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Urban Flood Susceptibility Mapping Using Multi-Criterion Decision Analysis (MCDA)

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Abstract

Throughout the world, floods gravely affect people's lives and property. Recently, humans have been susceptible to a growing number of natural hazards, the most severe and frequent of which is flooding. In this study, we assessed the modeling capabilities of four Multi-Criteria Decision-Making (MCDM) analysis techniques. This study aims to prepare flood hazard risk zone maps of Hyderabad District based on the MCDM-AHP method and RS-GIS tools. Various parameters like physiographic, climatic, LULC, and pedological were used, and thematic maps were prepared from various sources, which were integrated into the ArcGIS 10.8 software to identify the flood hazard zone based on the weighted overlay method. Each parameter has been given a relative weightage depending on its significance, and a sub-class of each parameter was given a ranking from 0 to 5. The resultant flood risk map is classified into low, moderate, and high-flood risk zones, and the result was verified further using past flood events that occurred in the area. This study can be useful to the planners and local authorities in developing flood prevention and mitigation strategies in Ado-Ekiti and Environs

Keywords: Flood susceptibility; Analytic Hierarchy Process; Multi-Criterion Decision Analysis; Geospatial Analytics, Ado-Ekiti

Introduction

Flooding is one of the most damaging natural disasters worldwide, causing significant financial losses and threatening infrastructure and human lives (Msabi & Makonyo, 2021). Due to its location, climate, and land use, Ado-Ekiti, a rapidly growing city in Nigeria, is vulnerable to flooding (Ogundele & Jegede, 2011). Despite various mitigation efforts, the city still frequently experiences flooding, emphasizing the need for effective flood risk management policies (Nkwunonwo et al., 2016). Identifying vulnerable areas through flood susceptibility mapping is essential for improving preparedness and resilience against flood risks. Such mapping helps pinpoint flood-prone zones, which is a key step in enhancing community resilience to flood hazards (Albano et al., 2018; Lin et al., 2019). Floods are a common natural disaster that pose

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serious risks to communities, infrastructure, and the environment. Ado-Ekiti, the capital of Ekiti State in Nigeria (Hamsat, 2021), has experienced numerous flooding events, causing property damage, deaths, and disruption of livelihoods. Flooding is a recurrent problem in Ado Ekiti, Nigeria, causing damage to property, infrastructure, and disrupting livelihoods (Aladelokun & Ajayi, 2014). To mitigate these impacts, creating accurate flood susceptibility maps is crucial for disaster preparedness and land-use planning (Adedeji et al., 2012). Overall, studying flooding is essential for addressing the multifaceted challenges posed by natural hazards, climate change, and human activities. It enables informed decision-making, promotes sustainable development, and enhances resilience in the face of uncertain and dynamic environmental conditions (Kausar & Smith, 2023). By addressing these challenges, MCDA can provide a robust and data-driven approach to flood susceptibility mapping in Ado Ekiti, empowering stakeholders to make informed decisions for flood risk reduction. This study aims to determine the areas susceptible to flooding within Ado-Ekiti and Environs, using Geospatial Analytics. The scope of the study is designed to provide a comprehensive understanding of flood susceptibility in Ado Ekiti, enabling effective flood risk management and urban planning strategies. (Olufemi et al., 2018)**.** What are the long-term impacts of anthropogenic interventions, such as dam construction and urbanization, on the frequency and severity of flash floods in urban areas? This research question delves into the complex relationship between human activities and the occurrence of flash floods, aiming to understand how human interventions in natural water systems contribute to the increased risk of flooding in urban environments. It could involve interdisciplinary approaches, including hydrology, urban planning, climatology, and environmental science, to assess historical trends, model future scenarios, and develop strategies for mitigating flood risks in urban settings.

Literature Review

This section explores the basic concepts of floods, flooding, and methods used to analyze and measure flooding (Flood & Carson, 2013). Generally, flooding refers to the process of artificially flooding land with water (Shen et al., 2019). This is often done for various purposes, such as creating reservoirs, flood control, irrigation, or environmental restoration. Flooding can also be used in hydrographic surveys to measure water depth or to study how water bodies behave under

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different conditions. It is an important technique in both civil engineering and environmental science for managing water resources effectively and understanding aquatic ecosystems (Council, 1992). Understanding these different types of flooding is crucial for surveyors and engineers involved in water resource management, disaster risk reduction, and infrastructure development. By considering the characteristics and dynamics of each type of flooding, professionals can create effective strategies to reduce risks and leverage the benefits of flooding in surveying and related fields (Wilby & Keenan, 2012). Flash floods are rapid and unexpected inundations of water, typically caused by intense rainfall over a short period or by the sudden release of water from a dam or levee. Surveyors need to consider flash flooding risks when planning infrastructure projects and designing flood control measures to ensure resilience against sudden inundation events. Riverine flooding occurs when rivers overflow their banks, inundating adjacent floodplains and low-lying areas. It is often influenced by factors such as heavy rainfall, snowmelt, or upstream dam releases. Natural Flooding occurs due to natural processes such as heavy rainfall, snowmelt, or storm surges. Natural floods can cause significant damage to property, infrastructure, and ecosystems, making them a concern for surveyors and engineers involved in disaster risk management and mitigation (Van Westen, 2013). Artificial Flooding, known as controlled flooding, this type involves deliberately inundating a particular area with water for various purposes such as reservoir creation, flood control, irrigation, or environmental restoration. Artificial flooding is carefully managed to minimize adverse impacts and maximize benefits, making it an essential tool in water resource management and environmental conservation (Loucks et al., 2017). Coastal flooding occurs when seawater inundates coastal areas, often due to factors such as storm surges, high tides, or sea level rise. Coastal flooding poses significant challenges for surveyors and coastal engineers in designing resilient coastal infrastructure and managing coastal resources sustainably. This study introduces the application of Multiple-Criteria Decision Analysis (MCDA) for flood susceptibility mapping in Ado Ekiti. Traditional methods often struggle to account for the complex interplay of factors that influence flooding. MCDA offers a powerful framework to address this challenge. MCDA allows us to integrate various physical, land-cover, and human-induced factors that contribute to flood susceptibility in Ado Ekiti. These factors might include rainfall patterns, topography, soil type, vegetation cover, and drainage infrastructure. Not all factors influencing floods hold equal weight. MCDA enables us to assign weights to each factor based on its relative importance in causing floods within the specific context of Ado Ekiti (OYEDELE, 2017). This project will utilize MCDA to create a flood susceptibility map for Ado Ekiti. Here's a glimpse of the process: First, identifying flood-influencing factors, this was carried out by collaborating with experts and analyzing historical data to pinpoint the key factors that lead to flooding in Ado Ekiti (Burby et al., 2000). Second, weighing the factors using expert input and data analysis, we'll assign weights to each factor, indicating their relative importance in causing floods (Thomas et al., 2016). Third, choosing an MCDA Method: We'll select an appropriate MCDA approach, such as the Analytical Hierarchy Process (AHP), to combine the weighted factors and produce a susceptibility map (Otuoze, 2021). This MCDA-based flood susceptibility mapping project holds the potential to significantly improve flood risk management in Ado Ekiti, fostering a safer and more resilient future for its residents. A literature review of flood susceptibility mapping using GIS-AHP multi-criteria analysis for Ado-Ekiti would involve examining existing research, studies, and publications related to this topic. It would include summarizing key findings, methodologies, data sources, and limitations of previous studies. Additionally, it may discuss the relevance of GIS (Geographic Information System) and AHP (Analytic Hierarchy Process) in assessing flood susceptibility, as well as the specific challenges and opportunities in the context of Ado-Ekiti. This review serves as a foundation for understanding the current state of knowledge, identifying gaps in research, and guiding future investigations in flood risk management for the area.

Methodology

Study Area

Ado-Ekiti is the capital city of Ekiti State in southwestern Nigeria, characterized by its hilly terrain, tropical climate, and rapid urbanization. The city is prone to flooding due to its location within the drainage basin of the Osse River and the presence of informal settlements in low-lying areas. The study area encompasses urban neighborhoods, peri-urban zones, and surrounding rural areas affected by flood hazards.

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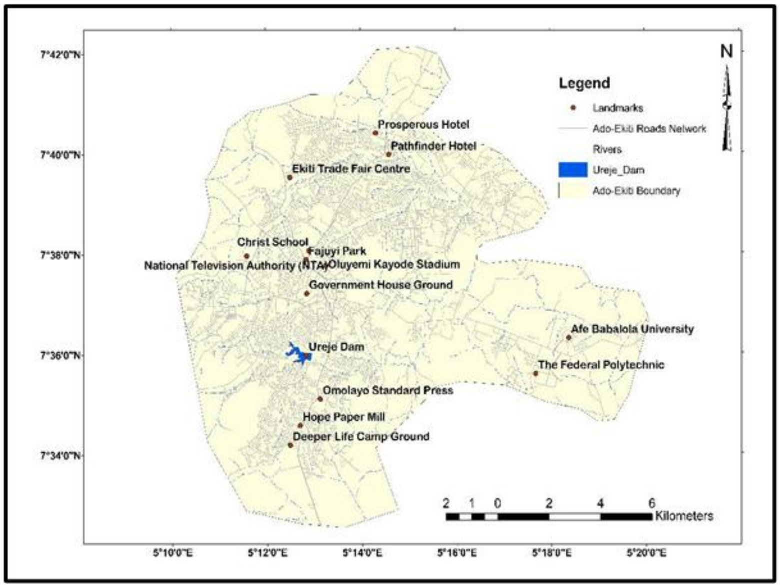

Figure 1: Map of the Study Area

Methods

For this study, preparation of various thematic maps, such as elevation, slope, drainage density, annual rainfall, flow accumulation, distance to drainage network, aspect, NDVI, LULC, and soil types, was conducted for the generation of a flood hazard map. Arc GIS 10.8. Software tools were used to generate thematic maps. The Landsat 9 OLR image of 2020 was used to produce the land use/land cover map (LULC) and the normalised differential vegetation index (NDVI) map. Landsat 9, with a spatial resolution of 30 m, was downloaded from the USGS website, where the path/row number is 54/190 and the date of acquisition was 2018. A land use and land cover (LULC) map was produced by using a supervised classification technique using the maximum likelihood classification (MLC) algorithm. The elevation, slope, drainage density, flow accumulation, distance to drainage network, and aspect were prepared from the Shuttle Radar Topographic Mission (SRTM) digital elevation model (DEM) image. The SRTM DEM with a spatial resolution of 90 m was also obtained from the USGS website (https://earthexplorer.usgs.gov). The rainfall map was generated with the ArcGIS 10.8 Spatial Analyst software process. The rainfall data was used to prepare the rainfall map. The soil data was downloaded from the soil grids website (https://soilgrids.org/), and the map was prepared using

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ArcGIS 10.8 software. This study will use the MCDA-AHP approach combined with geospatial techniques for mapping the flood susceptibility zone in Ado-Ekiti and Environs, as well as the use of the Weighted Overlay Analysis (WOA) and Analytical Hierarchy Process (AHP) methodologies. The methodology used in the study involves the following steps: Collection of data on parameters such as elevation, slope, drainage density, flow accumulation, soil type, annual rainfall, aspect, distance to drainage network, land use/cover, and NDVI. Analysis of data using ArcGIS software, including the use of SRTM DEM dataset for slope map, drainage network for drainage density map, Landsat 9 imagery for land use/land cover, and NDVI index for vegetation cover data. Categorization and ranking of the analyzed data based on their influence on flood susceptibility. Preparation of a flood susceptibility zone map using the weighted overlay index (WOI) approach with ranking on a GIS platform. The flood susceptibility analysis was carried out using ten individual parameters, namely landforms, LULC, slope, elevation, soil texture, soil drainage, lithology, Topographic Wetness Index (TWI), distance from the river, and surface runoff. Table 1 shows the data products used for this entire study. Preparation of the geodatabase and the integration of these layers were done using ArcGIS 10.8 Software. The landform and LULC maps prepared by a visual interpretation method using Google Earth imagery (2018) and National Remote Sensing Centre (NRSC) classification (level 2 classification for LULC) were adopted for this Interpretation. The elevation and slope are key parameters for flood susceptibility mapping, and variations in elevation influence climate characteristics (Samanta et al., 2012). The slope of the area can control the surface runoff (Adiat et al., 2012) and also vertical percolation (Youssef et al.,2011). The elevation and slope map was prepared using globally available Shuttle Radar Topographic Mission (SRTM) Digital Elevation data (Jena et al. 2016) in the ArcGIS spatial analysis tool.

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Table 1 Data sets used for flood susceptibility mapping

S. no.	Data description	Purpose	Year	Source	Resolution/ Scale
1	Google earth imagery	Landform and Lu/Lc	2018	Q-GIS software	0.3 m
2	SRTM DEM	Elevation, slope, TWI	2014	USGS (Earth Explorer)	30 m
3	Rainfall	Surface runoff	2004–2018	Public works Department (PWD)	–
4	Soil	Soil texture	1996	National Bureau of Soil Survey and Landuse Planning	1:500,000
5	Lithology	Lithology	1995	Geological Survey of India (GSI)	1:500,000
6	Historic flood locations	Frequency Ratio Model	Before 2018	News reports and satellite imagery of pre and post flood event	–

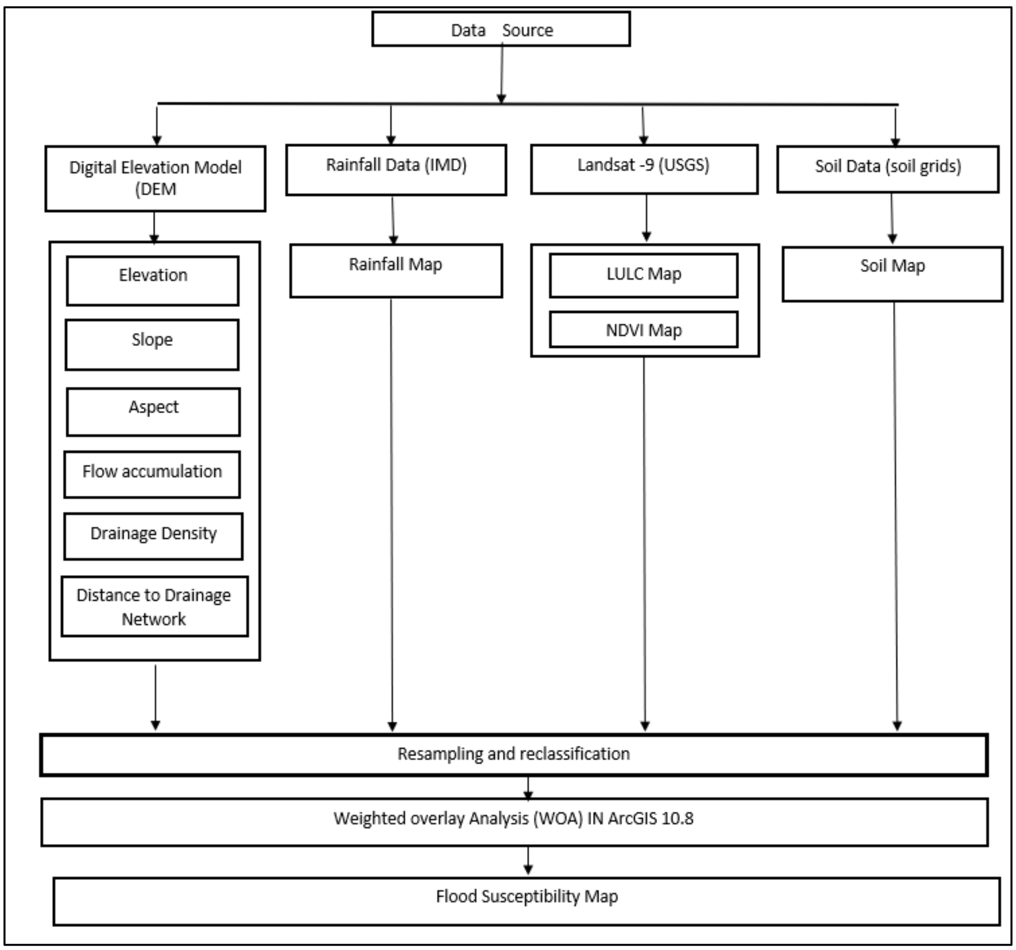

Figure 2: Methodological Flow Chart for the Study

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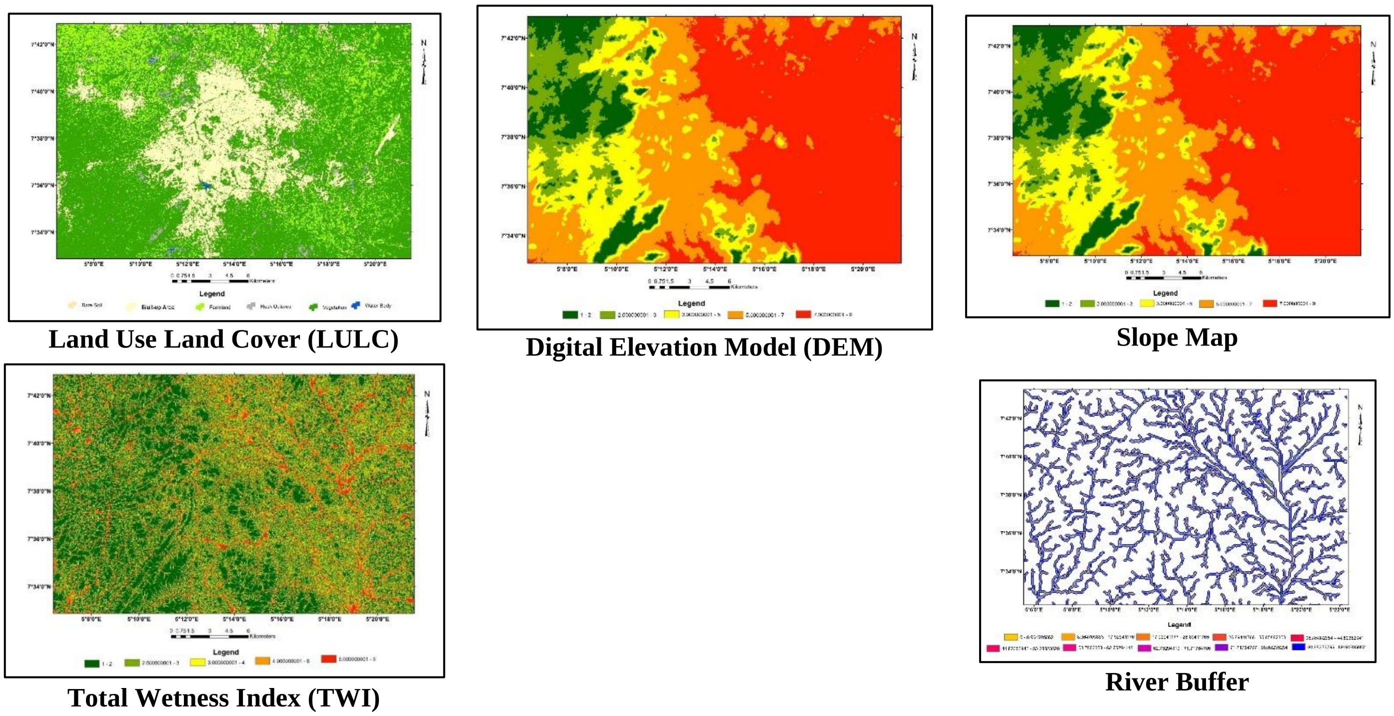

Figure 3: Various thematic Layer used for the final Susceptibility Map

Weighted overlay is a spatial analysis technique used in Geographic Information Systems (GIS) to combine multiple raster layers into a single output layer based on a set of criteria. Each layer represents a different factor influencing a particular outcome, such as flood susceptibility, land suitability, or environmental impact. Weighted overlay combines multiple raster layers, assigning weights to each layer based on its importance.

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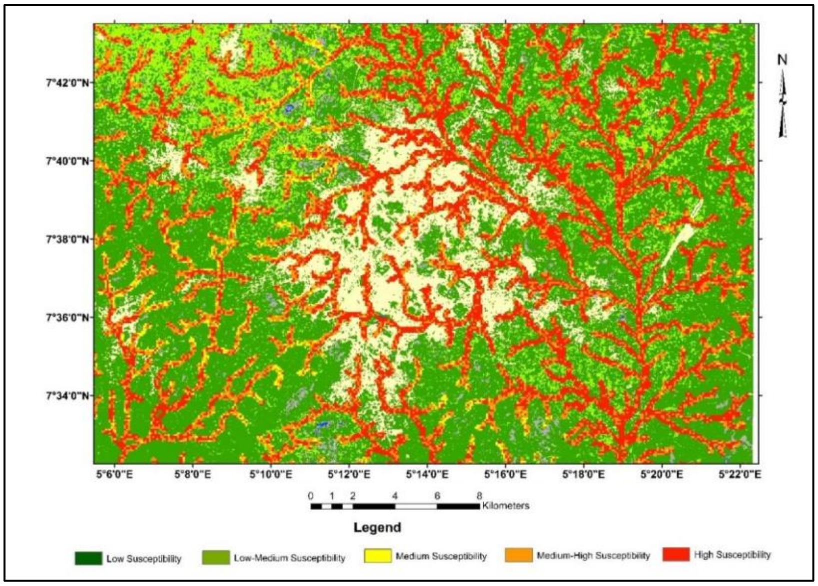

Figure 4 : Final Flood Susceptibility Map of Ado-Ekiti and Environs

Conclusion

In conclusion, Multi-Criteria Decision Analysis (MCDA) for flood mapping susceptibility has proven to be a successful technique for identifying and prioritizing flood-prone areas. Through the meticulous integration of several factors such as land use, hydrology, terrain, and socioeconomic conditions, we have developed a detailed understanding of the area's vulnerability to flooding. The results enable stakeholders to make educated decisions that enhance preparedness and resilience by highlighting the critical areas that require immediate attention and action. As climate change continues to increase the possibility of flooding, the analysis's findings will be essential in guiding strategic planning, resource allocation, and community engagement activities aimed at reducing the effects of future floods. Our ability to adapt to evolving challenges in flood risk management. Disaster preparedness and effective risk management require mapping flood susceptibility. Multi-Criteria Decision Analysis (MCDA) offers a robust framework for integrating multiple factors that influence flood risks, such as topography, land use, soil type, rainfall patterns, and historical flood data. Using MCDA, decision-makers can systematically evaluate and rank these factors based on their significance and relationships. Techniques like the Analytical Hierarchy Process (AHP), Weighted Sum Model (WSM), or Technique for Order of Preference by Similarity to Ideal

Solution (TOPSIS) can be used to measure and rank flood vulnerability in different locations. The outcome is a comprehensive flood susceptibility map that identifies regions at different risk levels, enabling more targeted interventions and allocation of resources. Since flooding is becoming more likely due to urbanization and climate change, I suggest mapping flood risk using Multi-Criteria Decision Analysis (MCDA). MCDA makes it possible to integrate a number of variables, such as topography, land use, rainfall patterns, and historical flood data, to enable a comprehensive assessment of flood dangers. This approach not only increases the accuracy of susceptibility models but also promotes stakeholder engagement by accounting for various goals and points of view. Using MCDA, decision-makers may prioritize measures, allocate resources wisely, and develop targeted plans to mitigate the effects of flooding, ultimately leading to more resilient communities. By integrating MCDA into flood risk assessment, a robust, data-driven framework for understanding and effectively managing flood hazards will be guaranteed.

REFERENCES

Adedeji, O. H., Odufuwa, B. O., & Adebayo, O. H. (2012). Building capabilities for flood disaster and hazard preparedness and risk reduction in Nigeria: need for spatial planning and land management. *Journal of Sustainable Development in Africa*, *14*(1), 45–58.

Aladelokun, A. O., & Ajayi, C. F. (2014). An appraisal of the socio-economic impacts of urban flood in Ado–Ekiti Metropolis in Ekiti State. *International Journal of Asian Social Science*, *4*(10), 1027–1034.

Albano, R., Sole, A., Adamowski, J., Perrone, A., & Inam, A. (2018). Using FloodRisk GIS freeware for uncertainty analysis of direct economic flood damages in Italy. *International Journal of Applied Earth Observation and Geoinformation*, *73*, 220–229.

Hamsat, K. A. (2021). *Effects of Environmental Education on Knowledge, Attitude, and Practices of Flood Disaster Prevention Among Residents in the Ibadan Metropolis, Nigeria*.

Kausar, S., & Smith, D. (2023). Strategic Decision-making in Turbulent Environments: A Case Study of Resilient Organizations. *Management Science Research Archives*, *1*(01), 8–17.

Lin, L., Wu, Z., & Liang, Q. (2019). Urban flood susceptibility analysis using a GIS-based multi-criteria analysis framework. *Natural Hazards*, *97*(2), 455–475.

Loucks, D. P., van Beek, E., Loucks, D. P., & van Beek, E. (2017). Water resources planning and management: An overview. *Water Resource Systems Planning and Management: An Introduction to Methods, Models, and Applications*, 1–49.

Msabi, M. M., & Makonyo, M. (2021). Flood susceptibility mapping using GIS and multi-criteria decision analysis: A case of Dodoma region, central Tanzania. *Remote Sensing Applications: Society and Environment*, *21*, 100445. https://doi.org/10.1016/j.rsase.2020.100445

Nkwunonwo, U. C., Whitworth, M., & Baily, B. (2016). A review and critical analysis of the efforts towards urban flood risk management in the Lagos region of Nigeria. *Natural Hazards and Earth System Sciences*, *16*(2), 349–369.

Ogundele, J. A., & Jegede, A. O. (2011). Environmental influences of flooding on urban growth and development of Ado-Ekiti, Nigeria. *Studies in Sociology of Science*, *2*(2), 89.

Olufemi, O.-F., Ambrose, A., & Pauline, A. (2018). The paradox of livelihood strategies and urban landscape degradation in contested spaces: towards attaining a sustainable green city in Ado-Ekiti, Nigeria. *International Journal of Development Research*, *8*(11), 24031–24040.

Otuoze, S. H. (2021). *Sustaining critical transport infrastructure space in megacities: multimodal assessment of railway and road systems in Kano & Lagos—Nigeria*. University of Birmingham.

OYEDELE, A. A. (2017). *INTEGRATED METHODS FOR DELINEATING GROUNDWATER RESOURCE IN ADO-EKITI, SOUTHWESTERN NIGERIA.*

Van Westen, C. J. (2013). Remote sensing and GIS for natural hazards assessment and disaster risk management. *Treatise on Geomorphology*, *3*(15), 259–298.