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(RESEARCH ARTICLE)

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GIS-based interactive web-mapping of primary school located in flood-prone area for disaster risk reduction in Ouagadougou (Burkina Faso)

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Abstract

Flooding remains one of the most recurrent environmental hazards affecting urban areas in Sub-Saharan Africa, particularly in rapidly growing cities where urban expansion often exceeds planning capacities. In Ouagadougou, Burkina Faso recurrent floods increasingly threaten educational infrastructures and disrupt school activities. Despite the growing use of Web GIS technologies in disaster management, limited studies have explored interactive geovisualization tools for educational risk communication in African urban environments. This study aims to develop an interactive web-based geovisualization platform for mapping flood-prone areas and identifying primary schools exposed to flooding in the municipality of Ouagadougou. The methodological approach combined geospatial databases of flood susceptibility zones and primary school locations. Spatial datasets were processed in QGIS and integrated into a web environment using open source geospatial and web-mapping technologies. The platform was designed to support interactive visualization, user navigation and spatial information retrieval. The results indicate that 925 primary schools were identified within the municipality, including 227 public schools and 698 private schools. Spatial analysis revealed that 5.19 % of schools are located in areas with very high flood susceptibility, while 20.78 % are situated in highly exposed zones. Moderate susceptibility concerns 26.30 % of schools, whereas 28.35 % and 19.37 % are located in low and very low susceptibility areas respectively. The developed platform enables users to visualize flood-prone areas interactively, access spatial information dynamically and filter zones according to flood susceptibility levels. The study demonstrates that interactive geovisualization can significantly improve the communication and interpretation of flood related information in educational contexts. The study further contributes to the development of low cost spatial decision support systems for educational resilience and urban climate adaptation in rapidly growing African cities. The platform represents a useful decision support tool for local authorities, urban planners and educational stakeholders involved in disaster risk reduction and climate adaptation.

Keywords: Web GIS; Web Mapping; Flood Susceptibility; Primary Schools; Disaster Risk Reduction; Ouagadougou

1. Introduction

Floods are among the most destructive natural hazards affecting urban and rural communities worldwide. Their frequency and intensity have increased considerably over recent decades due to climate variability, environmental degradation and rapid urbanization (IPCC, 2023;Wright, 2016). Flood related disasters disproportionately affect rapidly urbanizing cities in developing countries where urban planning and drainage infrastructures remain insufficient. In many developing countries particularly in African cities, the consequences of flooding are becoming increasingly severe because of inadequate drainage systems, unplanned urban growth and population pressure in vulnerable areas (Ntajal et al., 2017; Da, 2021).

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In West Africa, flooding constitutes a major environmental and socio-economic challenge. Several countries in the Sahel regularly experience extreme rainfall events that lead to substantial human and material losses (ECOWAS, 2020; Hangnon et al., 2015). According to regional reports, floods have affected hundreds of thousands of people across the sub-region during the last two decades, causing deaths, displacement, destruction of infrastructure and the deterioration of livelihoods. The impacts are particularly significant in urban areas where informal settlements often occupy naturally flood-prone zones.

Burkina Faso is highly exposed to climate-related disasters, especially floods and droughts (Da, 2021). In recent years, the country has experienced recurrent flooding events that have caused extensive damage to housing, roads, schools and agricultural lands. The city of Ouagadougou, the political and economic capital of Burkina Faso, is one of the most affected urban areas. Rapid demographic growth and uncontrolled urban expansion have increased the occupation of low-lying and poorly drained zones, thereby intensifying flood vulnerability (Kafando et al., 2023; Hangnon, De Longueville, et al., 2015).

Several studies conducted in Ouagadougou have shown that flood hazards are influenced by both natural and anthropogenic factors. Heavy rainfall, land-use changes, soil impermeabilization and insufficient drainage infrastructure contribute significantly to the recurrence of urban flooding (Kafando et al., 2023). These events not only affect households and economic activities but also disrupt public services, including education. The increasing exposure of public infrastructures to flood hazards reflects broader urban resilience challenges observed across many African cities experiencing rapid and insufficiently regulated urban expansion.

Schools represent critical social infrastructure that should remain functional during and after disasters. However, many educational establishments in developing countries are located in environmentally vulnerable areas. Flooding can damage classrooms, interrupt learning activities, destroy educational materials and expose pupils and teachers to health and safety risks. Young children are particularly vulnerable because of their limited capacity to respond effectively during emergencies (Masocha et al., 2025; Noviana et al., 2019). Educational infrastructures therefore play a strategic role in disaster preparedness, community resilience and climate adaptation planning.

In recent years, geospatial technologies have become essential tools for disaster risk management. Geographic Information Systems (GIS), remote sensing and Web GIS applications provide efficient solutions for hazard mapping, spatial analysis and decision support. Web-based cartographic platforms also facilitate the dissemination of spatial information to a wider audience through interactive and user-friendly interfaces (Veenendaal & Brovelli, 2017; Mericskay, 2011). In this context, interactive geospatial technologies increasingly provide opportunities for improving disaster preparedness and spatial decision-making within vulnerable public infrastructures, including schools.

Interactive geovisualization has emerged as an important component of modern disaster communication. Unlike static maps, interactive web maps enable users to explore spatial data dynamically through zooming, filtering and querying functions. Such functionalities improve the understanding of spatial phenomena and enhance communication between scientists, decision-makers and communities.

Although Web GIS technologies are increasingly used in flood management, their application within educational environments remains insufficiently explored, particularly in African urban contexts. Existing studies mainly focus on hydrological modeling and flood susceptibility assessment, while limited attention has been paid to interactive geovisualization tools designed for educational risk communication and school resilience planning in Sub-Saharan Africa. There is still limited knowledge regarding how interactive geovisualization tools can support risk communication and awareness in schools exposed to flooding.

This study therefore seeks to contribute to disaster risk reduction efforts by developing an interactive web-based geovisualization platform for primary schools located in flood-prone areas of Ouagadougou. The study also contributes to the growing field of spatial decision-support systems for educational resilience and urban climate adaptation in rapidly growing African cities. More specifically, the objectives of the study are:

- To develop an interactive web mapping platform for visualizing school located in flood-prone area eas,
- To analyze the spatial distribution of primary schools according to flood susceptibility levels,
- To evaluate the contribution of geovisualization tools to flood risk communication and decision support.

Beyond the case of Ouagadougou, the study provides a transferable framework for integrating interactive geospatial technologies into educational risk management and urban resilience strategies in rapidly growing African cities.

2. Methodology

2.1. Study Area

The municipality of Ouagadougou is located in the Centre Region of Burkina Faso within the province of Kadiogo (figure 1). As the national capital and largest urban center in the country, Ouagadougou plays an important political, administrative and economic role. The municipality covers approximately 518 km^2 and is subdivided into twelve administrative districts and fifty-five sectors.

Geographically, Ouagadougou lies between latitude 12°21'56'' North and longitude 1°32'01'' West. The municipality is bordered by the rural communes of Pabré and Loumbila to the North, Saaba to the East, Koubri and Komsilga to the South, and Tanghin-Dassouri to the West.

The city has experienced rapid urban growth over the last decades due to demographic expansion and rural-to-urban migration. This rapid growth has led to the development of informal settlements in environmentally fragile areas, many of which are highly exposed to flooding. In addition, the increase in impermeable surfaces and inadequate stormwater drainage systems have intensified runoff accumulation during heavy rainfall events. These conditions have considerably increased the exposure of urban infrastructures, including schools, to recurrent flood hazards.

Ouagadougou experiences a tropical Sudanian climate characterized by a rainy season extending from May to October and a dry season from November to April. Average annual rainfall generally ranges between 700 mm and 900 mm, with intense rainfall episodes frequently generating urban flooding in low-lying districts. Rainfall variability combined with urban expansion contributes significantly to recurrent flood events within the municipality. The selection of Ouagadougou as the study area is justified by its high demographic growth, increasing flood vulnerability and the growing concentration of educational infrastructures located within environmentally sensitive urban zones.

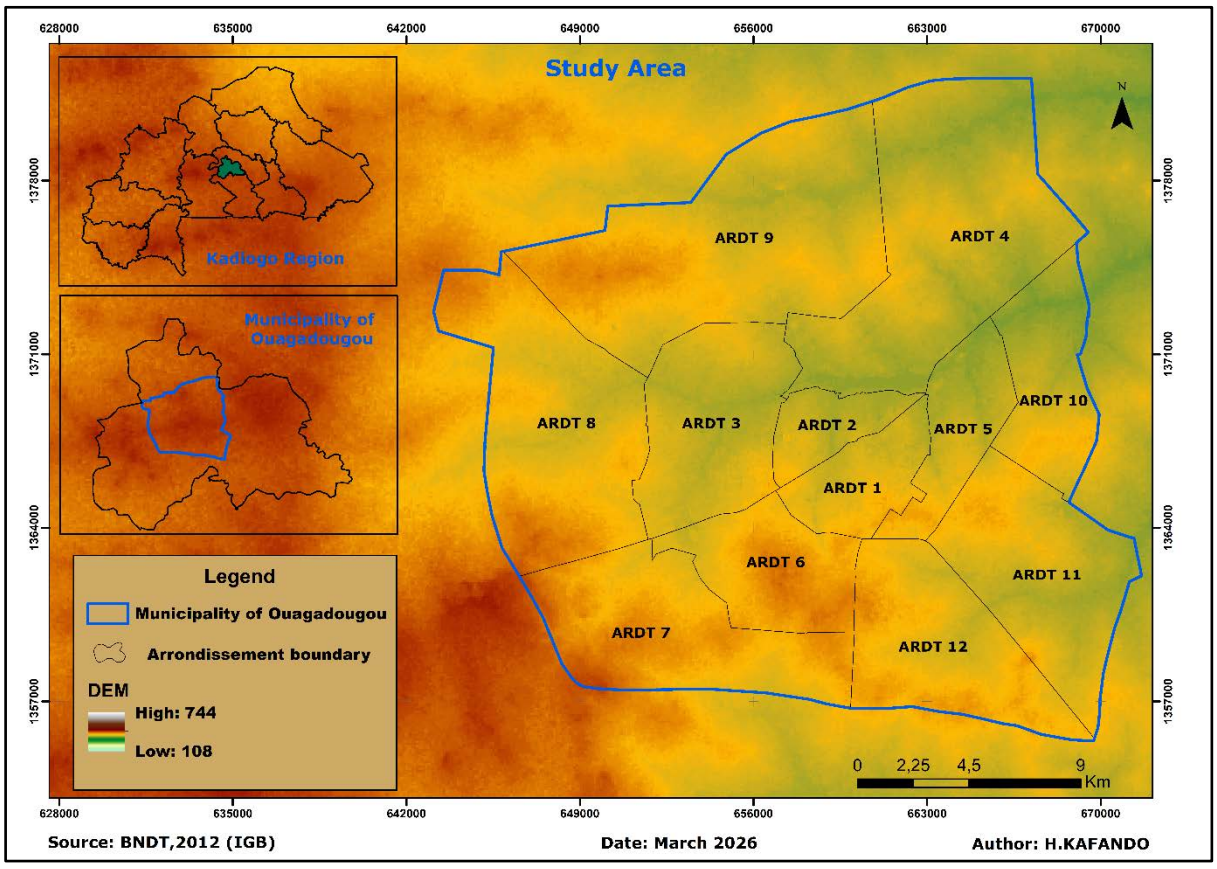

Figure 1 Study area the municipality of Ouagadougou

2.2. Data Collection and Processing

This study relied on both spatial and non-spatial datasets related to flood susceptibility and primary school distribution in the municipality of Ouagadougou. The main datasets included: A flood susceptibility database developed from previous geospatial analyses, a database of public and private primary schools obtained from educational authorities, GPS coordinates collected during field verification, Administrative boundary layers for the municipality. Field verification was conducted to improve the spatial accuracy and reliability of school location data. The collected GPS coordinates were used to validate and update the existing spatial database. The main datasets used in the study are summarized in table 1.

Table 1 Main datasets used in the study

Data The platform architecture included the following components	**Source**	**Format/Resolution**	**Acquisition Year**	**Purpose**
Flood susceptibility zones	Previous geospatial analysis	Shapefile	2023	Flood hazard mapping
Primary schools database	Ministry of Education	Excel database	2024	School distribution analysis
School spatial layer	ASPENO	Shapefile	2015	School mapping
GPS coordinates	Field survey	GPX	2024	Spatial verification

Spatial data processing and analysis were conducted using QGIS software. The different datasets were harmonized and converted into compatible geospatial formats before being integrated into the web mapping environment. Data preprocessing included coordinate system harmonization, attribute verification, geometry correction and format standardization to ensure spatial consistency across all datasets. Flood susceptibility zones were categorized into five (5) classes: Very low susceptibility, Low susceptibility, Moderate susceptibility, High susceptibility, Very high susceptibility. The classification scheme facilitated the spatial interpretation of flood exposure levels and supported the identification of schools located within highly vulnerable zones.

The spatial distribution of schools was then analyzed in relation to these flood susceptibility classes in order to identify educational establishments exposed to flood hazards.

2.3. Development of the Web Mapping Platform

The interactive platform was developed using open-source geospatial technologies and standard web development tools. The methodological framework combined spatial data management, web cartography and interactive geovisualization. The use of open-source technologies was motivated by their flexibility, accessibility and cost-effectiveness for developing spatial decision-support systems in resource-constrained environments.

The platform architecture included the following components: QGIS for spatial data preparation and cartographic processing, PostgreSQL/PostGIS for geospatial database management, GeoServer for spatial data publication and web services, Apache Tomcat as the web server environment, Leaflet JavaScript library for interactive map visualization, HTML, CSS and JavaScript for interface development. The conceptual architecture of the Web GIS platform is shown in figure 2.

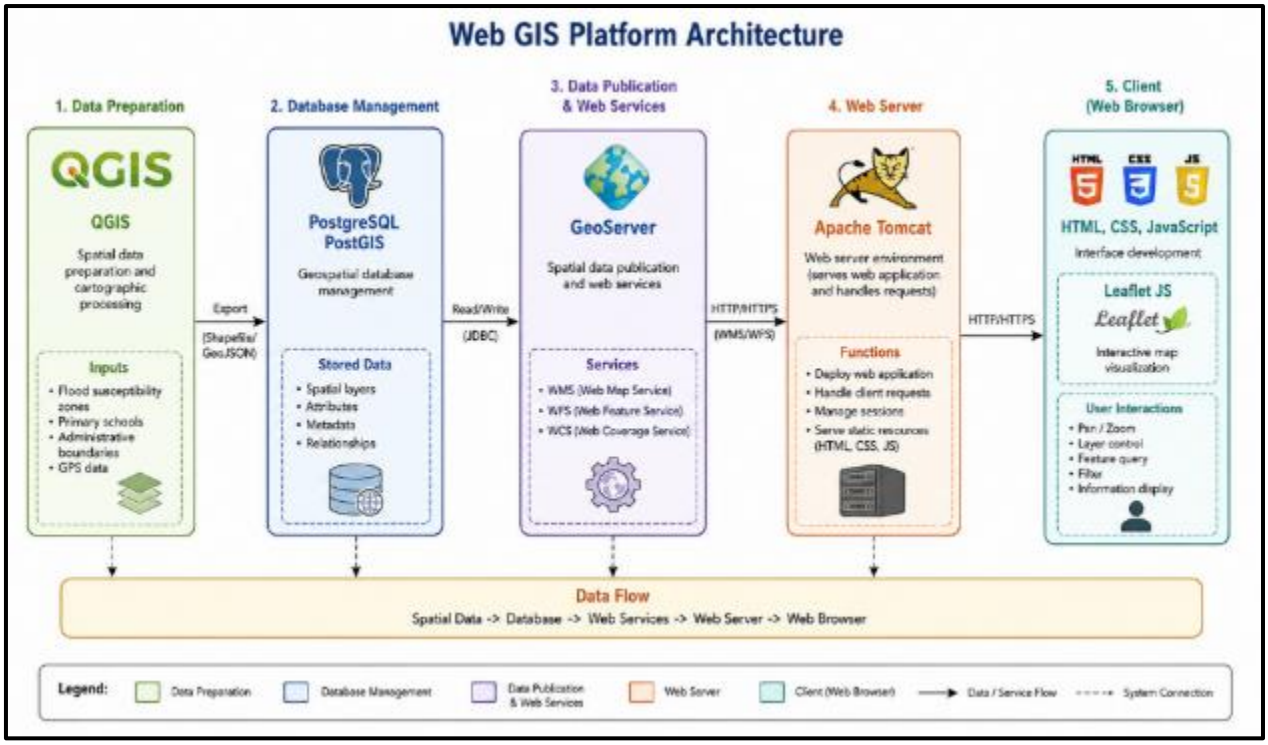

Figure 2 Conceptual architecture of the interactive Web GIS platform

The technological architecture of the developed platform is summarized in Table 2.

Table 2 Technologies and components used for the Web GIS platform

Components	Technologies/Tools
Web browser	Mozilla Firefox, Google Chrome
GIS software	QGIS
Web server	Apache Tomcat
Map server	GeoServer
Spatial database	PostgreSQL/PostGIS
Web mapping library	Leaflet JS
Web services	WMS and WFS
Programming languages	HTML, CSS and JavaScript

The spatial datasets were converted into GeoJSON format to facilitate their integration into the Leaflet environment. Web Map Services (WMS) and Web Feature Services (WFS) were also used to ensure efficient spatial data dissemination.

The platform was designed according to geovisualization principles emphasizing: usability, interactivity, accessibility, visual clarity, dynamic information retrieval. Special attention was given to interface simplicity in order to facilitate the use of the platform by non-specialized users, including educational stakeholders and local decision-makers with limited GIS expertise.

Users can interact with the map through zooming, filtering, layer selection and attribute querying functions. These functionalities improve the readability and interpretation of flood-related spatial information.

2.4. Spatial Analysis

Spatial overlay analysis was performed to determine the level of exposure of primary schools to flood susceptibility zones. Each school was associated with a specific flood susceptibility category according to its geographic location. The overlay analysis enabled the intersection of school location data with flood susceptibility layers in order to identify schools exposed to different levels of flood risk. This approach facilitated the spatial assessment of educational infrastructure vulnerability across the municipality. The analysis enabled the identification of schools located in highly vulnerable areas and provided insights into the spatial distribution of educational infrastructures across the municipality.

3. Results

3.1. Distribution of Primary Schools

The municipality of Ouagadougou contains a total of 925 primary schools. Among these establishments, 227 are public schools, representing 24.54% of the total number of schools. Private schools account for 698 establishments, corresponding to 75.46%. This distribution highlights the predominance of private educational institutions within the municipality. Such a pattern reflects the increasing role of private actors in meeting the growing demand for primary education, driven by rapid demographic expansion and urban growth in Ouagadougou. The spatial proliferation of private schools may also be associated with the expansion of residential areas in peripheral urban zones, where planning control is often weaker. The distribution of primary schools according to institutional status is presented in table 3.

Table 3 Distribution of primary schools according to institutional status

School category	Number	Percentage
Public schools	227	24.54%
Private schools	698	75.46%
Total	925	100%

The predominance of private educational institutions reflects the growing involvement of the private sector in the provision of primary education within the municipality.

3.2. Schools According to Flood Susceptibility Levels

The spatial analysis revealed varying levels of flood exposure among primary schools.

Results show that: 19.37 % of schools are located in areas with very low flood susceptibility, 28.35 % are situated in low susceptibility zones, 26.30 % are found in moderately exposed areas, 20.78 % are located in highly vulnerable zones, 5.19 % are positioned in areas with very high flood susceptibility. Percentage distribution of flood susceptibility categories is shown in figure 3.

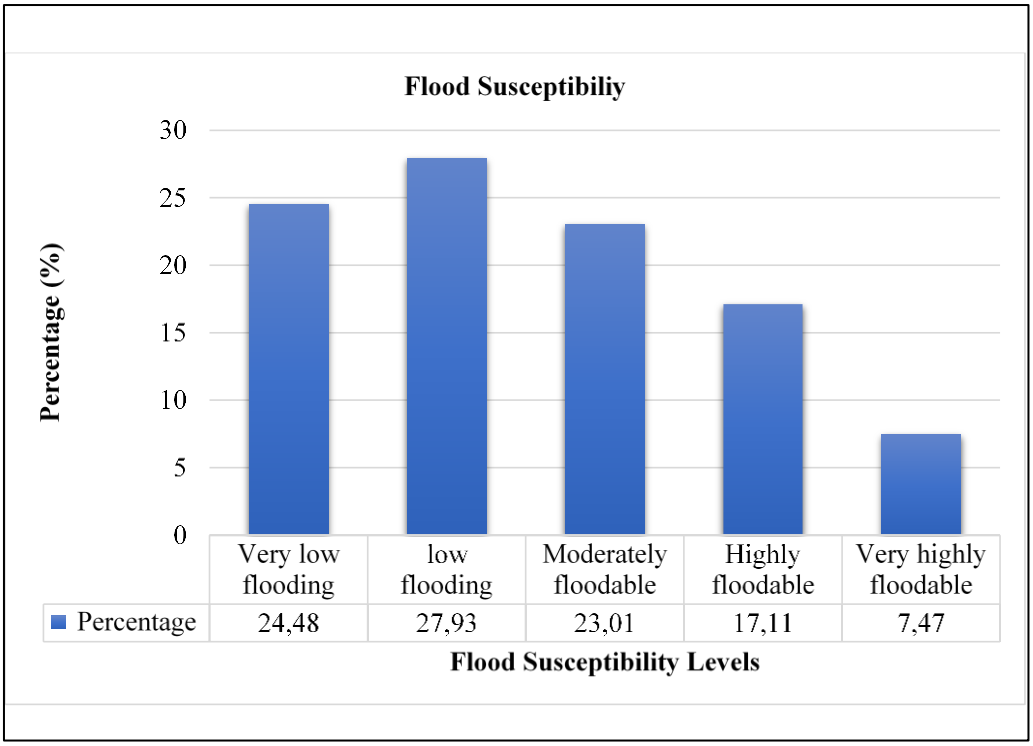

Figure 3 Percentage distribution of flood susceptibility categories in the municipality

Overall, these results indicate that nearly 52% of primary schools are located in moderate to very high flood susceptibility zones, revealing a significant level of exposure of educational infrastructures to urban flooding hazards. This spatial distribution underscores the increasing vulnerability of school systems in rapidly urbanizing environments where land occupation often extends into risk-prone areas. Schools according to flood susceptibility levels are summarized in table 4.

Table 4 Schools according to flood susceptibility levels

Flood susceptibility level	Public schools	Private schools	Total	Percentage
Very low	40	139	179	19.37%
Low	55	207	262	28.35%
Moderate	72	172	243	26.30%
High	54	138	192	20.78%
Very high	6	42	48	5.19%
Total	227	698	925	100%

These findings indicate that a considerable proportion of educational infrastructures are exposed to moderate and high flood risks.

3.3. Interactive Web Mapping of Flood-Prone Areas

The developed web mapping platform provides an interactive visualization of flood susceptibility zones across the municipality of Ouagadougou. The map classifies flood-prone areas into five susceptibility categories ranging from very low to very high.

The legend facilitates map interpretation by clearly distinguishing the different levels of vulnerability. Users can navigate through the map dynamically and explore spatial information at different scales. The results demonstrate that interactive web mapping significantly improves the accessibility and interpretability of flood risk information compared to traditional static cartography. This facilitates a better understanding of spatial risk patterns among educational

stakeholders, planners and local authorities. The interactive visualization of flood susceptibility zones is presented in figure 4.

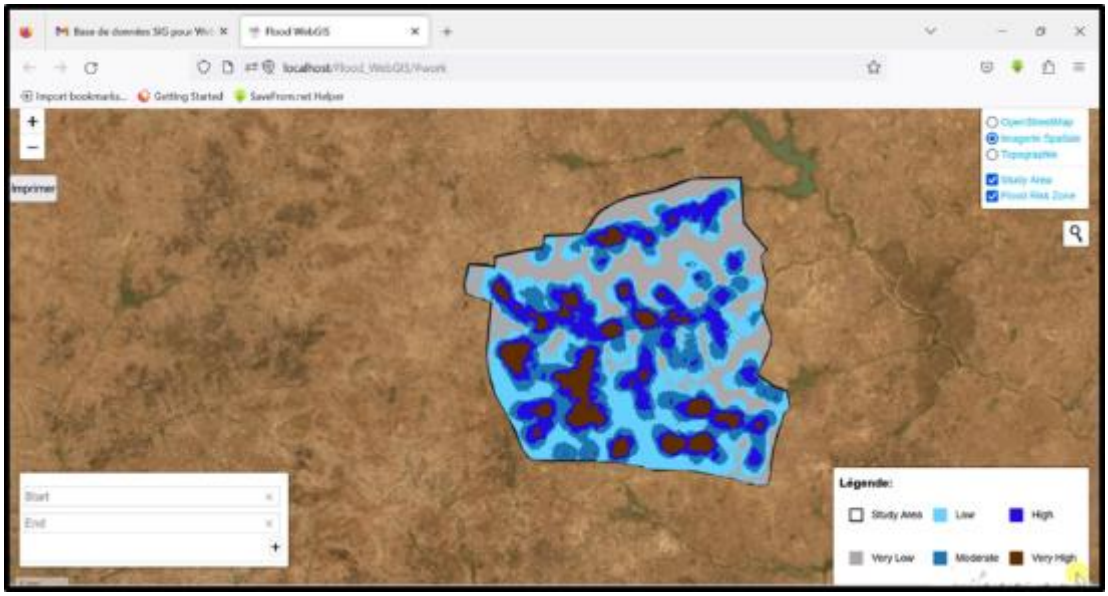

Figure 4 Interactive visualization of flood susceptibility zones in Ouagadougou

3.4. Visualization and Information Retrieval

One of the major functionalities of the platform is its capacity to provide detailed spatial information through interactive querying tools. By selecting a mapped feature, users can access descriptive information regarding flood susceptibility levels and school locations. This functionality enhances spatial decision-making by enabling rapid identification of schools located in risk-prone zones, thereby supporting targeted analysis for disaster preparedness and educational planning. Example of attribute information displayed through interactive querying is shown in figure 5.

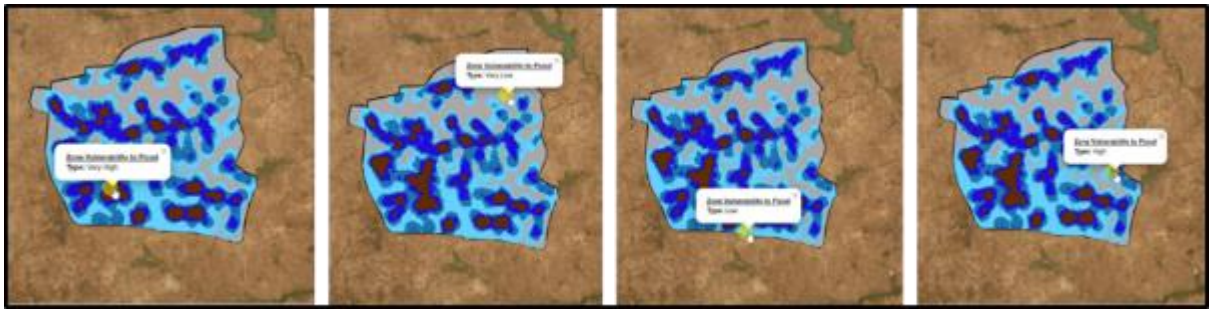

Figure 5 Example of attribute information displayed through interactive querying.

The platform also allows users to filter spatial layers according to specific flood risk categories. For instance, areas characterized by high or very high flood susceptibility can be displayed independently in order to support targeted analysis and decision-making.

This functionality is particularly useful for local authorities and disaster management stakeholders seeking to prioritize intervention areas. This filtering capacity improves the prioritization of intervention areas and facilitates more efficient allocation of resources for flood risk reduction and school safety planning. Visualization of areas characterized by very high flood susceptibility is shown in figure 6.

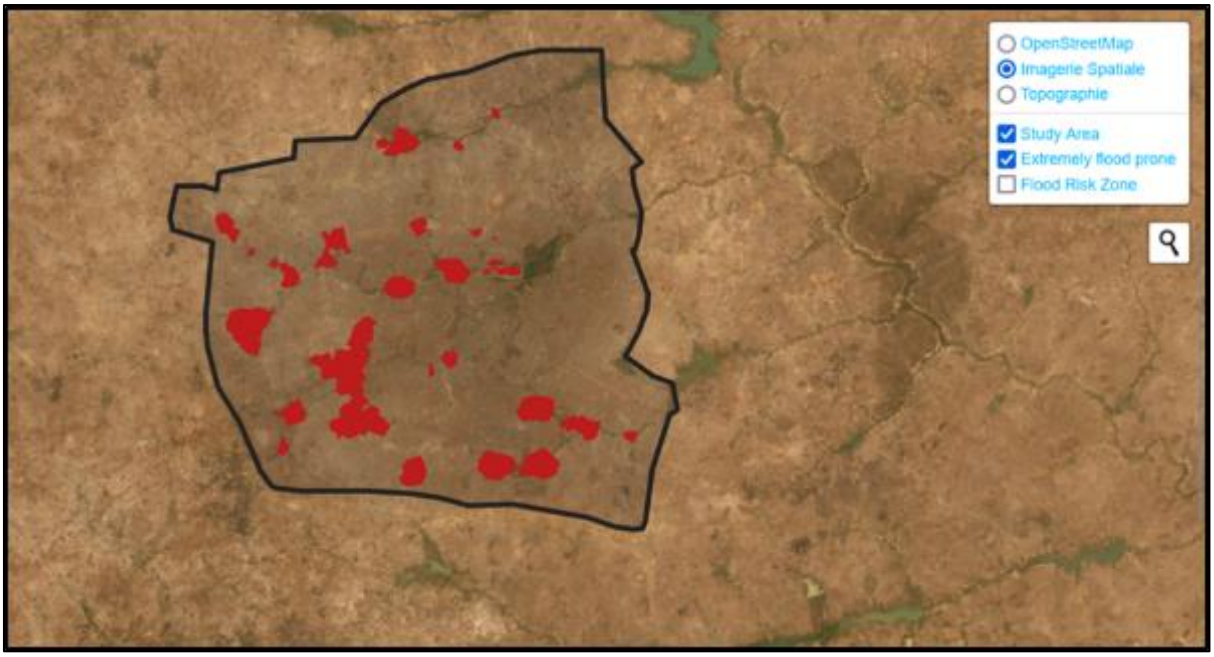

Figure 6 Visualization of areas characterized by very high flood susceptibility

3.5. Mapping of Schools Located in Flood-Prone Areas

The platform highlights schools located within flood-prone areas and illustrates their spatial distribution across the municipality. The analysis shows that several schools are concentrated in districts characterized by significant flood vulnerability. Both public and private schools located in high-risk zones can be visualized separately, facilitating comparative spatial assessment. The spatial pattern reveals a clear relationship between urban expansion dynamics and the location of educational infrastructures in environmentally vulnerable areas. Many schools appear to be established in densely built-up districts with limited drainage capacity, increasing their exposure to flood hazards. These results emphasize the need to integrate flood risk considerations into urban planning and educational infrastructure development policies, particularly in rapidly expanding cities such as Ouagadougou. Interactive mapping of primary schools located in flood-prone areas is shown in figure 7.

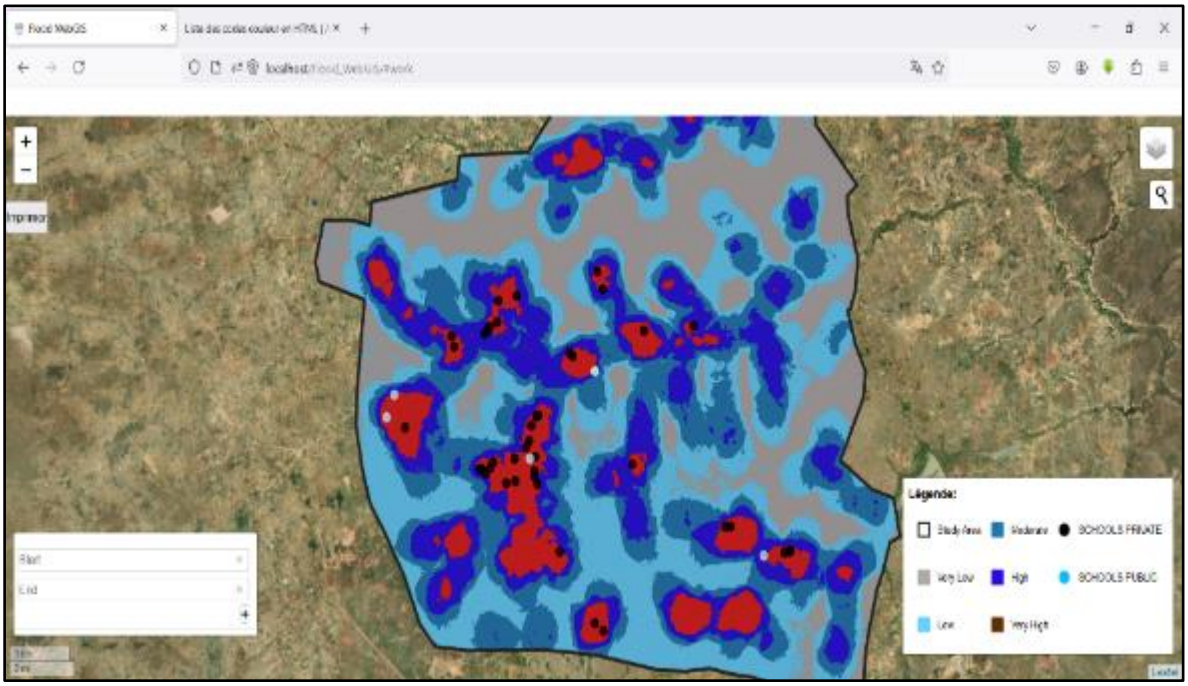

Figure 7 Interactive mapping of primary schools located in flood-prone areas.

The analysis demonstrates that several schools are concentrated in districts characterized by significant flood vulnerability. Public and private schools located in high-risk areas can be visualized separately, thereby facilitating educational planning and emergency preparedness.

The results further reveal that educational infrastructures remain highly exposed in certain urban sectors where flood susceptibility is particularly pronounced. Spatial distribution of public and private schools exposed to high flood risk is shown in figure 8.

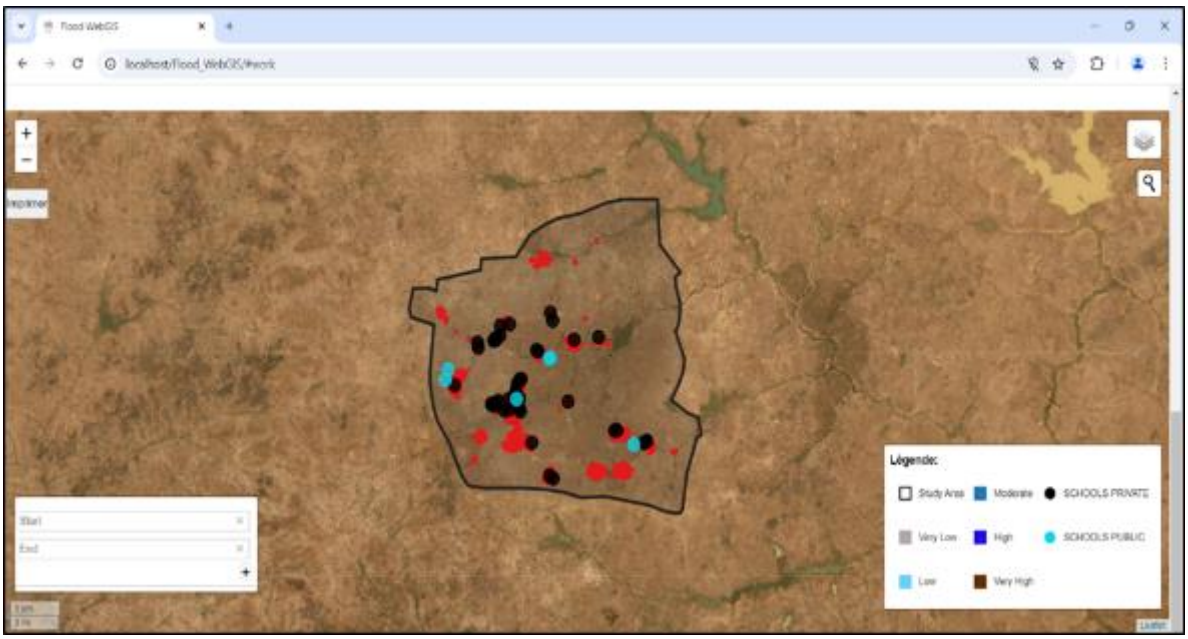

Figure 8 Spatial distribution of public and private schools exposed to high flood risk.

4. Discussion

The integration of interactive geovisualization into flood risk management offers important opportunities for improving spatial communication and decision support (Mericskay, 2011;Veenendaal et al., 2017). Unlike conventional static maps, interactive web mapping platforms enable users to explore geographic information dynamically and intuitively (Mbaha & Tchounga, 2020). This shift from static cartography to interactive geospatial environments represents a significant advancement in the way flood risk information is produced, communicated and utilized for decision-making.

The present study demonstrates that Web GIS technologies can play an important role in communicating flood-related information within educational environments. Through interactive functionalities such as filtering, zooming and attribute querying, users can better understand the spatial distribution of flood risks and identify vulnerable schools (Rodrigues da Silva et al., 2023). These functionalities enhance the accessibility of complex spatial datasets, particularly for non-specialist users such as school administrators and local education stakeholders.

The findings reveal that a significant proportion of primary schools in Ouagadougou are exposed to moderate and high flood susceptibility levels. This situation reflects broader urban development challenges observed in many rapidly growing African cities where educational infrastructures are increasingly established in environmentally fragile areas (Hangnon, Bonnet, et al., 2015 ;Da, 2021). Such spatial patterns highlight the tension between rapid urban expansion and risk-sensitive land-use planning, particularly in contexts where urban growth outpaces infrastructure regulation and environmental control.

The concentration of schools in flood-prone zones raises concerns regarding the safety of pupils and teachers during extreme rainfall events. Flooding may disrupt learning activities, damage infrastructure and increase health risks associated with waterborne diseases (Bronfort, 2017; Noviana et al., 2019). Beyond physical damage, such disruptions may also contribute to longer-term educational inequalities by affecting learning continuity and school attendance in vulnerable urban districts.

The platform developed in this study therefore represents a valuable decision-support tool for local authorities, educational planners and disaster management institutions. By facilitating access to geospatial information, the system can contribute to prevention strategies, emergency preparedness and urban resilience planning (Mohammed et al., 2023 ;Efraimidou & Spiliotis, 2024). In addition, it supports evidence-based planning by enabling spatial prioritization of high-risk schools for targeted interventions such as infrastructure reinforcement or relocation strategies.

The study also confirms the growing importance of open-source geospatial technologies in disaster risk reduction. The combined use of QGIS, GeoServer, PostgreSQL/PostGIS and Leaflet demonstrates that efficient Web GIS solutions can be developed using accessible and low-cost technologies (Mohammedain et al., 2022). This is particularly relevant for developing countries where financial and technical constraints often limit the adoption of proprietary geospatial systems.

In addition, the integration of geovisualization principles improved the readability and usability of spatial information. The interactive nature of the platform allows users with limited GIS expertise to access and interpret flood-related data more easily (Mericskay, 2011). This contributes to reducing the technical barrier between geospatial data production and its practical use in institutional decision-making processes.

Despite these advantages, certain limitations remain. The performance of interactive web maps may decrease when handling large geospatial datasets or multiple layers simultaneously. Furthermore, the current platform mainly supports two-dimensional visualization and does not integrate advanced three-dimensional representations (Rodrigues da Silva et al., 2023). These limitations suggest opportunities for future improvements through optimization techniques and the integration of more advanced visualization frameworks.

Internet access and electricity availability may also limit the use of the platform in some educational environments. In addition, effective utilization of the system requires a minimum level of digital literacy among teachers and school administrators (ECOWAS, 2020). This highlights the importance of accompanying technological solutions with capacity-building initiatives to ensure effective adoption and sustainability.

Nevertheless, the study highlights the potential of interactive geovisualization for strengthening disaster awareness and improving risk communication in school environments (Song et al., 2023). Overall, the approach contributes to the broader agenda of building climate-resilient educational systems in rapidly urbanizing African cities by bridging the gap between geospatial technology and practical risk governance.

Limitations and Future Perspectives

Although the developed platform provides useful functionalities for flood risk visualization, several limitations should be considered.

First, access to the platform depends on internet connectivity and the availability of digital devices. In some schools, particularly those located in vulnerable or under-resourced areas, these conditions may not always be guaranteed.

Second, the interpretation of interactive maps may remain challenging for users with limited experience in geospatial technologies. Capacity-building activities and digital literacy training are therefore necessary to improve platform usability.

Third, the current version of the platform mainly focuses on visualization and communication. Future developments could integrate real-time hydrological data, early warning systems and mobile-based functionalities.

Additional research should also evaluate user experience among teachers, pupils and local authorities in order to assess the educational effectiveness and practical usability of the platform. Future studies may further explore: 3D geovisualization techniques, integration of remote sensing data, mobile GIS applications, participatory mapping approaches, real-time flood monitoring systems.

5. Conclusion

This study developed an interactive web-based geovisualization platform for mapping flood-prone areas and identifying primary schools exposed to flooding in the municipality of Ouagadougou. The results revealed that a considerable number of schools are located within moderate and high flood susceptibility zones, highlighting the vulnerability of educational infrastructures to urban flooding. The developed Web GIS platform enables users to visualize flood-prone

areas dynamically, retrieve spatial information interactively and identify vulnerable schools more efficiently. Through its interactive functionalities, the system contributes to improving flood risk communication, awareness and decision-making processes.

The research also demonstrates the relevance of open-source geospatial technologies for disaster risk reduction in developing urban contexts. Interactive geovisualization tools can support urban resilience strategies by facilitating access to spatial information for both authorities and local communities. Beyond its local application, the study contributes to broader discussions on climate adaptation, disaster preparedness and educational resilience in African cities increasingly affected by environmental hazards. The platform may therefore serve as a useful tool for policymakers, urban planners, educational stakeholders and disaster management institutions seeking to strengthen flood risk mitigation and improve the safety of school environments.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The authors declare that there is no conflict of interest related to this study.

Data Availability Statement

The datasets used in this study are not publicly available. Additional information may be obtained from the corresponding author upon reasonable request.

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