Sensing techniques and Digital Elevation Models (DEM). This section discusses the key findings, implications, and limitations of the study, as well as suggestions for future research. The study highlights that the low elevation areas, particularly those between 0 to 20 meters, are the most susceptible to flooding. These areas are surrounded by higher elevations ranging from 60 meters to above, contributing to the runoff and eventual flooding in the low-lying regions. The topographical analysis shows that the slope gradients and aspect play a crucial role in directing the runoff towards the flood-prone areas. The slope gradient analysis indicates that the flood-prone areas are primarily located at the base of slopes ranging from 0 to 20 degrees. The higher slopes, exceeding 21 degrees, are less affected directly but contribute significantly to runoff. The flat areas within this slope range are more vulnerable due to their inability to facilitate quick drainage of excess water.

The curvature analysis further elucidates the runoff dynamics, showing that the flood sites are in flat areas with convexity plan curvature surrounding them. This indicates that runoff from higher elevations flows into these flat areas, exacerbating the flooding situation. The presence of convex curvatures also signifies areas of water accumulation, contributing to prolonged waterlogging during heavy rains. The contour map generated from the DEM data provides a clear visualization of the elevation differences across the study area. The higher contours (above 60 meters) around the flood-prone areas create a natural pathway for water to flow downwards into the lower elevations (0 to 20 meters), leading to the observed flooding. This contour analysis is critical in understanding the spatial distribution of flood risk areas.

Implications

The findings of this study have several important implications:

Urban Planning and Flood Management: Understanding the topographical influence on flooding can aid urban planners in designing more effective flood management systems. By identifying high-risk areas, mitigation strategies such as improved drainage systems, construction of levees, and strategic land use planning can be implemented to reduce flood risk.

Early Warning Systems: The topographical data can be integrated into early warning systems to predict potential flood events based on rainfall patterns and runoff predictions. This proactive approach can help in timely evacuation and preparation, minimizing the impact on residents.

Environmental Conservation: The study underscores the importance of maintaining natural topographies and vegetation that can aid in natural water absorption and reduce runoff. Conservation efforts should focus on preserving these natural features to mitigate flooding.

Limitations

While the study provides valuable insights, it is not without limitations:

Data Resolution: The DEM data used, though detailed, may still have limitations in capturing micro-topographical variations that can influence flooding at a very local scale. Higher resolution data could provide more precise insights.

Temporal Variability: The study relies on static topographical data, which does not account for temporal changes such as land development, deforestation, and other anthropogenic activities that can alter flood dynamics over time.

Hydrological Factors: The study primarily focuses on topography, whereas other hydrological factors such as soil permeability, rainfall intensity, and existing drainage infrastructure also play critical roles in flooding, which were not extensively covered.

Summary

This study investigates the topographical contributions to flooding in the Dick Tiger area of Owerri Municipal using advanced Remote Sensing techniques and Digital Elevation Models (DEM). By mapping the elevation, slope gradient, plan curvature, and contour features of the region, the study identifies the areas most susceptible to flooding and elucidates the mechanisms driving these flood events. The analysis highlights that low-elevation areas (0 to 20 meters) surrounded by higher elevations (60 meters and above) are particularly vulnerable to flooding due to the runoff from these higher areas. The study also underscores the significance of slope gradients and curvature in influencing water flow and accumulation, which are critical factors in the flooding dynamics of the region.

Conclusion

The research reveals that the topography of the Dick Tiger area significantly influences its flood vulnerability. The low-lying regions, characterized by flat slopes and surrounded by higher elevations, are prone to water accumulation and flooding during heavy rains. The contour and curvature analyses further demonstrate how runoff from higher elevations contributes to the flooding in these lower areas. These findings provide essential insights for understanding the spatial distribution of flood risks in the study area, highlighting the need for targeted flood management and mitigation strategies.

Recommendations

Based on the findings of this study, several recommendations are proposed to mitigate the flooding issues in the Dick Tiger area:

Enhanced Urban Planning:

Urban planners should integrate topographical data into the planning and development process to identify high-risk flood areas and design appropriate mitigation measures. This includes the construction of effective drainage systems, levees, and the strategic placement of green spaces to absorb excess water.

Improved Drainage Infrastructure:

Investment in modern and efficient drainage infrastructure is crucial. Ensuring that drainage systems are regularly maintained and capable of handling large volumes of water can significantly reduce the impact of flooding.

Early Warning Systems:

Develop and implement early warning systems that utilize topographical and meteorological data to predict potential flood events. These systems should provide timely alerts to residents and authorities, enabling proactive measures and reducing the risk to life and property.

Community Engagement and Education:

Engage the local community in flood risk management through education and awareness programs. Informing residents about the risks and teaching them how to respond during flood events can enhance community resilience.

Environmental Conservation:

Promote the conservation of natural topographical features and vegetation that aid in water absorption and reduce runoff. Protecting and restoring natural landscapes can play a significant role in mitigating flood risks.

Future Research

Future research should aim to address these limitations by incorporating higher resolution DEM data and integrating temporal analyses to capture the dynamic nature of flood-prone areas. Additionally, a comprehensive study that includes hydrological and meteorological data will provide a more holistic understanding of flood risks. Investigating the impact of climate change on rainfall patterns and its subsequent effect on flooding in the study area will also be crucial for long-term flood management planning.

In conclusion, this study provides a foundational understanding of the topographical contributions to flooding in the Dick Tiger area of Owerri Municipal. The insights gained can significantly aid in flood risk management and urban planning, ultimately contributing to the resilience of the community against flooding disasters

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