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RESEARCH ARTICLE

Climate Change and Urban Risks: Understanding and Analysing the Vulnerability of the City Of Brazzaville in the Republic Of Congo to Flooding in 2023

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ABSTRACT

The aim of this research is to understand and analyze the vulnerability of the city of Brazzaville in Congo to urban flooding in 2023. In order to achieve the research objectives, set, a research methodology based on socio-economic indicators (such as level of income and education, gender, age), exposure indicators (such as height of water, duration of flooding, building materials and location), sensitivity indicators (such as flood experience, causes of flooding, length of time in the area,.) and adaptive capacity (relief and assistance, return to normality, risk response and coping strategies). Analysis of the data collected from 287 people during the field surveys shows that rainfall in 2023 was above normal. The findings of this research show that 62.9% of the people surveyed were unaware of the potential dangers, while 37.1% had only a partial understanding of them. In addition, it was found that 52.2% of residents in areas at risk of flooding were unaware of the threat of flooding in their locality. During this period, the Congo administration provided relief items such as food, medicine and temporary shelter to some of those affected. In the light of the results obtained, it is recommended that the Congolese government (in Brazzaville) step up efforts to raise awareness of the risks of flooding and develop indicators to strengthen the resilience of urban areas to this phenomenon.

INTRODUCTION

Urban centers have increased vulnerability to many natural adversities due to the concentration of population, infrastructure and economic activities within their boundaries (Smith et al., 2017). This vulnerability depends on a number of factors, including geographical position, approaches to urban development, compliance with building regulations and degree of emergency preparedness (Brown & Jones, 2020). Location near coasts or rivers increases exposure to specific hazards such as hurricanes and floods, making urban settlements in these areas potentially vulnerable to devastation. (Garcia et al., 2019).

In addition, it is essential to recognize that urban centers can also be vulnerable to the ramifications of changing weather patterns, severe storms and rising sea levels, leading to more frequent and severe natural disasters (Johnson, 2018). The haphazard expansion of urban areas, the proliferation of informal settlements and the inadequacy or absence of sanitation infrastructure all contribute to amplifying vulnerability to hazards in urban landscapes (White et al., 2021).

In essence, the complex interaction of geographical, socio-economic and environmental factors underlines the multifaceted nature of urban vulnerability to natural disasters, requiring comprehensive mitigation and adaptation strategies to build resilience and mitigate the impact of these events on urban populations (Garcia & Smith, 2023).

This study understands flood risk as the combination of the probability of flooding and its adverse consequences. Similarly, the hazard is perceived as an unforeseen natural event. Risk is defined as a physical event resulting from possible or random natural phenomena. The measurement of adaptive capacity incorporates factors such as poverty level, level of education, gender and age. Within this framework, vulnerability is conceptualized as the gap between a community's adaptive capacity and its propensity and exposure to hazards. Clearly, the propensity to harm is a major aspect of vulnerability. Gleyze (2018) and Leneveu and Mary (2020) strongly support this idea in their research, emphasizing that vulnerability is closely linked to potential negative impacts. In their work (Gleyze, 2018; Leneveu and Mary, 2020), vulnerability is generally associated with a propensity to cause damage.

The vulnerability of the city of Brazzaville to flooding is a subject of vital importance, given the high risks incurred by this metropolis in the event of extreme weather events. Its particular topography, made up of hills and plains along the Congo River, and its dense urbanization, exacerbate its vulnerability to flooding (Boukary et al., 2019). The intense rainy season, which generally lasts from September to November, exposes the city to an increased risk of flooding, especially in low-lying, poorly drained areas (Kimpouni and Mabiala, 2020).

In addition, rapid population expansion and unregulated urbanization have led to the erection of informal housing in flood-prone areas, exacerbating the fragility of the most disadvantaged communities. (Kaya and Makaya, 2018). The saturation of drainage infrastructures and the pollution of waterways by waste also contribute to worsening the effects of flooding in Brazzaville (Nkoua-Nzila et al., 2021).

In addition, the limited capacity of local authorities to implement flood prevention and management measures and the lack of adequate protective infrastructure increase the city's vulnerability (Moussa et al., 2020). The effects of climate change, including the predicted increase in rainfall and extreme weather events, further underline the urgency of strengthening Brazzaville's resilience to flooding (Mfoutou et al., 2019). In conclusion, the vulnerability of the city of Brazzaville to flooding is the result of a combination of natural, socio-economic and environmental factors. Urgent measures are needed to mitigate these risks, including investment in drainage infrastructure, management of at-risk areas, and improved disaster preparedness.

The impact of the 2023 floods in Brazzaville was considerable, exacerbating the already existing challenges facing the city in terms of natural disaster management. The heavy rains that hit the region caused widespread flooding in many parts of the city, resulting in significant material damage, loss of life and massive displacement of people (Makaya et al., 2024).

The worst affected areas were often those located in low-lying, poorly drained areas, where informal housing was widespread and the lack of adequate drainage infrastructure amplified the effects of the flooding (Nkoua-Nzila et al., 2023). Residents of these areas were forced to leave their homes in a hurry, and often lost all or part of their possessions.

In addition, the floods had a significant impact on the city's infrastructure, damaging roads, bridges, water supply networks and sanitation systems (Boukary et al., 2024). The disruption to essential services has hampered relief and rehabilitation efforts, compounding the suffering of those affected. In economic terms, the floods of 2023 also had negative repercussions, affecting the livelihoods of the inhabitants and disrupting the city's commercial and industrial activities (Kaya and Makaya, 2024). The costs of reconstruction and rehabilitation were considerable, putting a strain on the already limited resources of the local authorities.

The urban living environment encompasses all the elements that make up our living space. According to Sachs (1992), this concept also includes urban management, the democratization of management practices, and the integration of urban issues into public policy. In the context of Brazzaville, the urban environment encompasses the issues of liquid sanitation and rainfall management.

The Brazzaville metropolis faces a number of environmental challenges, including spatial planning, water erosion, flooding and the vulnerability of urban infrastructure. The non-application of urban planning documents and anarchic land use, particularly in informal neighborhoods subject to the arbitrariness of landowners and residents, contribute to the emergence of erosion sites (Nzoussi and Li Jeng, 2014), with the corollaries of silting up and flooding.

Natural disasters and human activity have made several districts of the Congo's capital vulnerable. This susceptibility is due to a number of intersecting causes, such as heavy rainfall, the rapid increase in the urban population, unofficial land appropriation and various elements that exacerbate environmental hazards. For example, in December 2023, heavy rains caused material damage and loss of life. The rain also submerged homes and roads, causing disruption to traffic.

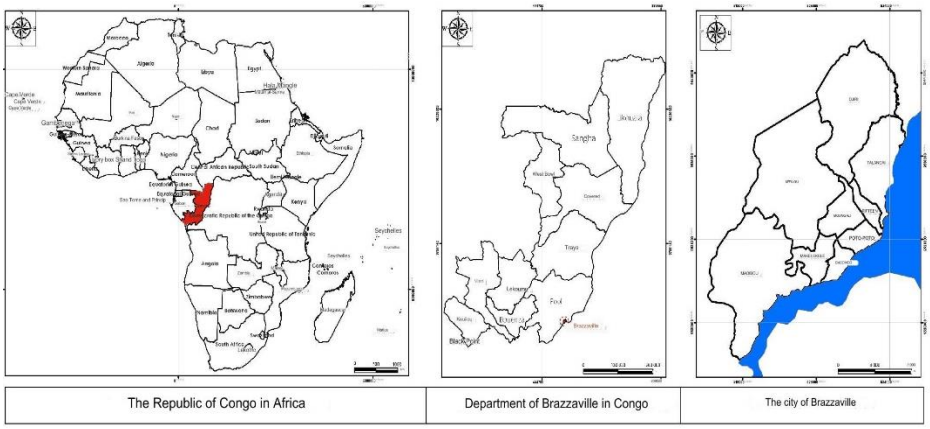
In summary, the floods of December 2023 left a devastating impact on the city of Brazzaville, highlighting the urgent need to strengthen natural disaster prevention and management measures in order to protect vulnerable populations and reduce the city's vulnerability to extreme weather events. The aim of this research is to analyze the vulnerability of the city of Brazzaville to flooding in December 2023.

2. METHODOLOGY

2.1. Study area

Brazzaville is the capital of the Republic of Congo and its main metropolis. It is located on the right bank of the Congo River, with geographical coordinates of 4°16'10'' south latitude and 15°16'16'' east longitude. It is bounded to the north by the Djiri river, to the south-east and east by the Congo river, and to the north-west, west and south-west by the Pool department. It covers an area of 32,640 ha, with a population of 2,141,788 (RGPH-5, 2023), giving a population density of 65,618.50 inhabitants per square kilometer.

The Brazzaville site has a contrasting landscape juxtaposing two (02) types of relief: plateau and plains in the form of steps, sloping NW-SE. It is made up of high areas with altitudes of between 350 and 650 m in the north and north-west parts, medium areas with altitudes of between 290 and 350 m and low areas with altitudes of between 220 and 290 m, consisting mainly of alluvial plains in the east and in the catchment areas of the main rivers.



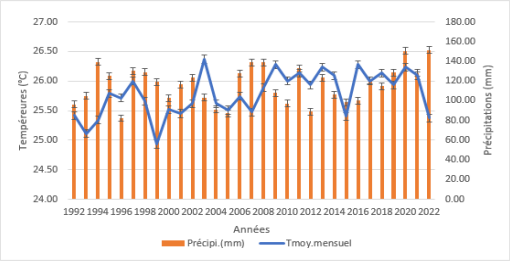
Map № 1: Location map of the city of Brazzaville
Source : Emvoulou, 2024

The city of Brazzaville is administratively divided into nine arrondissements: Makélékélé, Bacongo, Poto-poto, Moungali, Ouénzé, Talangaï, M'filou, Madibou and Djiri. This dynamic, multi-faceted city attracts a

large influx of new residents every year, and together with the District of Ile Mbamou forms the Department of the same name.

2.2. Climate

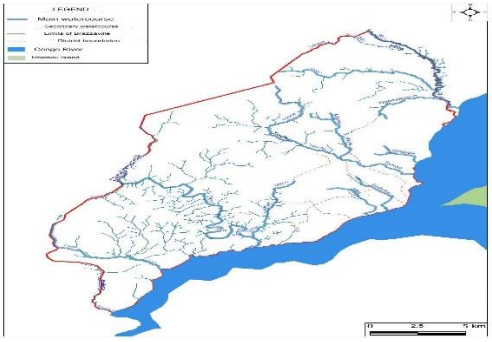
Brazzaville has a humid tropical climate, characterized by an alternating rainy and dry season (M. J. Samba-Kimbata, 1978, p.102). The rainy season lasts about eight months (October to May), with a decrease in the number of rainy days in January and February, corresponding to a drop in rainfall. Average rainfall in 2022 was nearly 1,500 mm/year (ANAC, 2022). Rainfall intensities often exceeded one millimeter per minute (1mm/min), and the frequency of rainfall, of the order of 15 to 17 rainy days per month, does not give the ground time to dry out. As a result, there is a tendency for instant flooding, which causes major damage. The average monthly temperature is relatively high (25°C) and the dry season lasts only four months (June to September), with an almost complete cessation of rainfall during the first three months (graph № 1). During rainy periods, on the Tsiémé for example, the height of the water varied from 0.70 to 1.66 m (Tsiémé Station, 2022). The surveys revealed that in December 2023, the duration of water stagnation after heavy rainfall was one day in 27% of plots, two days in 40%, and up to more than a week in 23%, particularly in the Ngamakosso bay in Talangaï (map no. 3).



Graph № 1: Change in average monthly temperature and rainfall in Brazzaville over the period 1992-2022
Source : ANAC, 2022

2.3. Hydrography

Brazzaville's hydrographic network is entirely included in the Congo River basin and is made up of rivers that cross the city from west to east, the most important of which are: the Djiri, the Kélékélé, the Tsiémé, the Madoukou, the M'foa, the M'filou, the Djoué and the Loua. The Djiri in the north, with an average flow of 300 m^3/second, and the Djoué in the south, with a flow of almost 500 m^3/second, are the most important rivers. On the other hand, the Tsiémé in the center, flowing through five (05) districts, is the largest catchment area, covering 6,370 ha (Egis BCEOM, 2009). All these rivers have their sources in the upper part of the city, and flow into the Congo River, crossing lowland areas such as Talangaï, Ouénzé, Moungali and Poto-Poto (Map 2). This river morphology makes the banks in these parts of the city permanently vulnerable to flooding from high water during the rainy seasons.



Map № 2: Hydrographic network of the city of Brazzaville
Source: Emvoulou, 2024

2.4. The floods of 2023

The 2023 floods in Brazzaville wreaked considerable havoc, affecting tens of thousands of people and causing significant material damage and loss of life. According to official reports (Ministry of the Interior, 2023), around 60,000 people were affected by the floods, while the tragic death toll rose to 6.

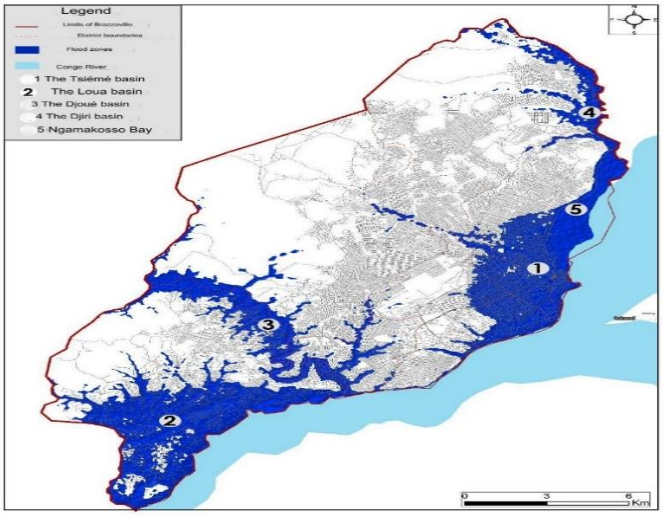
The floods destroyed or damaged 34 health centers, 120 schools and more than 64,000 homes in the affected areas. Humanitarian needs are expected to increase, which will further worsen the situation of affected populations, particularly vulnerable communities. The damage caused by the flooding has been extensive, with bridges washed away by rising rivers, schools and homes damaged or destroyed. These material losses have had a significant impact on people's daily lives, particularly in the worst-hit neighborhoods.

In addition, the town was paralyzed for several days due to the inaccessibility of the roads, made impassable by the stagnant water. This situation hampered rescue operations and made it difficult for residents to move to safe areas. In addition, essential services such as water and electricity were interrupted in several parts of the city, compounding the difficulties faced by the population already suffering from the floods.

Table № 1: Summary description of flooding

Main causes	**Heavy rain**
Extent of flooding (1 à 3)[1]	3 (high)
Severity level (1 à 4)[2]	3 (high)
affected area (km²)	8
Duration (days)	20
People affected	60 000
Damage to infrastructure	3 (fort)
Number of deaths	6

The floods paralyzed more than 40% of the city's surface area for weeks, preventing people from going about their normal business. The scale of the flooding was so great that essential urban services were disrupted in several parts of the city.



Map № 3: Flood zones in 2023
Source: Emvoulou, 2024

Scale: 1 – Low; 2 – medium; 3 – high[1]
Severity: 1 – Low; 2- medium; 3 - high; 4 – exceptional[2]

2.5. Vulnerability analysis

The sensitivity of the socio-economic, urban and ecological systems affected, or, more generally, their capacity to be impacted by a hazardous event, determines the actual extent of the damage caused by a given flood (Cutter 1996, Mitchell 1989). In general, the more vulnerable an element is, the more it is exposed to a hazard and the more sensitive it is to its forces and impacts, the more likely it is to be damaged or to malfunction. These factors can therefore be described in terms of indicators of elements at risk, indicators of exposure, indicators of sensitivity and their ability to withstand a shock, which are necessary for any analysis of vulnerability to flooding (Messner & Meyer. 2006).

For Attipo et al (2023), the analysis of flood vulnerability must be holistic and systemic in order to take into account not only indicators relating to exposure and sensitivity, but also to integrate social and economic indicators and the adaptive capacity of the environment in contact with the risk. The Intergovernmental Panel on Climate Change (IPCC) characterizes climate vulnerability as resulting from the interaction between adaptive capacity, sensitivity and exposure. This description corresponds to the holistic approach to vulnerability analysis emphasized by Attipo et al (2023). According to Füssel and Klein (2006), the risk-hazard pair (biophysical approach) can be equated with sensitivity in the IPCC lexicon, whereas adaptive capacity (relating to overall social development) corresponds to the socio-ecological approach. For the purposes of this research, vulnerability will be defined as follows:

Vulnerability = (Exposure + Sensitivity) - (Ability to adapt).

These vulnerability indicators are accompanied by sub-indicators for each sector in order to facilitate data collection in the study area. Each indicator is made up of several sub-indicators in order to facilitate a holistic approach to analyzing the vulnerability of the city of Brazzaville to flooding. The table below summarizes the various sub-indicators involved in this vulnerability analysis :

Table № 2: Vulnerability analysis indicators

Socio-economic indicator	**Exposure indicator**	**Sensitivity indicator**	**Adaptability indicator**
Age	Losses and damage	Type of house	Responses to risks
Occupation	Quality of wastewater infrastructure	Experience of flooding	Adaptation measures
Sex	Location	Perception of risk	Return to normal
Income	Duration of flooding	Cause of flooding	Reduction measures
Level of education	Height of water	Knowledge of risks	Rescue and Assistance

Source: Attipo (2023)

The information gathered focuses mainly on four key variables: people's socio-economic characteristics (such as age, gender, level of education, occupation, etc.), risk exposure factors (such as flood frequency, proximity of dwellings to watercourses, etc.), elements revealing people's susceptibility to flooding (including flood duration and depth, risk perception, past experience, etc.), and the adaptive capacity of urban systems.

The main sources of secondary data were annual reports from fire stations, reports from the National Environmental Protection Agency, recorded reports, published research on flooding in Brazzaville, official websites, local newspapers and scientific periodicals. The national meteorological station in Brazzaville provided rainfall data. We collected data from these institutions on the industry's most vulnerable to flooding, the national government's preventive and remedial actions, losses and damage in the city, how people have adapted, etc.

By combining these different variables, we can better assess the complexity of flood-related risks and develop effective strategies for reducing risk and adapting to climate change.

3. ANALYSIS AND RESULTS

3.1. Socio-economic indicators

During the data collection process, 287 people were interviewed, including 117 women (40.77%) and 170 men (59.23%). The research area is heterogeneous in terms of educational level, as shown by the fact that 29% of respondents said they had higher education, 36% secondary or post-secondary education, 19% only basic schooling and 16% no formal education at all. Most of the respondents belonged to the unorganized sector (32.7%), traders (16.9%), the unemployed (3.2%) and farmers (6.9%), although 8.8% of respondents were students and 31.5% civil servants. 46.9% of respondents earned more than 250,000 CFA francs a month, while 53.1% earned at least 250,000 CFA francs. Most of the respondents had modest incomes. The age distribution of respondents was as follows.

Table № 3: Age groups of people surveyed

Age group	**Number**	**percentage**
18-25	19	6.62 %
26-35	39	13.58 %
36-45	79	27.52 %
46-55	99	34.49 %
56-65	51	17.77 %

3.2. The exposure indicators

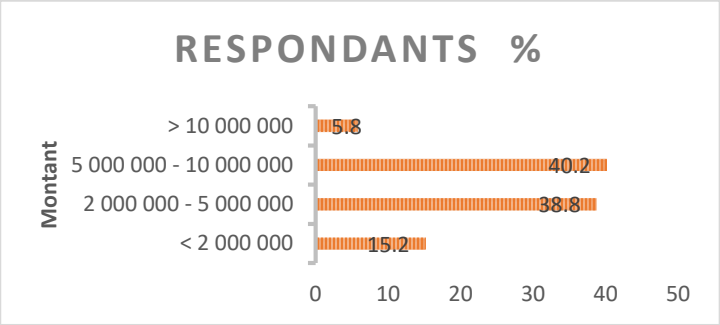
Location of infrastructures

The findings of the field investigations reveal that the susceptibility of homes to flooding in 2023 was not directly attributable to their proximity to lagoons or outfalls, but also to the inadequacy of rainwater retention and drainage systems, which exacerbates the risk of flooding and amplifies damage and losses. Research shows that 73% of people surveyed live more than one kilometer from a river, lagoon or the sea. However, 5.5% live less than 250 meters from a lagoon or river, while 21.5% live between 250 and 900 meters. The cascading effects of flooding seem to contribute in part to the spread of the risk of flooding in various parts of the city. The vulnerability of urban infrastructure and housing during the 2023 floods was not only due to their proximity to canals, lagoons and sewers, but also to inadequate construction and management of river water and drainage systems, which increased the risk of flooding. Floods and the damage they cause result in losses. According to the study, 73% of respondents live more than one kilometer from a river, lagoon or ocean. A further 5.5% live less than 100 meters from a lagoon or river, while 21.5% live between 100 and 500 meters away.

Losses and damage in the city

The usual precariousness of housing is exacerbated by a combination of factors including the lack of adequate infrastructure, the limited centralization of technical services, the high cost of building materials,

the scarcity and high cost of housing loans due to the lack of appropriate resources and the difficulties of borrowers in providing the guarantees required by financial institutions. The diagram below illustrates the losses and damage reported by respondents during field investigations in the study area.



graph № 1: cost of losses and damage

Taking into account the national economic context and people's income levels, the losses and damage suffered by respondents as a result of the 2023 floods were assessed as being particularly considerable. This confirms the scale and severity of the disaster.

The duration of flooding

Rising water levels can have a significant impact on buildings, especially when they exceed the usual benchmark. The basic structure of homes may be altered, while floors and walls may become waterlogged. If the flooding continues over a long period (even 48 hours), hygiene problems can arise, as the water is often contaminated by sewage and sometimes by fuel oil from tanks. The speed of the current depends on the gradient and roughness of the bed, and can reach several meters per second. The height and velocity of the current combine to make it dangerous. For example, above a speed of 0.50 m/s, the current becomes dangerous for people, exposing them to the risk of being swept away by the waves or struck by objects propelled at high speed. A significant proportion of those surveyed found themselves vulnerable due to the rising water levels in their area. Indeed, 73.7% of participants estimated that the water level had risen to 1m above the ground, while 26.3% estimated it at less than 1m (between 0.5 and 0.8).

When asked how long it took to return to normal after flooding, 13.9% of people said that the adverse effects lasted for more than two months, or around eight weeks. A further 49.2% said they had endured flood conditions for a month, equivalent to four weeks, while 36.9% said they had been under water for a fortnight.

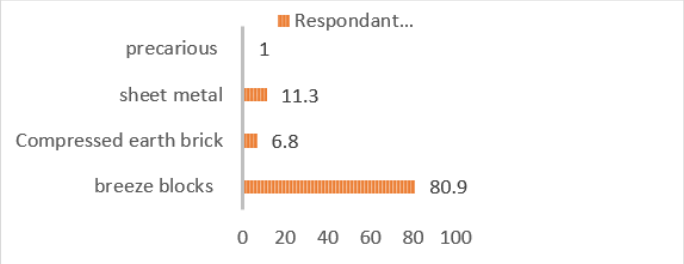
3.3. Sensitivity indicators

Experience of flooding and how long it lasts in the city

This research supports the idea that learning through practical experience can help to meet this challenge by collecting data on the ground and tracing the unfolding of situations and events in their spatial-temporal dimensions, in order to better understand and learn from crucial and unavoidable issues. This approach was also emphasized by researchers many years ago and is intended to provide a basis for comprehensive risk and disaster management planning, which may include various response elements (Attipo et Al, 2023). It helps us to deepen our understanding of crisis and risk management strategies and events.

Twenty years before the disaster, 31.7% of those surveyed were living in the area. Of these, 29.8% said they had lived there for ten years, of which 22.9% had moved five years ago and 15.6% had been there for between one and four years. Only 31.7% of residents had been here for at least twenty years, meaning that the lessons learned from past events remain relevant today.

Analysis of the data reveals that 80.9% of homes in the study area are built of cinder blocks, 6.8% of compressed earth bricks, 11.3% of metal sheets, and 1% of precarious materials. As the graph below shows



graph № 2 : Types of building materials

Awareness and perception of flood risks

Recognition of low-lying areas (2.2%), occupation of main and tributary watercourses (3%), increased rainfall in previous years (3.1%), poor and inadequate stormwater drainage systems (29.3%) and obstruction of drainage systems were identified as early signals to be taken into account. However, 52.2% of respondents said they were not aware of the local flood risk. The issue was not addressed by 10.2% of respondents.

Risk apprehension is the process by which individuals or groups identify, evaluate and judge the potential hazards associated with a given situation, action or choice. This requires a personal assessment and interpretation of the likelihood and severity of adverse consequences or potential harm. The way in which risks are perceived is influenced by various factors, including psychological, social, cultural and individual aspects. According to the study conducted by Bubeck et al (2012), risk perception refers to the assessment of the threat and likelihood of generally adverse outcomes, as perceived by a community or society.

Kellens et al (2011) argue that flood risk perception analysis focuses on how individuals perceive, feel and react to a threat. This facet is essential for assessing fragility, and a number of studies have shown that flood preparedness has a significant impact on how risk is perceived.

The perception of risk was shared by 62.9% of respondents who had already experienced flooding, compared with 37.1% who had never experienced flooding. The presence of the river and watercourses has not led to a significant increase in the perception of risk. The result is growing vulnerability.

3.4. The ability to adapt

In the event of flooding, emergency aid remains the main measure, providing material, food and health assistance to those affected. Shelters are also set up to house and care for the homeless until the waters recede. Local authorities have often been absent from flood management due to internal organizational flaws. The ability of the local population to cope with the risks helped to mitigate to some extent the harmful effects of flooding in urban areas. Residents have mobilized their knowledge to cope with flooding. Some 63% of respondents said that they had dug canals to facilitate the drainage of rainwater. A number of people affected by the floods benefited from government aid, mainly in the form of temporary emergency shelters and emergency aid supplies such as medicines, food and clothing. Of the beneficiaries of this government aid, 93% were low-income individuals.

Flood victims were asked about decisions or actions they had taken personally to reduce the risk of vulnerability to flooding in their area or home. Here are the results of the surveys.

As for responsibility for flood management, the vast majority of participants (97%) do not attribute this to governments, believing that they are not at the forefront of implementing sustainable urban development strategies, particularly with regard to urban resilience to flooding.

4. DISCUSSION

The approach adopted, which aims to take account of the various perspectives on vulnerability, justifies the multitude of indicators used. This work is based on examining the city with a shared vision of vulnerability.

It is important to stress that the competition between indicators reflects the social and objective dynamics that characterize a society, as it is essential to select a limited number.

The already fragile socio-economic situation deteriorated further following the floods. While many residents were forced to stop working, some lost their means of subsistence (such as damaged motorbikes, market stalls and various businesses).

The government has fallen behind in responding to the urgent needs of the large number of refugees scattered across the city, resulting in a crisis that is perceived as difficult to resolve. However, the most serious consequence lies elsewhere: sanitary conditions have deteriorated during these events, depriving the population of electricity and, consequently, of the possibility of storing food safely, thereby encouraging contamination and the spread of bacteria. The need to use candles for lighting increases the risk of accidental fires, which have multiplied in the space of a week. Above all, access to drinking water is restricted for the population, making it virtually impossible to maintain basic hygiene standards, at a time when increased vigilance is needed (Amoako et al, 2020).

Urban flooding in Brazzaville is the result of a complex combination of factors, including uncontrolled urban expansion, inadequate water infrastructure such as sewerage and drainage systems, inadequate waste management and the impacts of climate change. In 2023, Brazzaville experienced particularly heavy rainy seasons, resulting in considerable material damage and loss of life. The severity of the flooding varied from one area to another. The government authorities and their partners reacted swiftly. The urban floods of 2023 highlighted the fragility of the population, in relation to its socio-economic attributes, its level of exposure to risk, its sensitivity, and its ability to demonstrate resilience in the face of flooding. Victims' perception of flood-related risks is greatly influenced by the institutions that provide them with assistance and regulate urban management, and this confirms the research by Nkoua-Nzila et al (2021).

In many developing nations, understanding of hazards is limited due to the paucity of archives and historical data, as well as inadequate meteorological and hydrological records. For example, the results of a recent study on floods (Hubert and Ledoux, 1999) show that forecasting is difficult due to the lack of functional local weather stations.

Indicators of anthropogenic vulnerability include all human activities that increase susceptibility to flooding. Population growth, often linked to major rural displacement that is still underway in some developing nations, has stimulated the increasing urbanization of areas at risk. A recent study by Attipo et al (2023) points out that recurrent flooding in various Central African cities is largely attributable to various factors, but mainly to human behavior, in particular the persistent settlement of populations in areas at risk of flooding. Recent research indicates that many Central African cities are increasingly facing flooding problems as a result of environmental deterioration. A poor ability to adapt to flood risks, as observed in Brazzaville, or a lack of awareness, combined with exposure and vulnerability, have resulted in multiple losses and damage.

5. CONCLUSION

For many years, the capital of Congo has been struggling with the well-documented challenge of flooding. Population growth in dense urban areas is creating increased demand for residential space. Urban expansion makes surfaces impervious to water, obstructs natural drainage systems with structures, and heavy rainfall during the rainy season exposes the population to flood risks. By examining vulnerability to flooding through socio-economic, exposure and sensitivity indicators, as well as adaptation approaches, the main vulnerabilities of communities and their inhabitants were highlighted. These adaptations are essential if we are to promote sustainable urban development. The causes of this vulnerability lie in the lack of awareness of flood risks, the occupation of flood-prone areas along watercourses, and the lack or inadequacy of rainwater drainage infrastructure in certain regions. In addition to a systemic analysis of vulnerability to flooding, this study contributes to a better understanding of risk awareness, urban

management and resilience. It advocates greater participation by the public and national authorities in urban risk management practices to ensure resilient and sustainable cities.

Author contributions:

EMVOULOU Innocent Joachim: Conceptualization, data collection and processing, writing, revision and editing

ATTIPO Reich Vanel: Analysis, revision, translation, software;

GNONGBO Tak Youssif: Supervision and correction

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REFERENCES

Amoako C and E Frimpong Boamah, 2020. Becoming Vulnerable to Flooding: An Urban Assemblage View of Flooding in an African City. Planning Theory & Practice, 21(3), 371–391. https://doi.org/10.1080/14649357.2020.1776377

Attipo RV, Emvoulou IJ and Coffi AC, 2023. Climate change and urban stormwater: vulnerability analysis of the 2010 floods in Lomé, Togo. Frontiers in Climate, 5, 1281433: 1-10.

Attipo RV and Coffi AC, 2024. Public perception and resilience to flooding: An examination of vulnerability in Brazzaville, Congo during the 2019 floods. International Journal of Design & Nature and Ecodynamics, Vol. 19, No. 1: 211-219. https://doi.org/10.18280/ijdne.190123

Boukary O et al., 2019. Analyse de la vulnérabilité aux inondations à Brazzaville. Revue Géographique de l'Afrique, 47(2) : 189-201.

Boukary O et al., 2024. Impact des inondations de 2023 sur les infrastructures de Brazzaville. Revue d'Études Urbaines, 39(3): 401-415.

Brown E and Jones C, 2020. Understanding the Socio-Economic Elements Influencing Urban Flood Susceptibility: A Case Study in Southeast Asia. Natural Hazards, 38(2): 189-201.

Cutter SL, 1996. Vulnerability to environmental hazards. Progress in Human Geography 20 (4): 529-539.

Dube K, G Nhamo and D Chikodzi, 2022. Flooding trends and their impacts on coastal communities of Western Cape Province, South Africa. GeoJournal 87 (Suppl. 4) : 453–468 (2022). https://doi.org/10.1007/s10708-021-10460-z

Füssel HM and Klein RJT, 2006. Climate change vulnerability assessments: An evolution of conceptual thinking. Climatic Change, 75: 301-329. https://doi.org/10.1007/s10584-006-0329-3

Garcia F et al, 2019. Urbanization and Flood Susceptibility: A Review of Current Knowledge. Journal of Flood Risk Management, 42(4): 567-580.

Garcia F and Smith D, 2023. Enhancing Urban Flood Resilience: Insights from Interdisciplinary Research. Journal of Environmental Management, 35(1): 112-125.

Johnson H, 2018. Socio-Economic Determinants of Urban Flood Susceptibility: Insights from Comparative Studies. International Journal of Disaster Risk Reduction, 15(1): 78-91.

Kaya A et Makaya D, 2018. Urbanisation et risques d'inondations à Brazzaville : Enjeux et défis. Bulletin de Recherche Géographique, 40(2) : 245-259.

Kaya A et Makaya D, 2024. Conséquences économiques des inondations de 2023 à Brazzaville. Revue Économique et Sociale, 30(2) : 245-259.

Kimpouni J et Mabiala B, 2020. Évaluation de la vulnérabilité des quartiers périphériques de Brazzaville aux inondations. Revue d'Études Urbaines, 35(1) : 112-125.

Makaya D et al., 2024. Analyse des impacts des inondations de 2023 à Brazzaville. Bulletin de Recherche Géographique, 42(1) : 67-82.

Messner F and Meyer V, 2006. Flood damage, vulnerability and risk perception–challenges for flood damage research. In Flood risk management: hazards, vulnerability and mitigation measures. Dordrecht: Springer Netherlands: 149-167.

Mitchell JK, 1989. Hazards research. Gaile, G.L. and Willmot, C.J. (eds) Geography in America. Columbus, OH, Merrill: 410-424.

Mfoutou A et al., 2019. Impacts potentiels du changement climatique sur les inondations à Brazzaville. Climatologie, 25(1) : 78-91.

Moussa H et al., 2020. Évaluation de la capacité de réponse aux inondations à Brazzaville : Cas du quartier Mpila. Revue des Sciences de l'Environnement, 20(4) : 567-580.

Nkoua-Nzila R et al., 2021. Étude de la pollution des cours d'eau et son impact sur les inondations à Brazzaville. Journal de l'Environnement et du Développement Durable, 28(3) : 401-415.

Nkoua-Nzila R et al., 2023. Évaluation des dégâts des inondations de 2023 dans les quartiers de Brazzaville. Journal de Géographie Appliquée, 50(2) : 189-201.

Smith L, Liang Q, James P and Lin W, 2017. Assessing the utility of social media as a data source for flood risk management using a real-time modelling framework: Assessing the utility of social media for flood risk management, Journal of Flood Risk Management, 10: 370-380. https://doi.org/10.1111/jfr3.12154

Tiepolo M, 2014. Flood risk reduction and climate change in large cities south of the Sahara. Climate Change Vulnerability in Southern African Cities: Building Knowledge for Adaptation: 19-36.

White G et al., 2021. Assessing Urban Flood Susceptibility: Integrating Hydrological and Socio-Economic Approaches." Water Resources Management, 30(2): 245-259.