



Multi-criteria Decision Analysis for Flood Risk Management in Suleja, Nigeria

Sadiq Abubakar ^{1,*} Yisa M. Kodan ¹, and ¹Adams P. Ninma ¹

¹Department of Geography, Federal University of Technology, Minna. P.M.B. 65, Minna, Niger State, Nigeria

Corresponding Author Email: *sadiq.abubakar@futminna.edu.ng

Received: December 1, 2024

Revised: May 3, 2025

Accepted: June 15, 2025

Abstract

Climate and socioeconomic changes have made flooding the most expensive natural hazard in the world, and it is predicted to worsen in the future. The perennial urban flooding experience in Suleja has defied the usual mitigation methods and continues to cause loss of lives and destruction of valuable properties. This research aims to evaluate mitigation and adaptation strategies for flood control in Suleja using the CLIMATE Prio tool. Data were collected by integrating the perspectives of different stakeholders. The stakeholders includes professionals from the Ministry of Land and Housing, Niger State Water Board, Suleja area officer (Buntu dam management), Niger State Emergency Management Agency (Suleja area office), the Resident Engineer, representatives from affected communities, representatives from the emirate council, representatives of youths and women groups, and NGO's. Six adaptation action plans were chosen for evaluation by key stakeholders. The actions range from structural climate change measures, such as the construction and maintenance of drainage and canals; drainage systems and green areas; or river channel dredging, to non-structural climate change measures, such as green areas only, investing in early warning technology, or empowering and developing vulnerable groups. The drainage system and green area action plan, which proposed the construction of flood walls along the river's bank while preserving some green areas for water retention, was ranked as the most effective adaptation action capable of achieving the greatest risk reduction at the lowest cost. In addition, the adaptation plan best fits the most important criteria of flood damage reduction and the cost of implementation. On implementation of the recommended measures, local people of Suleja will be highly benefited.

Keywords: Adaptation, Action plan, Decision making, flood risk management,

1. Introduction

Climate change brings numerous problems to humanity, ranging from ecosystems to economies, and water is the primary way by which climate change impacts are perceived (Rowland et al, 2020). Water is gradually transitioning from one state to another as the world average temperature rises. Increased temperature in the polar or temperate zone and on mountain peaks has converted water from solid to liquid, whereas in the equator or tropical region, it has converted water from liquid to gaseous state. These have resulted in an

increasing number and severity of environmental issues, economic concerns, and social inequalities (Trung et al, 2023). Storms, floods, and droughts are among the major environmental challenges resulting from climate change. Water-related disasters accounted for over 74% of total natural disasters from 2001 to 2018, with floods and drought alone causing over 166,000 deaths over the last 20 years (UNESCO, 2020). These disasters have affected over three billion people and generated over \$700 billion in economic damage (EM-DAT, 2019). Despite significant diversity in the number of deaths, people affected, and economic losses, Africa and Asia have been hit the hardest in all categories (United Nations climate change, 2020).

In recent years, Nigeria has experienced extraordinary weather patterns, resulting in unpredictable rains and deadly flood disasters. The deadliest flood in Nigerian history occurred in 2022. Before that, a major flood event with severe consequences occurred in 2012, and it was dubbed the worst in recent history. History repeats itself in 2017, which nearly brought down the entire country and was also dubbed the worst in recent history. Floods have become more frequent and intense over the years, inflicting havoc across the country. Floods affected approximately 250,000 people in 2017, primarily in the country's eastern and central regions. In 2016, 92,000 people were displaced, and 38 perished; in 2015, over 100,000 people were displaced, with 53 deaths; and in 2012, a terrible flood displaced two million Nigerians, killing 363 (Orizu, 2022). The United Nations Office for the Coordination of Humanitarian Affairs (OCHA, 2024) report revealed that over 300 deaths and 1.2 million people were affected by flood events that occurred in 31 states in Nigeria.

In addition, metropolitan areas are becoming more vulnerable to floods because of increased human activity in flood-prone locations, particularly in developing countries. Because of their economic situation, the urban poor are typically the most vulnerable category, as they frequently dwell on low or marginal lands linked with flood risk. This implies that most people affected in the event of any disaster are usually poor; thus, more attention is needed in the area of risk and decision analysis in flood-prone locations in urban areas, by analysing the potential losses that are likely to occur and making the necessary recommendations for mitigating or adapting to such disasters when they occur.

Suleja Local Government Area in Niger State, Nigeria, features undulating terrain of steep hills, narrow valleys, and floodplain. The area's impervious geology and rapid urban expansion, often into natural waterways, have severely increased surface runoff and flood risk (Okotoni & Akintola, 2013). Combined with intense, short-duration rainfall events driven by climate change, Suleja faces frequent and devastating flash floods, particularly in densely populated districts (Adelekan, 2015). The absence of adequate drainage infrastructure further amplifies the town's vulnerability, making it a critical hotspot for climate-sensitive flood risk management.

Flood risk management in Suleja (LGA) remains predominantly reactive and based on historical hydrological patterns, despite repeated flood disasters in recent years (NEMA, 2021). Traditional risk assessments largely assume that the climate is relatively static, neglecting the emerging evidence that extreme rainfall events are becoming more frequent and intense under changing climate conditions (IPCC, 2021). This has resulted in outdated flood risk maps, unavailable (in some case) or ineffective early warning systems, a persistent vulnerability of urban and peri-urban communities, and poor mitigation and adaptation planning in Suleja.

Given Suleja's poor financial strength, unique environmental features (i.e. steep terrain), unplanned urban expansion, and inadequate drainage infrastructure (Okotoni & Akintola, 2013), the region is highly sensitive to even modest increases in rainfall intensity. However, local planning institutions, like the Ministry of Lands and Urban Development, and the Ministry of Works, currently do not only lack the necessary tools to integrate future climate

uncertainties into their flood risk analysis and mitigation strategies, but also lacks the financial resources to adequately respond to the disasters.

Decision-makers are simultaneously challenged by the need to balance multiple, often conflicting objectives, such as economic efficiency, environmental sustainability, and social equity, under conditions of increasing uncertainty (Aerts et al., 2018). While the traditional risk assessment methods usually focus on a single criterion, like probability of occurrence or expected loss, often using quantitative data and models to estimate risks, climate-informed Multi-Criteria Decision Analysis (MCDA) offers a structured method to evaluate and prioritize diverse flood risk management strategies (Linkov & Moberg, 2012). This tool is designed for situation where multiple, often conflicting criteria must be considered simultaneously with forward-looking climate projections. It is usually applied when risks must be evaluated based on a combination of factors (e.g. social, environmental, economic impacts), not just likelihood and severity.

Also, Suleja LGA has a well-documented financial limitations that hinder effective flood risk management. Like most local governments in Nigeria, Suleja depends heavily on federal allocation, which are often insufficient, irregular, and politically influenced, leaving little room for proactive infrastructure investment (Okotoni & Akintola, 2013). As a result, critical flood management measures such as, construction of drainage channels, riverbank stabilization, early warning systems, and public awareness programs are either underfunded or entirely absent. Budgetary allocations for disaster preparedness and environmental protection are typically low priority compared to competing social and political needs (Adelekan, 2015). This fiscal weakness not only delays response efforts but also perpetuates a cycle of vulnerability, where communities repeatedly suffer from the same flood impacts without long-term solutions being implemented.

To address this gap, there is an urgent need for a multi-criteria decision-support system capable of incorporating probabilistic climate projections into flood risk management frameworks. The Climate Prio tool is a decision support and assessment tool capable of providing the most acceptable, cost-effective, and implementable plan to lessen the impact of flooding or mitigate it when it occurs. Different prospective of mitigation and/or adaptation strategies must be adequately examined, especially in poor communities where resources are limited, to ensure that the chosen mitigation plan fits the available budget, technical capacity, and is cost-effective.

Birmah et al., (2021) explained that the study area has recorded series of flood event over the years and the worst flood ever recorded was in 1986. A severe flood event struck people of Niger state's Checheniya, Kaltuma, and Angwan Gwari in the Suleja Local Government Area (L.G.A), as well as Hayin-Nassarawa and surrounding areas in the Tafa local government region, in 2017. What began as normal rainfall evolved into massive flooding, claiming 15 lives, submerging approximately 100 dwellings, sweeping away farmlands worth millions of naira, and leaving other residents missing. The flood was triggered by torrential rain that lasted for more than five hours, and the intensity was high due to the terrain, which caused the Madaki River to overrun its banks into residential areas.

The response to this disaster from the relevant authority (Niger State Emergency Management Agency) was unscientific, uncoordinated, and reactive. Fortunately, it did not take too long for the water to recede into the river channel, but regrettably, it will occur again. As the effects of climate change continue to create extreme conditions, more environmental problems are observed to occur more frequently than usual.

Cities, according to Grafakos (2017), must decide which mitigation or adaptation steps to implement. Many countries around the world are seeing a significant transformation in their methods to flood management. This move has been prompted by devastating floods and an

awareness of the world's unending rise in flood susceptibility (Hall & Solomatine, 2008), as well as the prospective effects of climate change on flood frequency.

While recent floods in developed countries have prompted changes in flood risk management practises through an integrated risk-based approach to flood management, most institutions in Nigeria tasked with preventing and managing disasters are lagging in adopting a science-based approach to solving these problems. The current flood risk and decision analysis study will provide critical input towards understanding the magnitude of loss that this built environment might sustain, as well as the most effective mitigation and adaptation techniques to avoid disasters.

1.1 Literature Review

Numerous frameworks for analysing decision processes exist. According to Malczewski (2009), one of the most widely accepted generalisations of the decision-making process, introduced by Simon (1960), is that "any decision-making process can be structured into three major phases: intelligence (is there a problem or an opportunity for change?), design (what are the alternatives?), and choice (which alternative is best?)". Various assessment methods have been created to examine each alternative to determine the best solution. Modern flood risk management does not rely solely on constructed flood defence structures such as dikes, channel improvement works, and barriers, but also consider a variety of non-structural flood mitigation methods. The criteria for evaluating flood risk management strategies are rarely exclusively economic, but often take into account public safety, equity, and the environment.

Grafakos (2017) defined when decision support and assessment technologies can be used for climate change planning. He advocated that cost-benefit analysis (CBA) should be utilised when the advantages and costs of various adaptation or mitigation solutions are quantified in monetary terms. A cost-effectiveness analysis (CEA) can be used if the expenses are monetised and the major benefit in the form of an objective is quantified, such as the reduction of climate risk. He further stated that multiple criteria analysis (MCA) is the optimum tool for decision situations where both costs and benefits are quantified but not monetised. Furthermore, where costs and benefits are difficult to measure, an expert panel should complete the MCA.

Olivotto (2017) presented an overview of the technical capabilities, data demands, time, cost, and participation requirements required for CBA, CEA, and MCA evaluations. She noted that the tools require a high level of technical ability and a significant time and financial allocations to be accomplished proficiently. The main difference she noticed between the tools is the level of stakeholder involvement; MCA is very participatory and relies heavily on eliciting stakeholder preferences in decision-making to estimate final rankings of alternative options, whereas CBA and CEA are less participatory. Also, MCA can be performed with fewer data points than CBA and CEA, which require absolute quantification of costs and benefits. MCA will deal with circumstances where certain types of data are unavailable, and certain experts may contribute their opinions for scoring or assessing alternative activities.

Furthermore, the UNFCCC (2012) has advocated MCA as one of the most relevant strategies to assist national governments in building national adaptation action plans. Similarly, UN-Habitat has proposed the MCA method as the primary prioritisation technique to assist local governments in establishing local climate change action plans.

The use of Multi-Criteria Decision Analysis (MCDA) specifically in flood risk management has gained significant attention in recent years, due to the growing complexity of flood hazards under climate change and urbanization. Scholars have applied various MCDA techniques to support decision-making across different stages of flood management: risk assessment, mitigation planning, emergency response, and adaptation strategies.

Similarly, Papaioannou et al. (2018) stressed the value of participatory MCDA where different stakeholders (e.g., government, citizens, private sector) are involved in weighting decision criteria for flood management. Kourgialas et al. (2020) developed a participatory MCDA tool for flood mitigation in Greece, showing that early stakeholder engagement improves the legitimacy and acceptance of flood risk policies. Stakeholder involvement is now considered critical for successful implementation of MCDA outcomes.

Ornguze et al, (2023) employed Multi-Criteria Decision Analysis (MCDA) techniques to investigate flood vulnerability and elements at risk in Makurdi LGA in Benue State. Using the Analytical Hierarchy Process (AHP), topography, landuse and land cover, proximity to River Benue, rainfall and soil textures were integrated and weighted for the assessment of flood vulnerable areas in the Metropolis. Also, purposive sampling technique was used to assess disaster risk and exposure in the city. Flood vulnerability of the community were classified into: extremely, highly, moderately and low vulnerability. The result showed that the valleys of River Benue and other large rivers like River Gwe within the LGA were extremely or highly vulnerable to flood.

1.2 Study area

Suleja is located in Niger State, Nigeria, just north of Abuja, the capital of Suleja emirate. It is situated between latitude 9° 6'N and 9° 17'N and longitude 7° 6'E and 7° 12'E, as shown in Figure 1. It covers an area of 114.6 km² and has a projected population of approximately 368,900 people, with an annual growth rate of 3.4% (city population, 2022). Suleja is known as “Abuja's bedroom” as majority of its residents work in Abuja but live in Suleja due to the high cost of living in the FCT. The Suleja emirate consists of three local governments: Suleja, Tafa, and Gurara. However, Suleja City’s social and economic impact extends to the two other local administrations.



Figure 1: River Madaki during the flood



Figure 2: Suleja drainage tributary

The Madaki River (see figure 1) is the primary river that runs through Suleja. The river originates in the Kaduna River and flows to the south-western section of the country. The principal rivers that drain the area are the Iku and Madakin-Iku. Most of these rivers have numerous tributaries that run across the Suleja terrain. The river is vital to the survival of Suleja town because it is home to the famous Buntu dam, which provides drinking water to Suleja and its vicinity. The downstream segment of the river poses some risks to settlements along its floodplain (see figure 2), such as floods and riverbank erosion.

objectives that will be used to evaluate the chosen actions. Users rate the relative relevance of criteria and assign scores (qualitative and quantitative) to indicate how each choice fits each criterion while following the climate action prioritising process.

This tool is intended to assist decision-makers in identifying and prioritising local adaptation initiatives at the municipal level (in a specific situation). The analysis is carried out not only to identify adaptation actions but also to decide which actions should be carried out first (prioritisation). The tool is very essential in adaptation or mitigation plan for Suleja Local government area, as Suleja has a limited budget for disaster risk management, evaluating and prioritising the strategies that are relatively low-cost but effective and flexible.

3. Results and Discussion

The CLIMACT Prio tool allows the user to select from 13 different action plans; however, for this study, six (6) adaptation action plans were chosen for evaluation by the key stakeholders (the affected communities, represented by the various CBO's, the Professionals from the Ministry of Lands and Urban Development like the Resident Surveyor Suleja LGA, Area Land Officer Suleja, a civil engineer from the ministry of works, Suleja, representative from Niger State Emergency Management Agency (NSEMA), for their expert opinion, and representative of the Emirate council), as indicated in Table 1. The actions were chosen based on professional recommendations and case studies from other cities like Minna and the city of Durban in South Africa. The actions range from structural climate change measures, such as the construction and maintenance of drainage and canals, drainage systems, and green areas, or river channel dredging, to non-structural climate change measures, such as green areas only, investing in early warning technology, or empowering and developing vulnerable groups.

Table 1: List of the Adaptation Action Plan

No	Adaptation action	Type	Sector	Time frame
1	Construction and maintenance of drainage/canal	Structural	Flood management	Long term
2	Drainage system and green areas	Structural	Flood management	Medium term
3	Green area only	Non-structural	Ecological	Short term
4	Investing in early warning technology	Non-structural	Flood management	Short term
5	Dredge the river channel	Structural	Flood management	Long term
6	Empowerment and capacity development of vulnerable groups	Non-structural	Disaster management	Short term

The tool is pre-designed with multiple sectors, and each adaptation action plan is expected to be classified into these sectors by stakeholders. Construction and maintenance of drainage/canal, drainage system, and green areas, investment in early warning technology, and dredging of the river channel were classified as flood management actions, whereas green areas only and empowerment and capacity development of vulnerable groups were classified as ecological and disaster management sectors, respectively. Each action plan is

given a time frame for job completion. Structural adaptation acts are typically time-consuming and hence classified as long-term, whereas non-structural measures are typically classified as medium- or short-term.

After defining a list of different adaptation actions, it is critical to reduce the choices through an initial screening procedure. A feasibility evaluation is intended to screen out adaptation actions that may be unfeasible to undertake or have a low impact, while identifying other more feasible adaptation actions for a more complete review. The CLIMACT Prio recommends several feasibility and impact criteria, including stakeholder acceptance, technical feasibility, ease of implementation, financial viability, mainstreaming potential, effectiveness, and multi-sectorial and/or multiple objectives. The criteria are explained in Table 2.

Each adaptation action plan were reviewed and scored high, medium, or low against the feasibility and impact criteria (Table 3).

Construction and maintenance of the drainage system were rated "high" by stakeholders as a means of mitigating the annual flood in the local government, while technical feasibility was rated "medium" because stakeholders believe the local government has limited resources to develop, design, implement, and maintain the project. On the ease of implementation scale, stakeholders assessed construction and maintenance of the drainage canal as "low," because it would require earth-moving machines and compensation for communities along the channel, which would necessitate much bureaucratic processes and outside assistance.

Similarly, financial feasibility was rated poor," as stakeholders felt that the local government lacks the financial resources to complete the project successfully without the assistance of the state government or other financial organisations. Mainstreaming potential is minimal because integrating this initiative with existing local government planning and policy development will necessitate additional policies. The "Effectiveness" of creating and maintaining a drainage/canal system to lessen vulnerability was graded "high" for the Impact category, as they believe it will create a much-needed barrier between the river and their properties. The action plan's ability to handle objectives in other sectors (multi-sectorial and multi-objective) was rated "high," as this action plan will not only assure flood mitigation in the study region; but also a quality urban environment and planning.

The feasibility ranking sheet (Table 4) demonstrates how the adaptation activities scale from low to high is converted to a numerical scale of one to three. This produces three types of outcomes. The total score represents the sum of the feasibility and impact criteria of individual adaptation actions; the feasibility ranking, which indicates the actions that rank highest as an average of scores allocated to both the feasibility and impact criteria; and the feasibility index column, which captures the average score across the five feasibility criteria (stakeholder acceptability, technical feasibility, ease of implementation, and financial viability). These data (total score) were used to create a bar chart (Figure 2) indicating the feasibility of each adaptation action plan.

The feasibility ranking of adaptation activities allows us to compare the ranks of various adaptation action plans. To continue the examination of the action plans, a maximum of four (4) of the highest-ranked action plans were copied and pasted on the next sheet (Table 5) as selected actions to move on in the evaluation exercise. This table (Table 5) includes a column describing the chosen adaptation action plans.

Table 2: Feasibility criteria guide

Feasibility Criteria	Criteria	High	Medium	Low
Feasibility Criteria	Stakeholder acceptability: Would local residents accept it?	Majority of residents in area	Limited number of residents	Low support
	Technical feasibility: Will necessary design, implementation and maintenance support be available to the option?	Designs, implementation and maintenance are available	Resources to develop, design, implement and maintain are limited	No available resources to develop design, implement and maintain.
	Ease of Implementation: Can it be implemented at the local government level, or does it depend upon state provincial or national support?	City can implement this without external support	City can implement this with some external support	City needs external support
	Financial viability: Is it a financially realistic option? Does the city have funding or potential access to funding to cover the costs?	Financially realistic with available funding	Partially realistic because of limited funding	Expensive and no city funding option
	Mainstreaming potential: Could it be integrated with existing local government planning and policy development?	Easily and fully in existing climate plans and strategies	Partly and outside climate related plans and strategies	No, would require additional policies.
	Impact Criteria	Effectiveness: How well would it work on reducing vulnerability (in relation to the other actions)?	Vulnerability will be reduced to a large extent (in relation to the other actions)	Vulnerability will be reduced to a moderate extent (in relation to the other actions)
Multi-sectorial and multi-objective: Would it address objectives in other sectors?		Significant cross over with other sectors and objectives	Some cross over with other sectors and objective	No cross over with other sectors and limited impact on other objectives

Source: Institute for Housing Study (2017)

Table 3: Feasibility Assessment

Feasibility Assessment-Initial Screening of Adaptation Actions							
	Feasibility criteria					Impact criteria	
Adaptation Action	Stakeholder Acceptability	Technical Feasibility	Ease of Implementation	Financial Feasibility	Mainstreaming potential	Effectiveness	Multi-sectorial/objective
Construction and maintenance of drainage/canal	High	Medium	Low	Low	Low	High	High
Drainage system and green areas	High	Medium	Medium	Medium	Low	High	High
Green area only	Low	High	High	Medium	Low	Medium	Medium
Investing in early warning technology	High	Low	Low	Low	Low	Medium	Low
Dredge the river channel	Medium	Low	Low	Low	Low	Medium	Medium
Empowerment and capacity development of vulnerable groups	High	Low	Medium	Medium	Medium	Medium	Medium

Table 4: Feasibility Ranking.

Feasibility Assessment-Initial Screening of Adaptation Actions										
	Feasibility criteria					Impact criteria				
Adaptation Action	Stakeholder Acceptability	Technical Feasibility	Ease of Implementation	Financial Feasibility	Mainstreaming potential	Effectiveness	Multi-sectorial/objective	Total	Ranking	Feasibility Index
Construction and maintenance of drainage/canal	3	2	1	1	1	3	3	14	2	0.5
Drainage system and green areas	3	2	2	2	1	3	3	16	1	0.7
Green area only	1	3	3	2	1	2	2	14	2	0.7
Investing in early warning technology	3	1	1	1	1	2	1	10	5	0.5
Dredge the river channel	2	1	1	1	1	2	2	10	5	0.4
Empowerment and capacity development of vulnerable groups	3	1	2	2	2	2	2	14	2	0.7

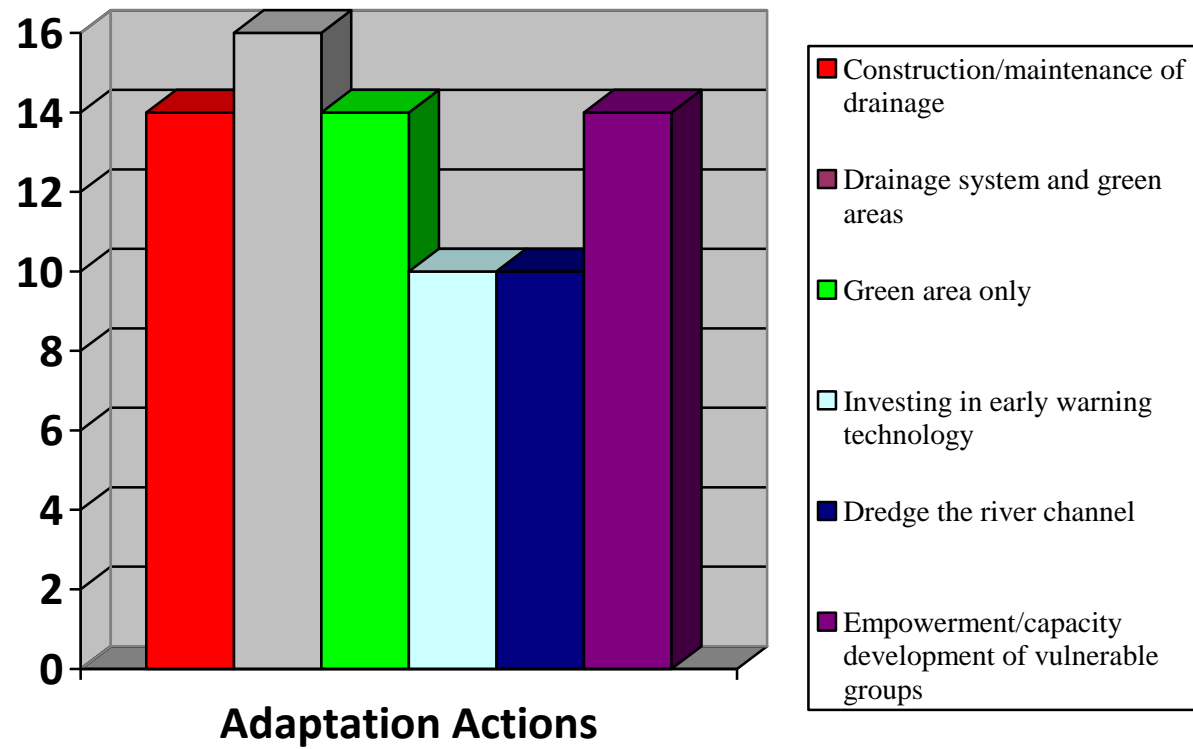


Figure 2: Feasibility ranking of adaptation action.

Table 5: Selected Adaptation Action Plan

Adaptation Action					
No	Adaptation action	Type	Sector	Time frame	Description
1	Construction and maintenance of drainage system	Structural	Flood management	Long term	This involves the building of flood embankments along the river channel to prevent flood
2	Drainage system and green area	Structural	Flood management	Medium term	This is a mixture of concrete wells and green area to prevent flood
3	Green area only	Non-structural	Ecological	Short term	This is to enforce setback along the river channel for vegetation
4	Empowerment and capacity development of vulnerable groups	Non-structural	Disaster management	Short term	This is to empower and build the capacity of vulnerable groups and make them resilient to flood

Table 6: Criteria Identification

Identification				
	Task 1	Task 2	Task 3	Task 4
	Criteria	Category of Criteria	Units	Min/Max
1	Flood disaster reduction	Climate	“1-5”	Max
2	Ecosystem restoration	Environment	“1-5”	Max
3	Cost of implementation	Economic	“1-5”	Min
4	Public acceptability	Social	“1-5”	Max

Specific assessment criteria to be utilised in the CLIMACT Prio tool to evaluate the impacts and benefits of adaptation measures must be developed in criterion identification (Table 6). This phase is critical because the final prioritisation of the tasks will be influenced by the evaluation criteria used. As the tool was being used for decision-making in the local government to solve the flood problem, the probable evaluation criteria for the selected adaptation activities were addressed with stakeholders. According to Olivotto (2017), the criteria should be SMART, which stands for Simple, Measurable, Achievable, Relevant, and Time-bound. This is true especially when the analysis is conducted in a participative fashion, as all stakeholders should be able to easily grasp the criteria.

Four (4) criteria were chosen for this study (as indicated in Table 6), and their respective categories were also chosen from the tool's pre-designed sets of categories. For example, flood damage reduction criteria were assigned to the category of climate; ecosystem restoration was assigned to the category of environment; implementation costs were assigned to the category of economics; and public approval was assigned to the category of social. The next step is to choose the scale of measurement for the various evaluation criteria.

The CLIMACT Prio tool has various measuring units, and data can be reported in percentages or currencies, square meters, or hectares. However, the Likert scale was used in this study. The Likert scale assessment (1-5) indicates that one (1) represents poor performance and five (5) represents excellent performance; this will establish the effect scoring range for the next stage.

Table 7: Impact Assessment Matrix

Scoring – Impact Assessment Matrix				
Action/Criteria	Flood disaster reduction	Ecosystem restoration	Cost of implementation	Public acceptability
Scale units	“1-5”	“1-5”	“1-5”	“1-5”
	Max	Max	Min	Max
Construction and maintenance of drainage system	5	3	1	4
Drainage system and green area	4	4	3	5
Green area only	3	5	5	3
Empowerment and capacity development of vulnerable groups	3	2	4	4

Scores are awarded for each adaptation activity against the selected evaluation criteria in the impact assessment (Table 7). This step is typically based on economic, social, environmental, and adaptive impact research, expert judgements and modelling exercises. To reduce ambiguity and subjectivity, the relevant stakeholders scored on a clearly defined and agreed-upon scale. During the scoring process, elements such as the merits and disadvantages, costs and benefits, and funding alternatives of each of the action plans were also examined.

To continue the assessment, a relative comparison was undertaken among the four adaptation actions chosen, in which the performance of each action was measured against another, one criterion at a time. Because the Likert scale for this criterion was set at one to five, the building and maintenance of drainage and canals had the greatest potential to prevent flood

damage of the four action plans; thus, a score of five was assigned to them. In comparison, the drainage system and green area received four points, whereas the green area alone and empowerment and capacity development of vulnerable groups received three points. The scoring is also accompanied by a comparable colour spectrum, ranging from green for the best performance to red for the worst. There is no need to normalise the results because all of the selected criteria use the same scoring system (i.e., Likert scale).

Table 8: Criteria Weighting.

Criteria Weighting							
				Stakeholder 1			
				Task 1	Task 2	Task 3	
Category of Criteria	Criteria	Units	Impact Range	Rank	Importance	Values	Weights
Climate	Flood disaster reduction	"1-5"	2	1	Very High	100	37.0%
Environment	Ecosystem restoration	"1-5"	3	3	Moderate	50	18.5%
Economic	Cost of implementation	"1-5"	4	2	High	70	25.9%
Social	Public accountability	"1-5"	2	4	Moderate	50	18.5%

Stakeholders must decide whether any criterion should be given a higher or lower weight than the others in the weighing of criteria (Table 8). The weight of each criterion was carefully considered by the group because it could influence the outcome of the adaption actions. Because the primary goal of this research is to reduce annual flooding in Suleja, flood disaster reduction criteria were determined to be the most essential and thus prioritised and assigned number one. The cost of implementation is the second most important criterion, as stakeholders debated the local government's ability to implement flood control measures, and is ranked second. The restoration of ecosystems and public acceptance were ranked third and fourth, respectively.

Similarly, the stakeholders assigned value to the criteria on a scale ranging from very low to low, moderate, high, and very high. In addition, the stakeholders supplied a brief arithmetic range to each word statement to aid in discriminating among the criteria. For example, flood catastrophe reduction that was ranked one (1) and classified as "very high" under the importance level was valued at 100, although a very high preference can be connected with 90 or 100. Stakeholders select the number that best symbolises each criterion's importance in the study region. The weight table (Table 9) shows the results of this phase.

Table 9: Results-weighted scores.

Results – Weighted Scores					
Final Score	Options	Flood disaster reduction	Ecosystem restoration	Cost of Implementation	Public acceptability
	Weights	37.0%	18.5%	25.9%	18.5%
0.68	Construction and maintenance of drainage system	0.37	0.11	0.05	0.15
0.79	Drainage system and green area	0.30	0.15	0.16	0.19
0.78	Green area only	0.22	0.19	0.26	0.11
0.65	Empowerment and capacity development of vulnerable groups	0.22	0.07	0.21	0.15

Construction and maintenance of drainage systems received the highest score (0.37) for reducing flood disasters but the lowest score (0.05) for implementation cost because this mitigation strategy will necessitate significant construction work along the river channel. This information was obtained from the results of the disaster mitigation options criterion weighting (Table 9). Drainage systems and green areas scored 0.30 for reducing flood disasters, 0.15 for restoring the ecology, 0.16 for implementation costs, and 0.19 for public approval. The "green area only" adaptation action had the highest scores (0.19) and (0.26) for ecosystem restoration and implementation costs, but the lowest (0.11) for public acceptance. The adaptation action "Empowerment and capacity development of vulnerable groups" received a score of 0.15 for public acceptability, 0.21 for cost of implementation, and 0.07 for ecological restoration.

Table 10: Final result – ranking.

RESULTS – Ranking		
Options	Score	Rank
Green area only	0.78	2
Construction and maintenance of drainage system	0.68	3
Drainage system and green area	0.79	1
Empowerment and capacity development of vulnerable groups	0.65	4

The final adaptation action plans' evaluation criteria are substantially included in the highly participative CLIMATE Prio tool. The adaptation action plan that proposed a combination of concrete drainage systems and green spaces received a 0.79 on the evaluation scale and was chosen as the best appropriate adaptation action plan for the recurring flood in the Suleja local government area. Plans for adaptation that only affect green areas came in second, while the creation and upkeep of drainage systems came in third with a score of 0.68. The adaptation action plan that calls for the empowerment and capacity building of vulnerable populations received a score of 0.65, ranking fourth overall.

The application of a stakeholder-informed Multi-Criteria Analysis (MCA) in this study highlighted the critical need for integrated structural and nature-based solutions to address Suleja's persistent flood risks. Among the prioritized interventions, the construction of flood walls along riverbanks and the preservation of green areas for water retention emerged as the most feasible and effective options under both current and future climate change effects. This aligns with findings by Fernandez and Lutz (2020), who demonstrated that combining gray infrastructure (such as flood barriers) with green solutions (like urban wetlands) improves long-term flood resilience, particularly in resource-constrained urban environments.

The prominence of drainage system upgrades in the MCA results echoes the work of de Brito and Evers (2019), who observed that in developing cities, inadequate drainage is often a more immediate flood driver than rainfall extremes alone. Importantly, the participatory MCA method adopted in this study ensured that community and stakeholder perspectives, including area town planners, resident surveyor, resident engineer, area land officer, community-based organisations, and State Emergency Management Agency, were integrated into decision-making, enhancing both the relevance and legitimacy of the final action plan. This participatory approach has also been supported by Papaioannou et al. (2017), who emphasized the value of multi-stakeholder engagement in increasing the acceptability and sustainability of the flood risk strategies.

Overall, the study demonstrates that climate-informed, stakeholder-driven MCA tools such as the Climate Prio framework are instrumental in guiding flood risk management policies that are both context-sensitive and forward-looking.

4. Conclusion

As the effects of climate change (such as rising temperatures, sea level rise, and flooding) continue to worsen, it is essential to recognise the need to act and reduce a city's vulnerability and increase their adaptive capacity. Prioritising and creating a plan for addressing climate change effects can be done using multi-criteria analysis. This study applied a Climate Prio-assisted Multi-Criteria Analysis (MCA) to flood risk management in Suleja, Nigeria, with emphasis on stakeholder-driven decision-making. The results underscored the necessity of a dual-action strategy that combines structural measures, such as the construction of flood walls and improved drainage systems, with ecosystem-based solutions, including the preservation of green spaces for water retention. By involving local stakeholders throughout the assessment process, the study not only enhanced the legitimacy and social acceptance of the proposed interventions but also revealed critical gaps in local preparedness, funding, and infrastructure planning.

The findings provide actionable insights for policymakers, emphasizing the need to incorporate climate-informed risk tools into local and regional planning frameworks. Given Suleja's limited financial and institutional capacity, the prioritization of cost-effective, multifunctional solutions, guided by participatory processes, can serve as a model for other flood-prone urban areas in Nigeria and beyond. Ultimately, this research demonstrates that combining stakeholder engagement with forward-looking climate analytics is not only feasible but essential for building adaptive, inclusive, and resilient flood risk governance systems.

References

- Adelekan, I. O. (2015). *Urbanization and flood risk in Nigeria: Current realities and future prospects*. Environmental Research Letters, 10(2), 024008. <https://doi.org/10.1088/1748-9326/10/2/024008>
- Aerts, J. C. J. H., Botzen, W. J. W., Emanuel, K., Lin, N., de Moel, H., & Michel-Kerjan, E. O. (2018). *Integrating climate change adaptation into flood disaster risk management: Comparing approaches and tools*. Annals of the New York Academy of Sciences, 1427(1), 77–91. <https://doi.org/10.1111/nyas.13919>
- Birmah M.N., Kigun P.A., Alfred Y.B., Majidadi ST., & Surajo L.A., (2021). Flood assessment in Suleja Local Government Area, Niger State, Nigeria. *International Journal of Research Publication and Reviews*, 2(3), 219-239. www.ijrpr.com
- City population (2022). Suleja (Local Government Area, Nigeria)-Population Statistics, Charts, Map and Location. https://citypopulation.de/en/nigeria/admin/niger/NGA027023_suleja/
- De Brito, M. M., & Evers, M. (2019). *Multi-criteria decision-making for flood risk management: A review of the current state of the art*. Natural Hazards and Earth System Sciences, 19(2), 313–332.
- EM-DAT, (2019). The International disasters database. www.emdat.be Accessed 21 Sept 2024
- Fernandez, P., & Lutz, M. (2020). *Assessing hybrid flood risk mitigation strategies using MCDA under climate uncertainty*. Water, 12(3), 742.
- Grafakos S., (2017, October 31). *Planning for Climate Change in African Cities* [course Presentation]. Institute for Housing and Urban Development Studies (IHS), Netherlands. <https://www.coursera.org/learn/climate-change-africa>

- Hall, J., & Solomatine, D. (2008). A framework for uncertainty analysis in flood risk Management decisions, *International Journal of River Basin Management*, 6(2), 85-98. DOI: 10.1080/15715124.2008.9635339
- IPCC. (2021). *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press.
- Linkov, I., & Moberg, E. (2012). *Multi-Criteria Decision Analysis: Environmental Applications and Case Studies*. CRC Press.
- Malczewski J. (2009). Central place theory. *International encyclopaedia of human Geography*. 26-30.
<https://www.sciencedirect.com/science/article/abs/pii/B9780080449104010427?via%3Dihub>
- National Emergency Management Agency (NEMA). (2021). *Annual Disaster Report for Nigeria*.
- Office for the Coordination of Humanitarian Affairs (2024). NIGERIA: Floods Situation Report No. 3 <https://reliefweb.int/report/nigeria/nigeria-floods-situation-report-no-3-15-october-2024>
- Okotoni, O., & Akintola, O. (2013). Capacity of Local Governments for Disaster Risk Reduction in Nigeria. *International Journal of Disaster Risk Reduction*, 6, 1-7.
<https://doi.org/10.1016/j.ijdr.2013.03.001>
- Olivotto V, (2017, October 31). *Planning for Climate Change in African Cities* [course presentation]. Institute for Housing and Urban Development Studies (IHS), Netherlands. <https://www.coursera.org/learn/climate-change-africa>.
- Ornguze, S. N., Ikusemoran, M. & Sambo, G.H., (2023). Multi-criteria decision analysis for assessment of flood disaster risk and vulnerability in makurdi local government area of Benue state, Nigeria. *Zaria Geographer*, 30(1), 74-90.
<https://www.researchgate.net/publication/379599968>
- Orizu, U. (2022, Oct 25). Flooding and need for more Dams in Nigeria. *Thisday news paper*
<https://www.thisdaylive.com/index.php/2022/10/25/flooding-and-need-for-more-dams-in-nigeria>
- Papaoiouannou, G., Vasiliades, L., & Loukas, A. (2017). A Flood Risk Multi-Criteria Decision Analysis approach for developing adaptation strategies under climate change. *Science of the Total Environment*, 578, 498–512.
- Papaoiouannou, G., Vasiliades, L., & Loukas, A. (2018). *Flood vulnerability assessment using MCDA and GIS: A case study in Greece*. *Water Resources Management*, 32(3), 1221–1239.
<https://doi.org/10.1016/j.scitotenv.2015.08.055>
- Rowland, S.W., Reiter, M.A., Cowan, L.C., Gaebel, S, Griffin, R, Hellmann, J. E., Whitney, K, J., Hyde, T.L., Morelli, T.L., Morisette, J.T., Pennington, R. C., Poley, A. J., Peterson, D. L., Prasad, R., Staudinger, M.D., Sutton-Grier, A.E., Thompson, L., Vose, J., Weltzin, J.F., & Withey, K.P. (2020). Climate change effects on biodiversity, ecosystems, ecosystem services, and natural resource management in the United States, *Science of The Total Environment*, 733,
<https://www.sciencedirect.com/science/article/pii/S0048969720312948>
- Simon H. A., (1960). The new science of management decision. Volume 3 of Ford distinguished lectures. Harper, the University of Michigan.
http://books.google.com/books/about/The_New_Science_of_Management_Decision.html?id=nktqAAAAMAAJ
- United Nation Climate Change (2020). *Climate change is an increasing threat to Africa*.

- <https://unfccc.int/news/climate-change-is-an-increasing-threat-to-africa>
United Nation Framework Convention on Climate Change (2012). *National adaptation plans: Technical guidelines for the national adaptation plan process*.
https://unfccc.int/files/adaptation/cancun_adaptation_framework/application/pdf/naptechguidelines_eng_high_res.pdf
- Trung, T.N., Ulrike, G., Frank, N., Dil, B. R., Manh, H. D., & Gokul, P.P., (2023). Security risks from climate change and environmental degradation: Implications for sustainable land use transformation in the Global South. *Current Opinion in Environmental Sustainability*, 63, 18773435.
<https://doi.org/10.1016/j.cosust.2023.101322>.
- The United Nations world water development report 2020: water and climate change
Corporate author: UNESCO World Water Assessment Programme [605] ISBN:978-92-3-100371-4 Collation: 219 pages : illustrations, maps Language: English Year of publication:
<https://unesdoc.unesco.org/ark:/48223/pf0000372985.locale=en>