ESI Preprints **Not Peer-reviewed**

Geospatial Model for Flood Mitigation along the Coast of the River Niger in Lokoja, Kogi State, Nigeria

Ijaware Victor Ayodele
Department of Surveying and Geoinformatics, School of Environmental Technology, Federal University of Technology, Akure, Ondo State, Nigeria

Doi: 10.19044/esipreprint.10.2023.p308

Approved: 14 October 2023
Posted: 16 October 2023

Cite As:
Ijaware V.A. (2023). *Geospatial Model for Flood Mitigation along the Coast of the River Niger in Lokoja, Kogi State, Nigeria*. ESI Preprints.
https://doi.org/10.19044/esipreprint.10.2023.p308

Abstract

Flooding is a recurring natural disaster with the potential to cause widespread devastation to communities and their environments. This study focuses on the spatiotemporal analysis of flood risk and mitigation strategies in Lokoja, Nigeria, a region susceptible to recurrent flooding due to its location at the confluence of the Niger and Benue rivers. The research aims to provide valuable insights into understanding the dynamics of flooding in Lokoja, assessing its potential impact, and proposing mitigation measures. The study employs an interdisciplinary approach, utilizing Geographic Information Systems (GIS), Remote Sensing (RS), surveying, and statistical techniques to collect, analyze, and model data related to flooding. Data sources include Shuttle Radar Topography Mission (SRTM) imageries, satellite data, historical flood records, and climatic information. Findings reveal a nuanced understanding of flood risk, encompassing the spatial distribution of flooding along Niger River and the contributory factors, such as increasing annual rainfall and river overflow. Also, recent findings from the Federal Government's flood prediction report indicated that heavy rainfall and potential flooding may impact multiple towns in Nigeria, including those along the Niger River. This highlights the continued importance of proactive flood mitigation efforts, not only in Lokoja but also in various regions susceptible to flooding. The study offers predictive models to anticipate future flooding scenarios. In the light of these findings, this study underscores the significance of comprehensive flood risk assessment and mitigation strategies in Lokoja. The research not only aids in understanding the behavior of the Niger River during heavy rainfall but also provides critical information for developing flood management plans, constructing flood barriers, and enhancing the resilience of the community to flooding. Furthermore, it recommends innovative approaches to harness the recurring dam overflow from Cameroon by channeling the water to Sambisa Forest for agricultural purposes, constructing new turbines for excess electricity generation, and utilizing the water for irrigation during the annual dam release. This study serves as a valuable resource for policymakers, urban planners, and researchers seeking to address the challenges posed by the flooding across Nigeria.

Keywords: Flood mapping; Remote Sensing (RS); Spatiotemporal analysis

Introduction

Flooding is an escalating natural disaster, often devasting communities and their surroundings when water breaches its confines, inundating dry land (Shah et al., 2018). Combatting this menace requires multifaced approaches encompassing understanding the various types of flooding, their causes, and comprehensive mitigation strategies. Lokoja, Nigeria, finds itself in the crosshair of the recurrent flooding due to its strategic location at the confluence of the Niger and Benue rivers. Over the years, efforts have been made to address this issue, with a focus on mitigation, yet numerous challenges persist.

Recently, the Federal Government revealed an imminent threat of heavy rainfall which may induce flooding across 48 towns spanning 13 Nigerian states, these rising waters, stemming from the River Benue and River Niger, pose a significant risk to communities, extending their reach all the way to Bayelsa State (Okechukwu, 2023). This alarming forecast serves as a poignant reminder of the persistent susceptibility of regions like Lokoja to recurrent flooding, intensifying the urgency for effective mitigation strategies. Other challenges include; temporary closure of businesses, resulting in significant economic losses for both individuals and the community as a whole; disruption of crucial transportation and communication systems, impeding emergency responses causing extensive community disruption; and contamination of water supplies which facilitate spread of diseases hereby posing significant health risks to affected the communities, jeopardizing public health and intensifying the burden on already-strained healthcare systems.

The aim of this study is to investigate the feasibility of constructing a flood mitigation model along the River Niger’s coastline in Lokoja, Kogi State, Nigeria with a view to provide stakeholders with a practical tool to discern whether their land lies within flood-prone zones or not. To achieve this, the study pursued several key steps; it gathered elevation data specific to the study area, it assessed the height fluctuations across the region using Shuttle Radar Topography Mission (SRTM) imageries, and it conducted an interpolation analysis to anticipate potential future flooding incidents in the study area. The following research questions provide the impetus that enables the research aims to be achieved: (i). What is the spatial distribution of flooding along the River Niger in Lokoja? (ii). What are the contributory factors of flooding in Lokoja? (iii) What will be the future flooding in Lokoja if not mitigated?

2.0 Literature Review

Despite the increased awareness of flood risk and its potential impact on the economy and lives of people, there is limited research on the spatiotemporal patterns of flood risk in Lokoja, Nigeria. Here are studies that has been carried out on flooding: Yusuf and Lawal, (2019) studied the "Assessment of Flood Vulnerability using GIS and Remote Sensing Techniques in Kano State, Nigeria. They assessed area's topography, land use, and climate. Abebe et al., (2018) assessed urban areas vulnerability to pluvial flooding using GIS applications and Bayesian Belief Network model. They quantified uncertainty and capture the casual nexus between pluvial flood influencing factors. Cai et al., (2019) examined the Flood Risk Assessment based on a hydrodynamic model and fuzzy comprehensive evaluation with GIS technique. They utilized the MFCE model input indicators which are; hazard, exposure and vulnerability factors to determine a very high-risk zone. Adebayo and Aina, (2017) studied the Spatial Assessment of Flood Hazards in Lagos Metropolis using GIS and Remote Sensing Techniques. Their studies analyzed the area topography, land use and climate. Hu et al., (2017) studied GIS-based flood risk assessment in suburban areas using a case study of the Fangshan District, Beijing. In their study three criteria were taken into account for vulnerability, and six elements related to danger were taken into account. Therefore, from the reviewed literature there is a lack of research that integrates both factors and examines their joint effects on flood risk. Morealso, no study is found to have studied the river Niger basin on the Lokoja bank. Hence, there is a need for comprehensive flood risk assessment to inform decision-making and enhance resilience to floods in Lokoja.

3.0 Materials and Methods

3.1 Study Area

Lokoja is a city located in central Nigeria and is known for its rich history and cultural heritage. In this academic discussion, we will explore the key aspects of Lokoja's location, geology, population, occupation, relief, climate, and economy. The study area is part of the River Niger Abutting Lokoja town. Lokoja is situated 7.8023° north of the equator and 6.7333° east of the Meridian. It is around 390 kilometers northeast of Lagos and 165 kilometers southwest of Abuja. The town is situated in the hot, humid tropical Wet and Dry Savanna climatic zone of Nigeria. Lokoja had been inhabited by people from several ethnic groups for hundreds of years before the arrival of the Europeans. It is possible that these villages' proximity to the Niger and Benue Rivers played a role in their development. Lokoja is situated at the confluence of the Niger and Benue rivers and is characterized by low-lying areas with a few hills. The city is situated in a valley surrounded by hills, and the nearby Mount Patti provides a panoramic view of the city. Lokoja has a tropical climate with two distinct seasons - the dry season and the rainy season. The dry season typically lasts from November to March, while the rainy season lasts from April to October. The average annual rainfall is about 1,500mm, with the highest rainfall occurring in July and August. The average temperature in Lokoja is around 27°C, with little variation throughout the year. The economy of Lokoja is largely agricultural, with crops such as yam, cassava, rice, and maize being the main source of income for farmers. Fishing is also an important economic activity due to the presence of the Niger and Benue rivers. Lokoja also has significant deposits of minerals such as limestone, kaolin, and clay, which are used in industries such as construction, ceramics, and agriculture. Additionally, the presence of several government institutions in the city provides employment opportunities and boosts the local economy.

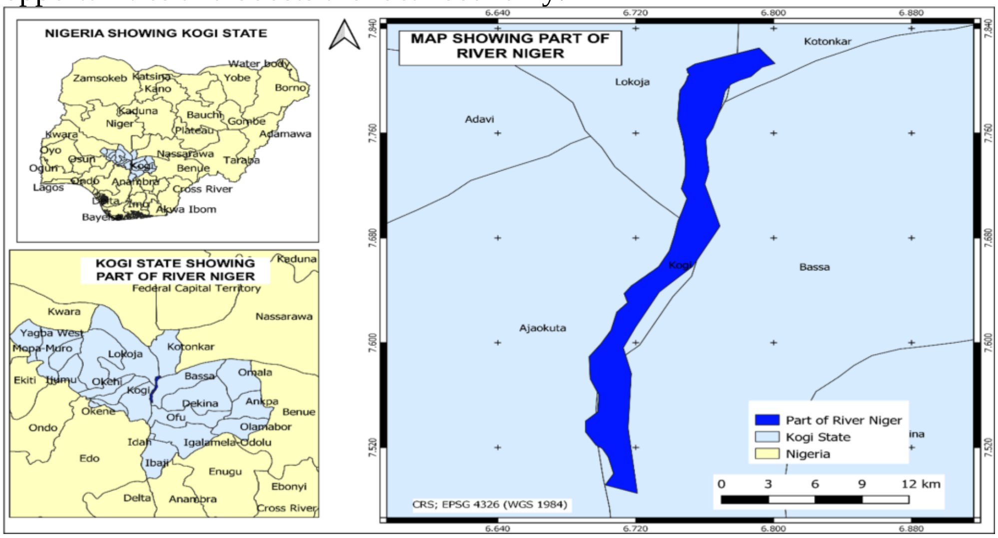

Figure 1. Map Showing the Study Area

3.2 Data Collection and Processing

In the context of this research, secondary data was used. The study area was carved out from the USGS platform and a query was performed; it showed that the platform only had SRTM imageries for the year 2002 and 2010 of the study which was used as the basis of the study. all necessary image processing such as mosaicking, extraction and clipping of the water body was carried out using ArcGIS 10.8. Height information for the two SRTM mosaicked data was generated for the study area.

4.0 Presentation and Analysis of Results

4.1 Presentation of Results

The data were used to generate maps and height information of the study area to deciding if there is any significant change in the elevation of the Niger river along Lokoja for the acquired SRTM images, such that the acquired information can be used for projection of future disaster and deployment of preventive measures. To depict the configuration of the flow of water as appeared within the study area, both SRTM images acquired were produced at a scale of 1:150,000.

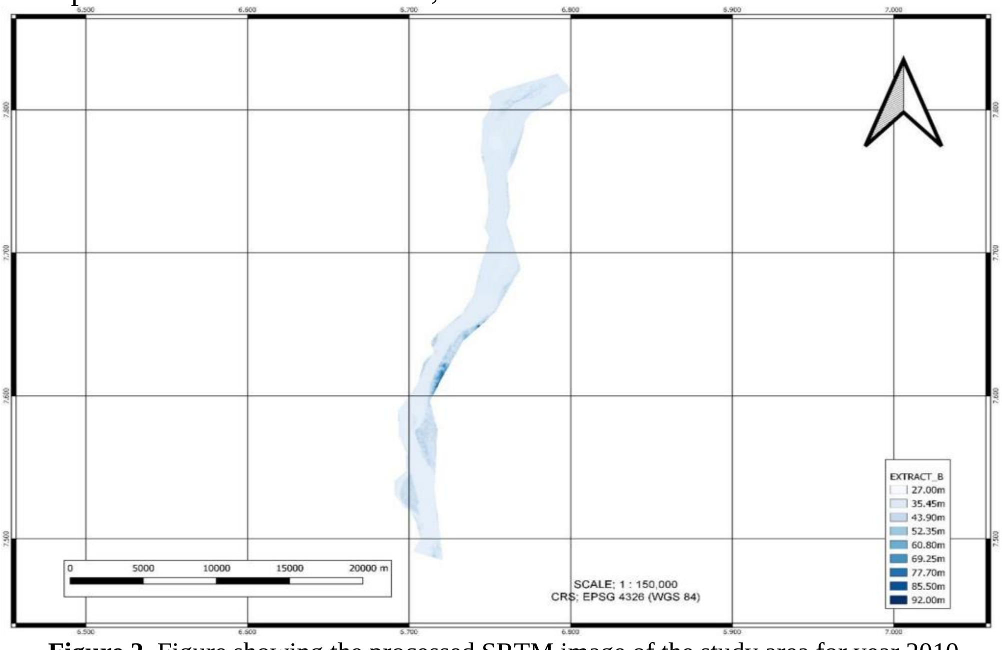

Figure 2. Figure showing the processed SRTM image of the study area for year 2010

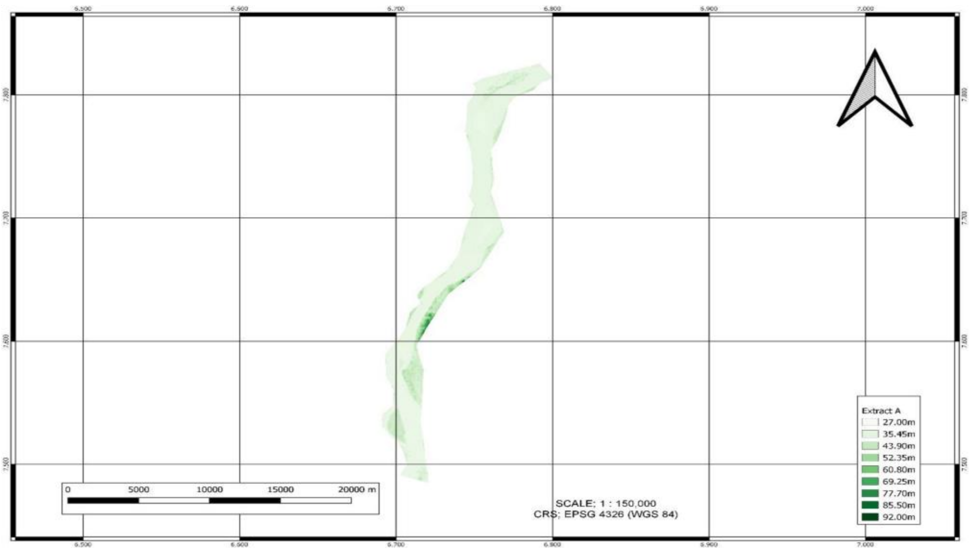

Figure 2. Figure showing the processed SRTM image of the study area for year 2002

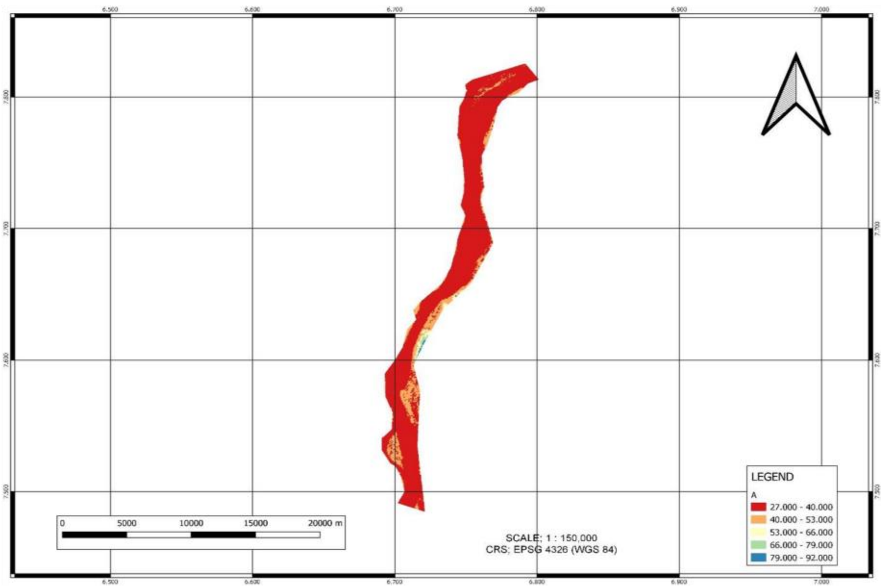

Figure 3. Figure showing the processed SRTM image of the study area transformed from pixels to polygons for proper extraction of height details

3.2. Querying Operation

Queries are then performed on the criteria classes in order to obtain the result analysis of both images acquired. Given below are the query operations performed and the results obtained. A total of 85,605 points were determined within the study area. The highest point was 92m while the lowest was 27. It was also observed that both SRTM images had similar properties and produced same results. With this, it shows that the acquired data was not primed to assist in the type of interpolation that was needed. (3D Kriging interpolation) since there was no visible difference in the values generated for the height of points in the study area. The figure below shows the coordinates of the points whose heights are generated in longitude and latitude and the height information are attached to it. The generated Height information for the year 2002 are represented in column A, B, and C while that of 2012 are presented in column F, G, and H. coordinates and height information were generated for 85,605 points within the study area. The first figure showed the first 22 points generated for the study area while the next figure showed the last points whose coordinates and height were generated.

	A	B	C	D	E	F	G	H	I	J	K
1	Height	Lat	Lon			Height	Lat	Lon			
2	38	7.82487	6.79102			38	7.82487	6.79102		0	
3	38	7.82487	6.79129			38	7.82487	6.79129		0	
4	38	7.82487	6.79157			38	7.82487	6.79157		0	
5	40	7.82487	6.79185			40	7.82487	6.79185		0	
6	33	7.82459	6.78991			33	7.82459	6.78991		0	
7	34	7.82459	6.79018			34	7.82459	6.79018		0	
8	36	7.82459	6.79046			36	7.82459	6.79046		0	
9	36	7.82459	6.79074			36	7.82459	6.79074		0	
10	37	7.82459	6.79102			37	7.82459	6.79102		0	
11	37	7.82459	6.79129			37	7.82459	6.79129		0	
12	38	7.82459	6.79157			38	7.82459	6.79157		0	
13	39	7.82459	6.79185			39	7.82459	6.79185		0	
14	38	7.82431	6.78907			38	7.82431	6.78907		0	
15	37	7.82431	6.78935			37	7.82431	6.78935		0	
16	35	7.82431	6.78963			35	7.82431	6.78963		0	
17	35	7.82431	6.78991			35	7.82431	6.78991		0	
18	36	7.82431	6.79018			36	7.82431	6.79018		0	
19	36	7.82431	6.79046			36	7.82431	6.79046		0	
20	36	7.82431	6.79074			36	7.82431	6.79074		0	
21	37	7.82431	6.79102			37	7.82431	6.79102		0	
22	37	7.82431	6.79129			37	7.82431	6.79129		0	

Figure 4. Figure showing the opening part of the height data generated for the study area

	A	B	C	D	E	F	G	H	I	J	K
85586	34	7.48598	6.71879			34	7.48598	6.71879			
85587	33	7.48598	6.71907			33	7.48598	6.71907			
85588	33	7.48598	6.71935			33	7.48598	6.71935			
85589	33	7.48598	6.71963			33	7.48598	6.71963			
85590	33	7.48598	6.71991			33	7.48598	6.71991			
85591	33	7.48598	6.72018			33	7.48598	6.72018			
85592	33	7.48598	6.72046			33	7.48598	6.72046			
85593	33	7.48598	6.72074			33	7.48598	6.72074			
85594	33	7.4857	6.71907			33	7.4857	6.71907			
85595	33	7.4857	6.71935			33	7.4857	6.71935			
85596	33	7.4857	6.71963			33	7.4857	6.71963			
85597	33	7.4857	6.71991			33	7.4857	6.71991			
85598	33	7.4857	6.72018			33	7.4857	6.72018			
85599	33	7.4857	6.72046			33	7.4857	6.72046			
85600	33	7.4857	6.72074			33	7.4857	6.72074			
85601	33	7.48542	6.71991			33	7.48542	6.71991			
85602	33	7.48542	6.72018			33	7.48542	6.72018			
85603	33	7.48542	6.72046			33	7.48542	6.72046			
85604	33	7.48542	6.72074			33	7.48542	6.72074			
85605	33	7.48514	6.72074			33	7.48514	6.72074			
85606											
85607											
85608											

Figure 5. Figure showing the closing part of the height data generated for the study area

Going by the obtained result there are a number of likely implications. The first implication is the prioritization formula of data acquisition by USGS. with the increasing volume and complexity of spatial data, USGS has identified the need to prioritize its data acquisition efforts to ensure that it is collecting the most relevant and useful data for its users.

Firstly, USGS prioritizes its data acquisition based on user needs and requirements. USGS regularly engages with its users, such as researchers, government agencies, and the private sector, to understand their needs and requirements for spatial data. Based on these inputs, USGS prioritizes its data acquisition efforts to collect the data that is most relevant and useful for its users. For example, if a particular user community requires high-resolution satellite imagery for a specific area, USGS may prioritize the acquisition of this data to meet their needs.

Also, USGS prioritizes its data acquisition based on scientific and policy priorities. USGS has a mandate to study natural resources and hazards, and to provide scientific information to support policy and decision making. Therefore, USGS prioritizes its data acquisition efforts to support its scientific and policy priorities. For example, if there is a policy priority to monitor the health of forests in a particular region, USGS may prioritize the acquisition of satellite imagery that can be used to monitor forest health. Also, USGS prioritizes its data acquisition based on technological advancements. With the rapid advancements in spatial technology, USGS regularly evaluates new technologies and platforms that can improve its data acquisition capabilities. For example, USGS may prioritize the acquisition of data from new satellite sensors or aerial platforms that can provide higher resolution and more accurate data.

Furthermore, USGS prioritizes its data acquisition based on cost and availability. USGS has limited resources, and it must balance its data acquisition efforts with its available budget and resources. Therefore, USGS prioritizes its data acquisition efforts based on the cost and availability of the data. For example, if there is a high demand for data from a particular sensor, but the cost of acquisition is high, USGS may prioritize the acquisition of data from a different sensor that is more cost-effective.

Additionally, USGS prioritizes its data acquisition on the Earth Explorer platform based on user needs and requirements, scientific and policy priorities, technological advancements, and cost and availability. By prioritizing its data acquisition efforts, USGS can ensure that it is collecting the most relevant and useful geospatial data for its users, which is essential for managing natural resources and hazards, supporting scientific research, and informing policy and decision making.

Based on this, there is an indication that little interest has been picked on the study area by top organizations for location-based research over the years. Hence, the reason for a deficiency of data in sizable quantity for the study area. The findings also indicates that government policies in the region are either not made to check for flooding and other attention worthy activities such as economic and commercial activities within the study area. It could also be that their policies are not taken seriously enough by USGS for reasons best known to them.

The deficiency of notable difference between the points picked in the study area for both acquired DEMs acquired could also signify a drop of quality in the data acquired by the satellite in the study area. If this implication is anything to go by, it signifies a deficiency in economic and sociopolitical power of the indigenous people of the study are and the international relevance of the country hosting the study area.

Conclusion

From the study, it was clear to see that data downloaded from USGS will not do much help in the performance of a proper flooding analysis for the river Niger along Lokoja town. In view of this it is recommended that other sources of SRTM data be utilized if a similar operation is to be carried out. Although, the agency has a rigorous quality control process in place to ensure that its data is accurate, unbiased, and of high quality. That is not to say their data is totally dependable. Rather, the reliability of USGS data can vary depending on the specific data set, the methods used to collect and analyze it, and the limitations of the data. Like any other scientific organization, USGS researchers may face challenges in collecting data in certain regions or under certain conditions.

Additionally, the use of secondary data may not capture site-specific details that could affect the height generation. For example, the presence of buildings, trees, or other obstacles could affect the height of the floodwater, and these details may not be captured in the secondary data sources.

Recommendation

Given the nature of the obtained results, it is recommended that government begin to throw their weight around the proper monitoring of the river Niger such that their activities will be able to get the attention of international organizations like the USGS. This will enhance the quality and quantity of data acquired within the study area and will in effect increase the quality of research and findings carried out on flood risk assessment and other related researches within the area. Also, there is a need to supplement the secondary data with on-site measurements and observations to improve the accuracy and reliability of the height generation. Furthermore, innovative approaches to harness the recurring dam overflow from Cameroon should be adopted by channeling the water to Sambisa Forest for agricultural purposes, constructing new turbines for excess electricity generation, and utilizing the water for irrigation during the annual dam release.

Conflict of Interest: The author reported no conflict of interest.

Data Availability: All of the data are included in the content of the paper.

Funding Statement: The author did not obtain any funding for this research.

References:

1. Abebe, Y., Kabir, G., & Tesfamariam, S. (2018). Assessing urban areas vulnerability to pluvial flooding using GIS applications and Bayesian Belief Network model. *Journal of Cleaner Production*, *174*, 1629–1641. https://doi.org/10.1016/j.jclepro.2017.11.066
2. Cai, T., Li, X., Ding, X., Wang, J., & Zhan, J. (2019). Flood risk assessment based on hydrodynamic model and fuzzy comprehensive

evaluation with GIS technique. *International Journal of Disaster Risk Reduction*, *35*, 101077.

3. Hu, S., Cheng, X., Zhou, D., & Zhang, H. (2017). GIS-based flood risk assessment in suburban areas: A case study of the Fangshan District, Beijing. *Natural Hazards*, *87*(3), 1525–1543. https://doi.org/10.1007/s11069-017-2828-0
4. Shah, M. A. R., Rahman, A., & Chowdhury, S. H. (2018). Challenges for achieving sustainable flood risk management: Challenges for achieving sustainable flood risk management. *Journal of Flood Risk Management*, *11*, S352–S358. https://doi.org/10.1111/jfr3.12211