

# Mapping Flood Risks across the Thiès City Catchment Area Using the Flood Potential Index (Senegal)

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## Abstract

Flood risk management in Thiès, a city in Senegal, has become a major challenge due to rapid urbanization and the impacts of climate change. The main objective of this study is to assess flood potential in urban areas using the flood potential index (FPI), a multi-criteria method integrated into a geographic information system (GIS). This approach makes it possible to map vulnerable areas and identify contributing factors such as topography, precipitation, urbanization, and drainage infrastructure. The results show that certain areas of Thiès, particularly low-lying areas close to drainage networks, are particularly exposed to flood risks. Factors such as poor drainage infrastructure capacity, soil degradation and the lack of strict land use regulations amplify the city's vulnerability. In the city of Thiès, flood risk is classified into five levels. 27.22% of the area is at moderate to high risk, 19.86% at high risk and 9.66% at very high risk, requiring urgent action. This study also highlights the importance of integrating IPI into urban planning and risk management policies. The results suggest that mitigation strategies, such as improving drainage infrastructure, rehabilitating soils and integrating green spaces, are necessary to reduce the impact of flooding in Thiès. Ultimately, proactive flood risk management will require greater collaboration between local authorities, urban planners and the scientific community.

## Keywords

GIS Analysis, Flood Risk Management, Flood Zones, Flood Risks, Analytical Hierarchy Process

## 1. Introduction

The issue of flood risk in Thiès, one of Senegal's largest cities, is a topical one due to rapid urbanisation and the effects of climate change. Although flooding is a natural phenomenon, it is exacerbated by the expansion of urban infrastructure and environmental degradation, making the assessment of these risks essential for urban planning and natural disaster management. Indeed, floods are ranked among the most frequent and devastating natural disasters worldwide, affecting nearly 170 million people each year [1].

Flooding in urban areas can have devastating consequences, affecting not only human life, but also critical infrastructure, housing, and agriculture, which is a source of livelihood for many families. In response to this issue, flood risk assessment tools, such as the Flood Potential Index (FPI), have proven to be powerful instruments for mapping vulnerable areas and for proactive risk management [2].

The Flood Propensity Index FPI classifies areas according to their susceptibility to flooding, taking into account a range of environmental and anthropogenic parameters. In the case of Thiès, the methodology combined with geographic information systems (GIS) provides an accurate picture of areas at risk, using criteria such as altitude, slope, distance by from drainage networks, vegetation cover, as well as data on precipitation and soil geology [3].

Thiès is particularly vulnerable to flooding due to its topography and increasing urbanization. The phenomenon is exacerbated by climatic factors such as torrential rains and poor stormwater management, combined with poorly controlled human activities [4]. Population growth, urban expansion in sensitive areas and increased infrastructure have significantly exacerbated flood risks in the region [5].

Climate hazards are amplified by aggravating factors such as poverty, poor-quality building materials, the construction of dwellings in flood-prone areas, and the lack of adequate urban development plans [6]. In addition, inadequate drainage infrastructure, weak warning mechanisms and gaps in risk management are all factors contributing to increased flood potential in urban areas of Thiès [7].

Flood risk analysis in Thiès is based on the use of geospatial methods and the IPI, which incorporates several vulnerability factors. These methods not only make it possible to assess the most exposed areas but also to predict the potential impact of flooding, thus facilitating decision-making for local authorities [8]. The use of GIS allows different layers of geospatial information to be superimposed to produce a detailed flood risk map.

The theoretical framework is based on a flood risk management approach that incorporates elements of multi-criteria analysis, in particular the Analytical Hierarchy Process (AHP), used to assign weights to the various parameters. This method is applied in a GIS environment, allowing different layers of information to be superimposed to produce a flood risk map. Several studies have demonstrated the effectiveness of this approach in various contexts, particularly in river basins in Africa and Asia [9].

Although similar AHP-GIS methods have already been used in other contexts, this study presents an innovative application for Thiès and its region due to several distinctive features.

First, the use of specific local data, such as precise data on drainage networks, topographic conditions, and recent rainfall data, gives the study a dimension particularly suited to the geographical and climatic characteristics of Thiès. This data allows for a detailed assessment of flood risks in a rapidly expanding urban context, where the challenges of stormwater management and unregulated urbanization are particularly crucial [5].

Second, the application of this method to urban planning in Thiès is innovative because it allows for the combination of spatial analysis tools (AHP and GIS) for informed decision-making [2]. This approach facilitates the prioritization of vulnerable areas and provides local authorities with a solid basis for implementing risk management strategies, directly aligned with specific infrastructure and urban management needs.

In Thiès, this method will be implemented by analysing parameters such as rainfall, flow accumulation, distance from watercourses, and other geological and anthropogenic factors specific to the region [10]. Combining these data will enable the generation of detailed risk maps, facilitating infrastructure planning and risk mitigation measures. According to these geospatial approaches enable better management of the area in the event of extreme weather events.

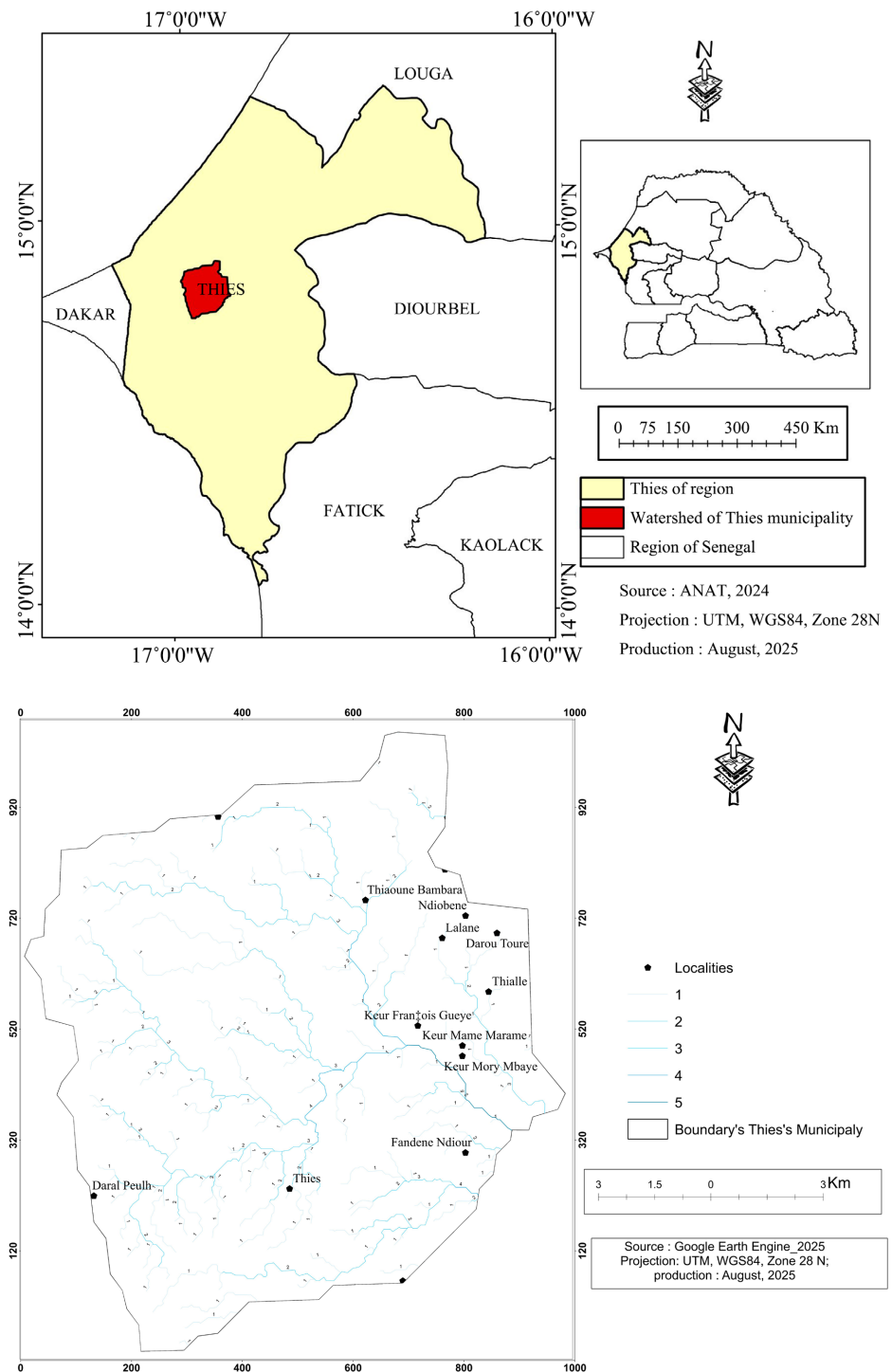
The use of tools such as the IPI to assess flood risks in Thiès represents a step forward in natural disaster management in Senegal. These assessments not only protect existing infrastructure but also minimise the impact on the population. The results of this study will guide future decisions on urban planning and flood prevention measures, while taking into account climate forecasts and population growth dynamics. The risk maps generated will provide local authorities and planners with valuable tools for proactive and effective flood risk management, in order to protect citizens and urban infrastructure.

The main objective of this study is to map the flood potential in the city of Thiès using the flood potential index and to identify the areas most exposed to flood risks. The results of this study will be crucial for the implementation of risk management strategies, particularly in urban planning, rainwater management and disaster prevention [7]. Indeed, flood risk assessment is an important tool for sustainable urban planning and mitigating the impacts of natural disasters [11].

## 2. Study Area

The Thiès region is located in the west of the country, surrounding the Cape Verde peninsula. It is one of Senegal's 14 administrative regions, located 70 km east of the capital, Dakar (**Figure 1**). The city of Thiès, the capital of the Thiès region, is the third most populous city in Senegal and covers an area of approximately 68.82 km<sup>2</sup>. The region's terrain plays an important role, with the city of Thiès built on a 130-metre-high plateau consisting of mountain ranges (the Thiès, Diass and Notto ranges), valleys and cliffs, and criss-crossed by waterways that drain each

rainy season. The city is surrounded by protected forests and extractive industries and plays an important role in the country's economy, particularly in the agriculture, trade and industry sectors. Rainfall is spread over a maximum of three months, from mid-July to mid-October, varying between 200 and 500 mm per year [5].



**Figure 1.** Presentation of the city of Thiès and the Thiès city watershed.

Similar to Dakar, Thiès is characterised by increasing urbanization and population growth. This unplanned and uncontrolled urban expansion has put pressure on natural resources, with increased deforestation of the plateau limiting its ecosystems and the services they provide, and the occupation of certain flood-prone areas (*non aedificandi*) disrupting the hydrographic network and the natural flow of runoff water [12]. Despite the persistent drought, large quantities of runoff water from the plateau flow through the city before reaching their natural outlets to the north and east of the city, which are the lowest-lying areas and most prone to flooding. [4] This characteristic makes it particularly susceptible to rainwater stagnation and drainage system saturation, causing serious damage to homes, roads and tracks, which become impassable.

The drainage infrastructure, which is often obsolete and inadequate, is unable to effectively manage large volumes of rainwater, leading to recurrent flooding in several neighbourhoods [11]. All these factors combined mean that the city of Thiès faces a high risk of flooding. Added to this are underlying vulnerabilities linked to the economic situation and poverty, which exacerbate climate risks and further worsen living conditions for communities.

Flooding in Thiès has serious consequences: it affects the daily lives of residents, damages homes, roads and public infrastructure, and disrupts agricultural activities, a key source of income for many rural families [7].

Given the considerable damage caused by flooding, it is crucial to map vulnerability and flood risks in Thiès to ensure effective management and planning to protect communities and their livelihoods, thereby reducing future losses.

### 3. Materials and Methods: FIGUSED Method

The FIGUSED (Floods, Inundations, Geographic Information System, and Urban Environmental Design) method is a multi-criteria approach used to assess flood risks in a geographical environment using geographic information systems (GIS). This method allows flood risks to be modelled by taking into account several environmental and anthropogenic parameters. The following steps describe the equipment and methodology used to apply this method.

#### 3.1. Data Collection

The successful application of the FIGUSED method relies on the acquisition and analysis of various geospatial and environmental data. The main data sources are as follows:

Precipitation data: Rainfall data are essential for understanding the distribution of precipitation in the study area. This data is produced by the Global Modelling and Assimilation Office (NASA) and is available for download from the NASA-POWER website in geoTIFF and NetCDF formats at daily, monthly and annual scales at <https://www.chc.ucsb.edu/data/chirps>.

Topographic data: Topographic maps and elevation data (digital terrain models, DTMs) are used to determine the altitude and slope of the terrain. This infor-

mation is essential for modelling water runoff and identifying low-lying areas that are susceptible to flooding. This data is global in scale and is obtained from the ASTER GDEM (Advanced Spaceborne Thermal Emission and Reflection Radiometer) site with a resolution of 30 m and available at the following link:

<https://search.earthdata.nasa.gov> [13].

Satellite images: Satellite images such as Landsat or Sentinel can be used to map land use, vegetation cover, infrastructure and hydrographic networks. These images are used to detect changes in the environment and observe specific geographical features (such as building density) [14]. As part of this work, we used Sentinel 2025 satellite imagery through Google Earth Engine (GEE), an online scientific platform offered by Google that allows users to work with massive geospatial data (satellites, climate, topography, etc.) to determine in detail the land use in the city of Thiès.

Drainage maps: Information on drainage networks (canals, rivers, sewers) is collected to assess their capacity to manage water flow and to identify areas of congestion in the drainage network that can cause flooding [15].

Data on the hydrographic network (hydrographic network map) was used to represent water flow lines from a Digital Terrain Model (DTM). This topographical data was obtained from the ASTER GDEM (Advanced Spaceborne Thermal Emission and Reflection Radiometer) website with a resolution of 30 m and is available at the following link: <https://search.earthdata.nasa.gov> [13].

Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, sc, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

### 3.2. Risk Assessment Parameters

The FIGUSED method is based on the integration of several parameters to assess flood risks. These criteria may include, but are not limited to:

Flow accumulation: This parameter is used to assess the volume of water accumulated in the areas studied based on precipitation and topography.

Distance to drainage network: The proximity of areas to drainage networks influences their vulnerability to flooding. Areas far from drainage channels have a higher risk [16].

Elevation and slope: Low-lying or gently sloping areas are more susceptible to flooding because water accumulates more easily there [17].

Land use: Urbanization, agriculture and vegetation types affect the ability of soils to absorb water and alter runoff characteristics [18].

Precipitation intensity: Precipitation intensity and frequency are key factors in flood analysis.

Soil geology: The nature of the soil, whether impermeable or permeable, affects water infiltration capacity and influences flood risk [19].

The FIGUSED method is a comprehensive framework for flood risk assessment

that integrates several environmental and anthropogenic parameters, such as topography, vegetation cover, rainfall intensity, and geology. The Flood Potential Index (FPI) is calculated by overlaying these criteria in a Geographic Information System (GIS). The AHP (Analysis of High Potential) is used to assign relative weights to the criteria based on their importance in flood occurrence. The AHP thus allows for the weighting of different parameters within the FPI calculation, resulting in a more objective and structured analysis [17] [18].

### 3.3. Multi-Criteria Analysis

- Once the data has been collected, multi-criteria analysis is applied using the AHP (Analytic Hierarchy Process) method. This hierarchical process allows the criteria to be weighted according to their relative importance in the occurrence of a flood. The key steps include:
  - Structuring the criteria: The risk criteria (precipitation, distance to drainage, slope, etc.) are structured in the form of a hierarchy [20].
  - Criteria evaluation: Each criterion is evaluated according to its ability to influence flood risk. This is done through calculations and models based on historical and empirical data.
  - Criteria weighting: Using pairwise comparison matrices, each criterion is given a weight based on its influence on flood risk. For example, terrain slope might be considered more critical than land use in certain areas [17].
- Data overlay: Data layers, such as elevation, land use and precipitation, are overlaid in the GIS to generate a final flood risk map.

### 3.4. Risk Mapping

Overlaying different layers of information in a GIS allows a flood risk map to be generated, classified according to different risk levels (low, medium, high, very high). This makes it possible to visualize areas at risk in a spatially and geographically accurate format, facilitating decision-making for local authorities and urban planners.

### 3.5. Validation of Results

The results obtained using the FIGUSED method are then validated using field data or previous flood cases (Table 1). This makes it possible to test the accuracy of the predictions and adjust the model based on actual observations [16].

**Table 1.** Values of the parameters of the FIGUSED method.

Parameters	Classes	Rank	Area (km <sup>2</sup> )	Share (%)
F: Flow accumulation	0 - 2898.54	2	152.54	98.86
	2898.54 - 11111.07	4	1.02	0.66
	11111.07 - 22705.23	6	0.39	0.25
	22705.23 - 52173.74	8	0.16	0.10
	52173.74 - 123,188	10	0.18	0.11

**Continued**

	37 - 57	2	29.71	19.55
	57	4	45.82	30.15
I: Precipitation intensity	73 - 88	6	50.38	33.15
	88 - 104	8	22.12	14.55
	104 - 136	10	3.96	2.60
G: Geology	Alternating limestone and marl	2	22.00	14.25
	Eocene limestone and marl	4	132.35	85.75
	Vegetation	2	96.07	62.28
	Cultivation areas	4	11.88	7.70
U.: Land use	Built-up	6	6.76	4.38
	Bare floors	8	5.36	3.47
	Water	10	34.18	22.42
	0 - 1.36	10	49.78	32.58
	1.36 - 2.42	4	53.93	35.30
S: Slope	2.42-3.69	6	34.19	22.38
	3.69 - 5.53	8	12.65	8.28
	5.53 - 24.77	10	2.22	1.45
	33 - 57	2	26.59	17.24
	57 - 73	4	41.03	26.60
E: Elevation	73 - 88	6	41.60	26.90
	88 - 104	8	29.70	19.25
	104 - 136	10	15.33	9.93
	0 - 1	10	56.77	36.83
	1 - 2	8	46.15	29.94
D: Distance from drainage	2 - 3	6	32.47	21.06
	3 - 4	4	14.70	9.54
	4 - 5	2	4.05	2.62
	9.75 - 14.90	Very low	25.07	16.42
	14.90 - 20.05	Low	40.93	26.81
FIGUSED: Flood risk	20.05 - 25.20	Moderate	41.56	27.22
	25.20 - 30.35	High	30.33	19.86
	30.35 - 35.55	Very high	14.76	9.66

The FIGUSED method is a powerful approach for assessing and mapping flood risks in urban areas, particularly in rapidly growing cities such as Thiès. Using a combination of geospatial data, multi-criteria analysis and GIS modelling, this

method provides a solid basis for flood risk planning and management, contributing to greater resilience to natural disasters.

To address this comment, it is essential to clarify the validation methodology used to test the accuracy of the FIGUSED method model. The results were validated by comparing the maps generated by the model with historical flood maps and field data collected in areas identified as high-risk. Verification points were selected at sites critical for flooding, where field observations confirmed the model's predictions. The results showed a strong correlation between the at-risk areas identified by the model and the areas affected by actual flooding, thus validating the model's robustness for future forecasts [17] [18] [20].

The weights assigned to each criterion in an AHP method are calculated from pairwise comparison matrices, where each criterion is compared with all the others based on their relative importance in the occurrence of the phenomenon under study, in this case, flooding. The judgment scale used in this method ranges from "equally important" (weighting of 2) to "extremely more important" (weighting of 10), with several intermediate values allowing for the specification of greater or lesser levels of importance [14]. These comparisons are then translated into a matrix that allows for the calculation of relative weights for each criterion. For example, if one criterion is judged to be twice as important as another, this will be reflected in the matrix with a weighting of 4 for the first criterion and 2 for the second.

Once the weights were calculated, it was important to justify their assignment. This justification is based on empirical data and literature reviews. Previous studies can provide strong arguments for the impact of the different criteria on flooding, which helps to justify the assigned weights. For example, it is well established that rainfall intensity plays a predominant role in densely populated urban areas, where drainage infrastructure is often insufficient to handle large quantities of water. Therefore, this criterion could be given greater weight compared to other factors such as terrain slope. Such comparisons and justifications strengthen the credibility of the results obtained through AHP, ensuring rigorous consideration of local specificities and existing data.

The results obtained using the FIGUSED method are then validated using field data or previous flood cases. This makes it possible to test the accuracy of the predictions and adjust the model based on actual observations [16].

The FIGUSED method is a powerful approach for assessing and mapping flood risks in urban areas, particularly in rapidly growing cities such as Thiès. Using a combination of geospatial data, multi-criteria analysis and GIS modelling, this method provides a solid basis for flood risk planning and management, contributing to greater resilience to natural disasters.

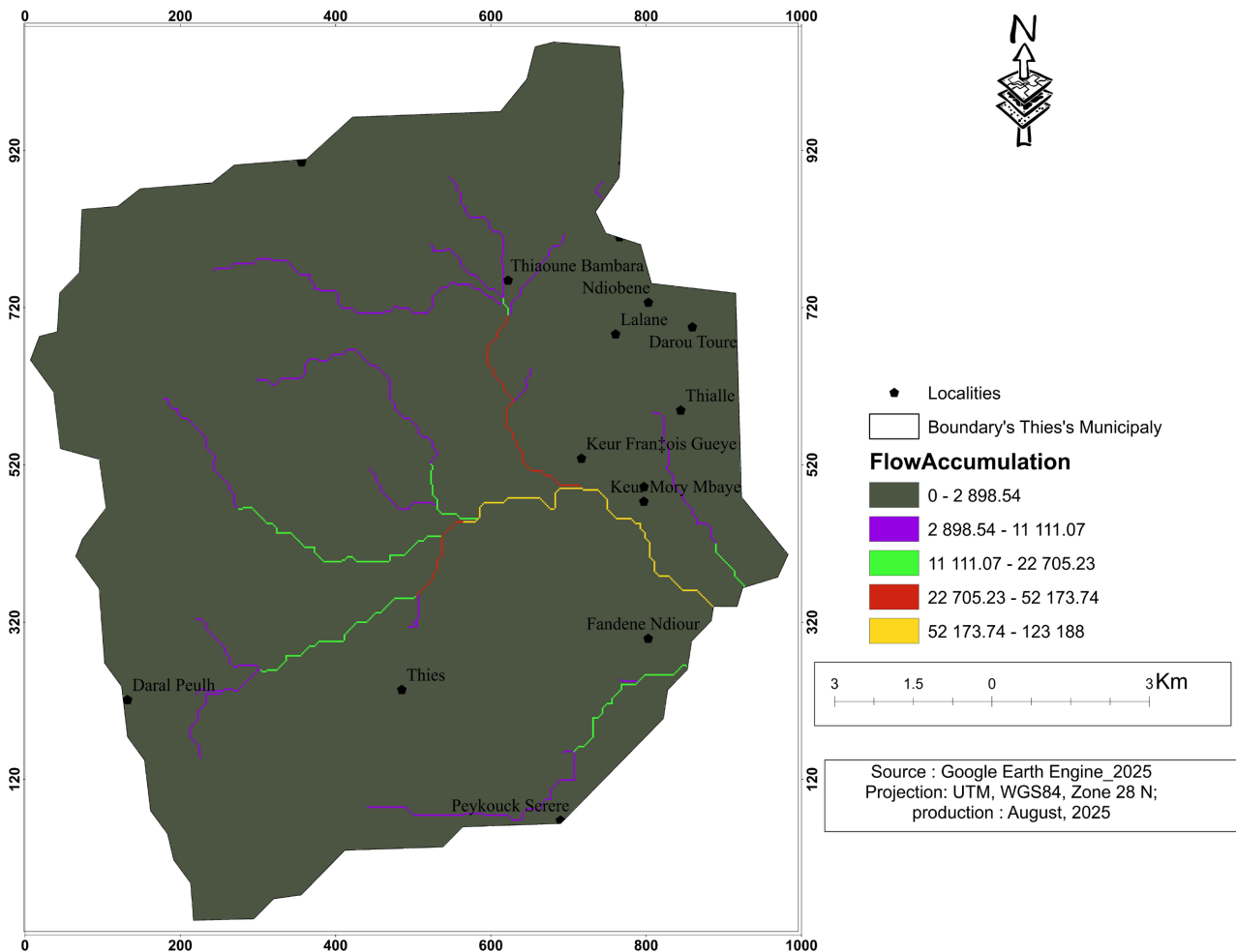
## 4. Results

**Table 1** shows the values of the parameters used for the FIGUSED method as well as those for flood risks.

### 4.1. Analysis of the Parameters Used for the FIGUSED Method

#### 4.1.1. F: Flow Accumulation

The “flow accumulation” parameter for the city of Thiès watershed (**Figure 2**) shows that most of the area (98.86%) is classified in the first category, representing areas where flow accumulation is low.



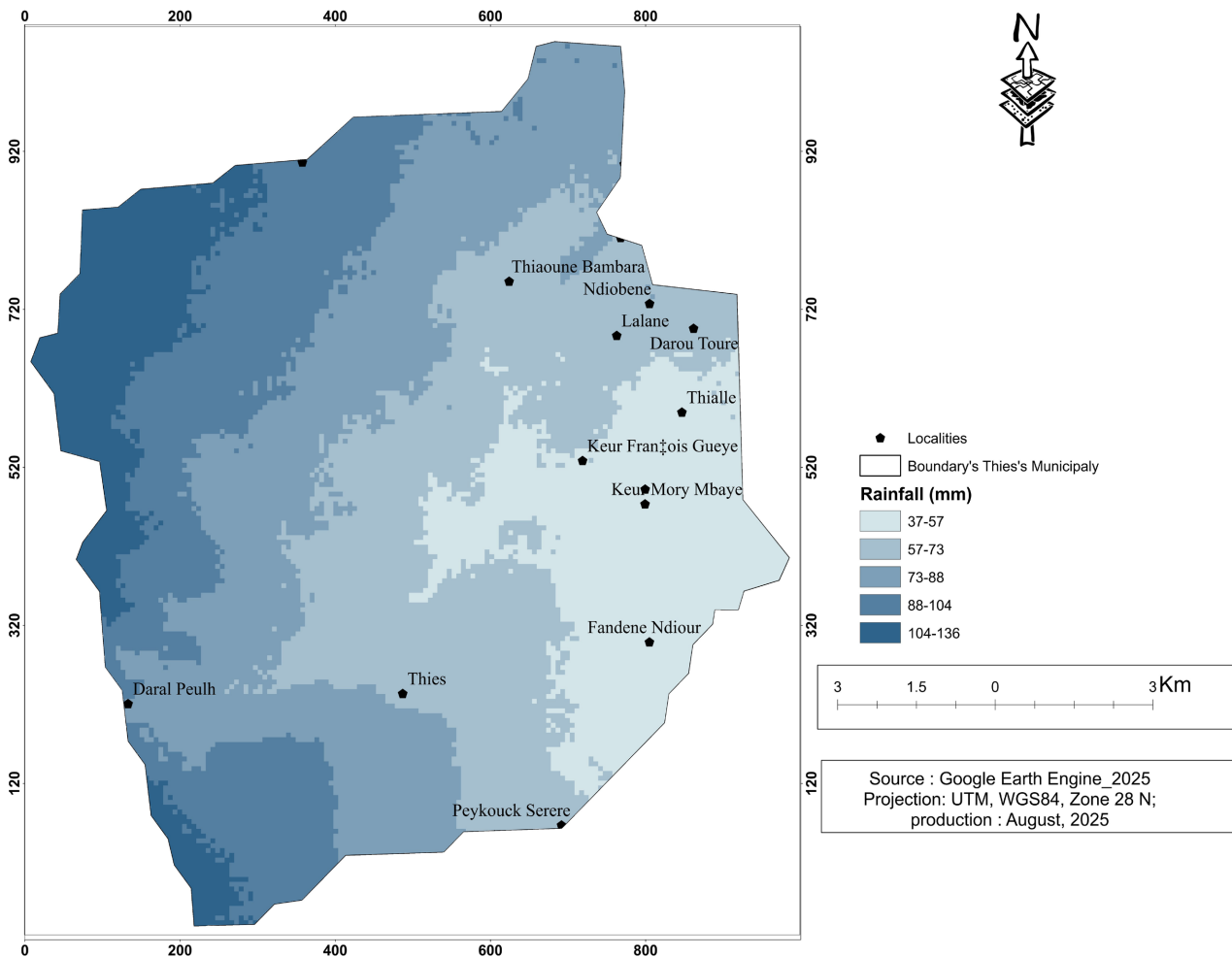
**Figure 2.** Values of the “flow accumulation” parameter for the Thiès municipality watershed.

This indicates regions that are relatively less affected by intense runoff. On the other hand, the other classes, representing areas with higher flows (from 0.66% to 0.25% of the area), cover sectors where accumulation is more pronounced, but these remain relatively rare. The most affected areas, although representing less than 1% of the total area, are localized and could have significant impacts on soil erosion and water resource management in these specific areas. Water management in these areas with high flow accumulation therefore becomes crucial.

#### 4.1.2. I: Precipitation Intensity

The values of the “Precipitation intensity” parameter in the Thiès city watershed (**Figure 3**) show a varied distribution of precipitation intensity across the region.

The majority of the area (33.15%) is in the 73 - 88 mm class, indicating that more than a third of the area experiences relatively high rainfall, probably favouring increased water management. This is followed by the 57 - 73 mm (30.15%) and 37 - 57 mm (19.55%) classes, representing areas where rainfall intensity is moderate but still significant. The highest classes, 88 - 104 mm (14.55%) and 104 - 136 mm (2.60%), cover smaller areas and suggest regions where rainfall is particularly intense, with increased risks of runoff and erosion.



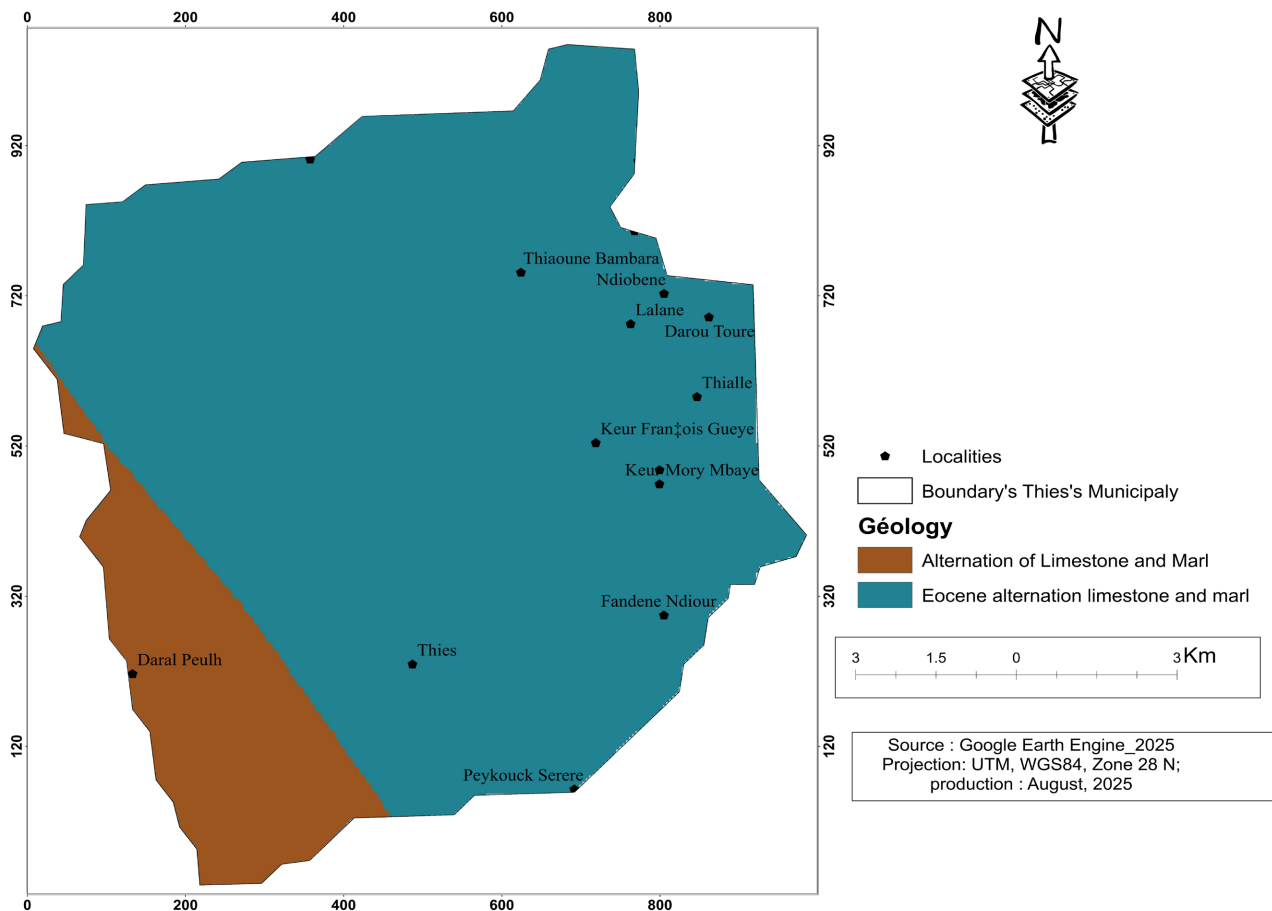
**Figure 3.** Values for the “Precipitation intensity” parameter for the Thiès city watershed.

These values highlight the need to adapt water and infrastructure management to cope with different levels of rainfall intensity across this territory.

#### 4.1.3. G: Geology

The “Geology” parameter for the Thiès city watershed (**Figure 4**) indicates a predominance of Eocene limestone and marl, which cover 85.75% of the area. These geological formations are likely associated with specific soil characteristics that influence water management, biodiversity and agriculture in the region. In contrast, alternating limestone and marl represent only 14.25% of the area, suggesting

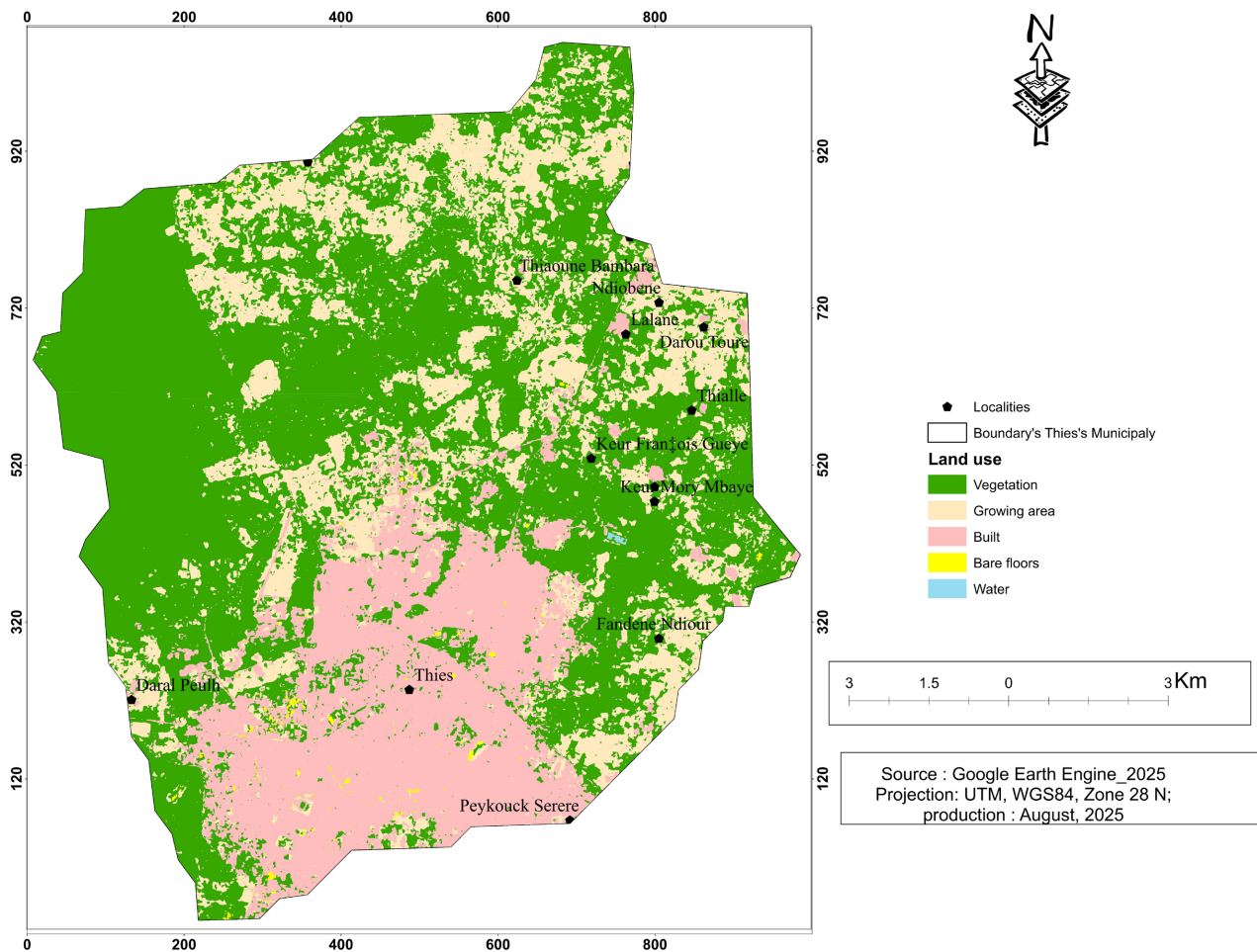
that this geological configuration is less widespread. This may have implications for drainage capacity, water infiltration and soil quality, with notable differences between areas dominated by limestone and marl and those with Eocene formations. This geological information is crucial for land use planning and natural resource management in the city.



**Figure 4.** Values for the “Geology” parameter for the Thiès city watershed.

**4.1.4. U: Land Use**

Land use in the city of Thiès watershed reveals a varied distribution of different types of land use. Vegetation dominates, covering 62.28% of the area, indicating a predominantly green zone that is favourable to biodiversity and water regulation. Cultivated areas occupy 7.70% of the territory, representing spaces dedicated to agriculture, which is essential for local subsistence (Figure 5). Built-up areas, representing 4.38% of the territory, indicate the presence of urbanization, mainly around the city of Thiès, with residential and commercial infrastructure. Bare land, which covers 3.47%, suggests undeveloped or partially degraded land. Finally, water areas (22.42%) indicate a significant presence of water bodies or wetlands, which are essential for ecosystems and water resource management. This distribution highlights a balance between urbanization, agriculture and nature conservation in the city.



**Figure 5.** Values for the “land use” parameter for the Thiès watershed.

#### 4.1.5. S: Slope

The “Slope” parameter for the Thiès watershed shows a varied distribution of terrain inclines (**Figure 6**). The majority of the area (35.30%) is in the 1.36% to 2.42% slope class, closely followed by the 0% to 1.36% class, which covers 32.58% of the area. These low to moderate slopes suggest a relatively flat topography, favourable to agriculture and human settlement. Areas with steeper slopes (2.42% to 3.69%), representing 22.38% of the territory, indicate more pronounced but still usable relief. Steeper slopes, from 3.69% to 5.53% (8.28% of the area), are present but limited. Finally, slopes greater than 5.53% cover only 1.45% of the area, indicating very steep areas that are probably inaccessible or difficult to develop for human activities. This diversity of slopes plays a crucial role in land use planning and natural resource management.

#### 4.1.6. E: Elevation

The “Elevation” parameter for the Thiès watershed shows significant variation in altitude within the region. The most common class is between 73 and 88 meters, covering 26.90% of the territory, followed by the 57 to 73 meter class, representing 26.60% of the area (**Figure 7**). These two classes suggest a majority of moderately

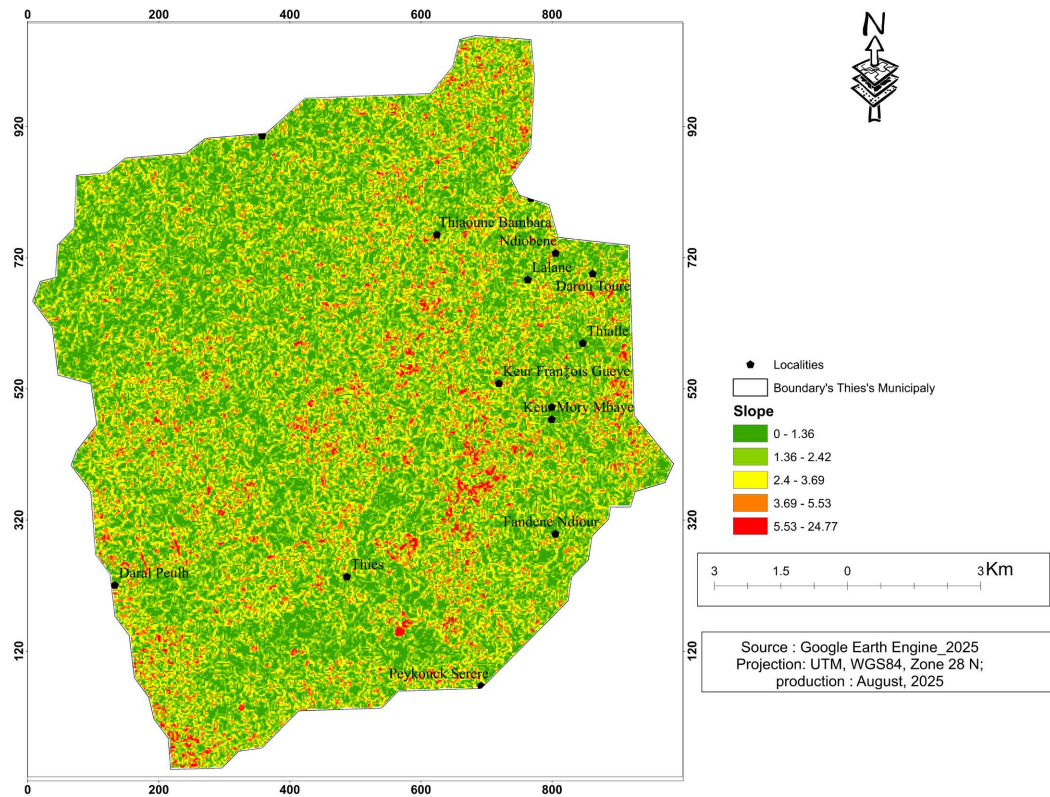


Figure 6. Values of the “Slope” parameter for the Thies commune watershed.

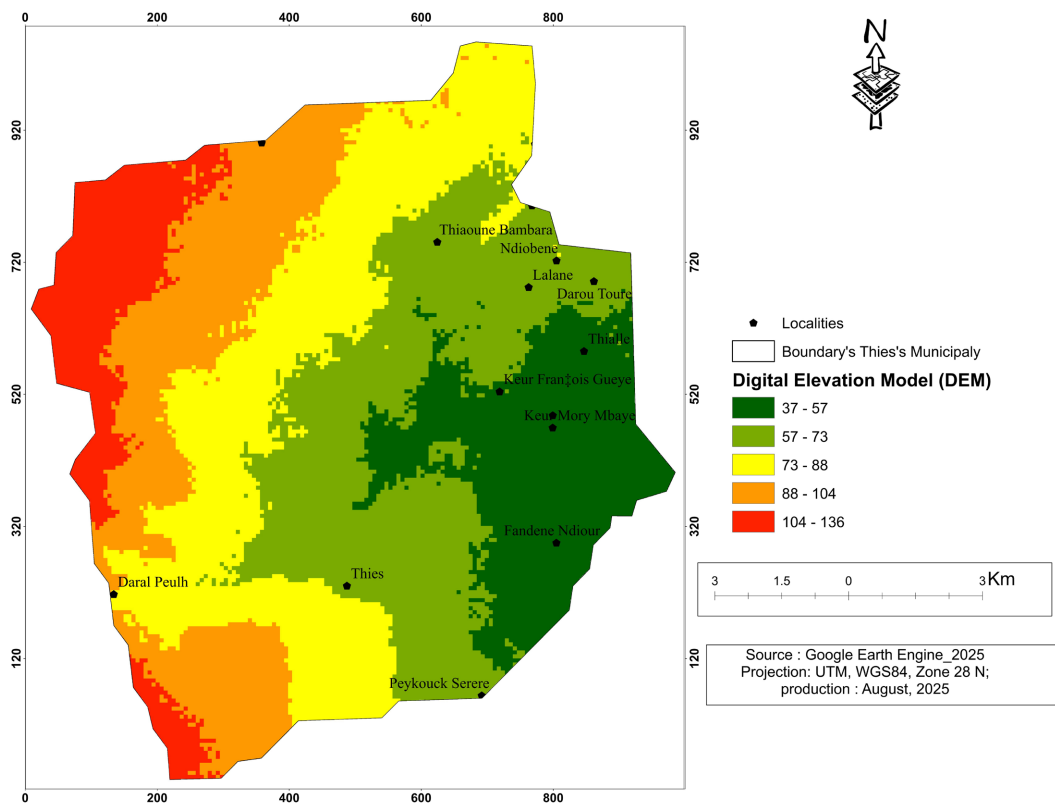


Figure 7. Values of the “Elevation” parameter for the watershed of the municipality of Thies.

elevated terrain, suitable for agriculture and urbanization. The slightly higher altitude areas, between 88 and 104 meters (19.25% of the area), indicate more pronounced relief but are still accessible for land use planning. The lowest areas, between 33 and 57 meters, represent 17.24% of the watershed, probably close to watercourses and floodplains. Finally, areas above 104 meters occupy a small portion (9.93%), representing higher relief areas that are probably less developed. These differences in altitude influence water management, erosion risks and land use.

#### 4.1.7. D: Distance from Drainage

The “Distance from drainage” parameter for the Thiès watershed indicates a significant distribution of areas close to drainage networks. The 0 - 1 km class, covering 36.83% of the area, represents the areas closest to the drainage system, probably characterised by better water management and a reduced risk of flooding (Figure 8). The 1 - 2 km class, representing 29.94% of the area, shows an area still fairly close to the drains, but potentially more prone to water accumulation. The 2 - 3 km (21.06%) and 3 - 4 km (9.54%) classes represent areas moderately distant from drainage, with a higher risk of flooding in the event of heavy rainfall. Finally, the 4 - 5 km areas, which cover only 2.62% of the catchment area, are the furthest from the drainage networks, which could pose challenges for surface water management and require specific interventions to avoid the risk of waterlogging and stagnation.

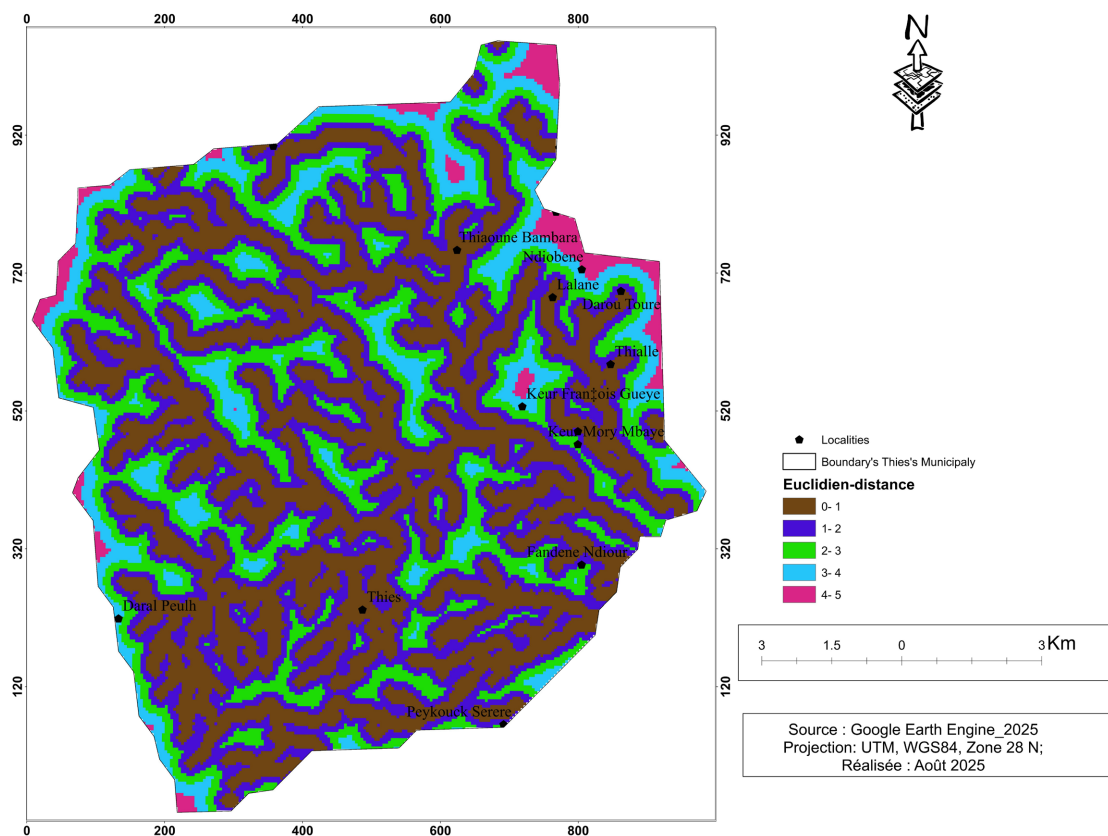


Figure 8. Values of the “Distance from drainage” parameter for the Thiès watershed.

### 4.2. Flood Risk Analysis

The “flood risk index” parameter in the Thiès watershed is essential for assessing the area’s most vulnerable to flooding. This risk varies according to several factors such as altitude, the hydrographic network, and land use planning. The data presented allows the areas of the basin to be classified according to their susceptibility to flooding, ranging from “very low” to “very high” risk areas. The different risk classes are distributed as follows (Figure 9):

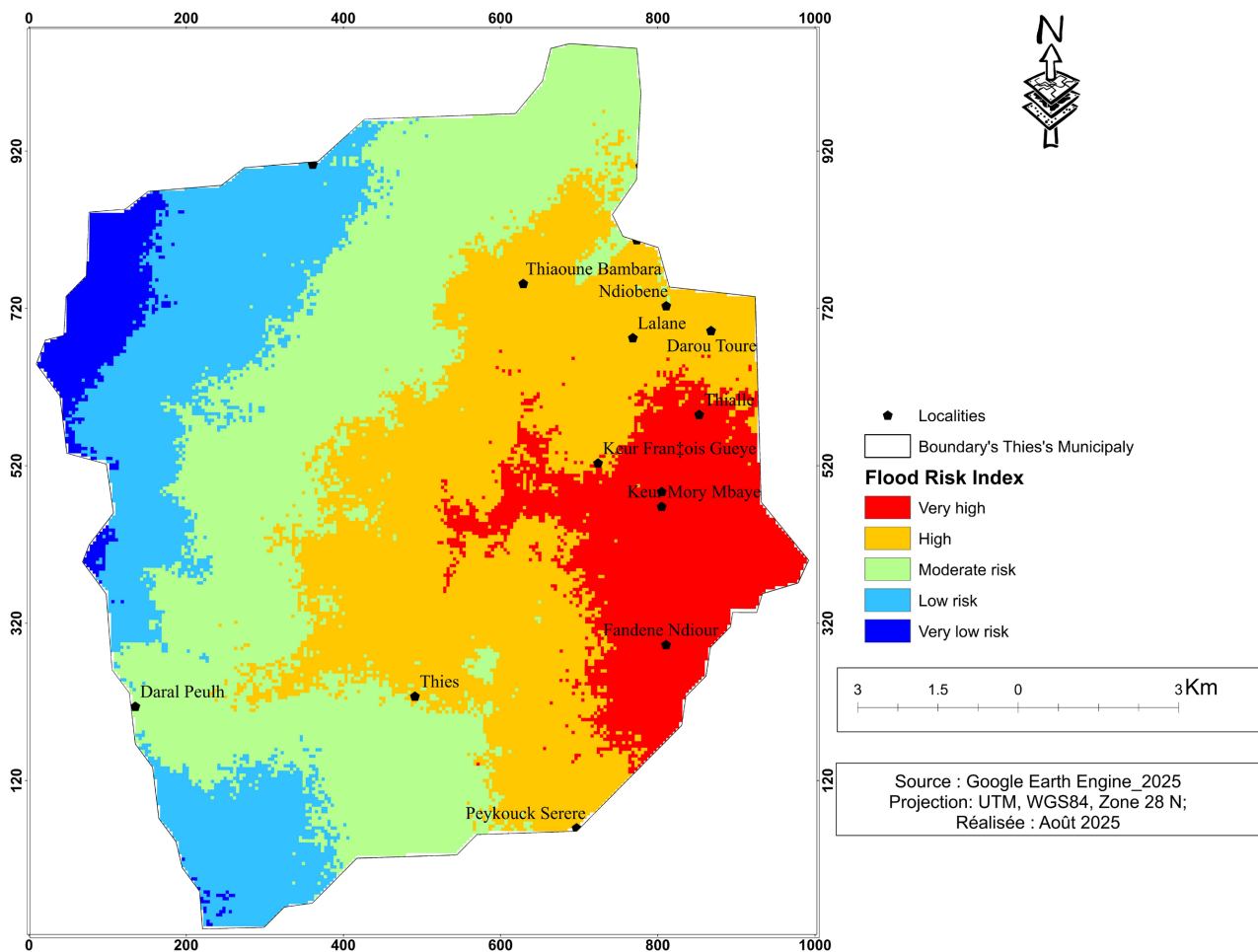


Figure 9. Flood risk index for the Thiès watershed.

1) **First class** (area: 25.07 km<sup>2</sup> of the basin surface, or 16.42%): This category covers areas where the risk of flooding is low to moderate. These regions are generally located in slightly higher areas, far from the main water flow routes. Developments in these areas can contribute to better rainwater management and minimise the risk of flooding. However, these areas remain vulnerable in the event of extreme weather events, such as torrential rain.

2) **Second class** (area: 40.93 km<sup>2</sup> of the basin’s surface area, or 26.81%): These areas present a moderate to high risk of flooding. They are often located near drainage areas or rivers, where water is more likely to accumulate during heavy

rainfall. These areas require preventive measures such as the installation of effective drainage systems to prevent overflowing.

**3) Third class** (area: 41.56 km<sup>2</sup> of the basin surface, or 27.22%): This category includes areas with a higher risk of flooding. These areas are often located at the bottom of valleys or plains, where rainwater accumulation is greater. Developments in these areas should include advanced drainage infrastructure and rigorous stormwater management to prevent flooding.

**4) Fourth class** (area: 30.33 km<sup>2</sup> of the basin's surface area, or 19.86%): These regions present a high risk and require immediate mitigation measures. They are the most vulnerable to flooding, particularly after heavy rainfall. High-risk areas are often characterised by low relief, where water has less opportunity to drain away naturally, thus requiring infrastructure works to redirect the water.

**5) Fifth class** (area: 14.76 km<sup>2</sup> of the basin surface, or 9.66%): These areas are the most vulnerable, with a "very high" risk of flooding. They are generally located in the lowest-lying areas or in sectors in the immediate vicinity of rivers and other watercourses. Emergency measures and risk management plans must be put in place in these areas to reduce potential damage.

A comparison between the risk map generated by the FIGUSED model and historical flood data for Thiès reveals a strong correlation between areas identified as high-risk by the model and areas historically affected by flooding. Low-lying areas, close to drainage networks, are clearly identified as vulnerable, validating the model's effectiveness in predicting at-risk areas. However, some areas less exposed historically could benefit from increased attention due to growing urbanization and recent climate change.

In summary, the city of Thiès presents a variety of flood risks, requiring an in-depth analysis of each area and the implementation of appropriate strategies to reduce these risks. High- and very high-risk areas must be given special attention in order to prevent the dramatic consequences of flooding.

## 5. Discussion of the Results of the Urban Flood Risk Assessment in Thiès (Senegal)

The results obtained through the flood risk assessment in Thiès have highlighted several critical aspects related to the city's vulnerability to hydrometeorological hazards. Using the flood potential index (FPI) and a multi-criteria modelling approach, it was possible to spatialise flood risk areas, revealing worrying vulnerabilities in terms of both infrastructure and populations. This discussion will focus on the contributing factors, the implications of the results and the approaches needed to improve risk management in this city.

### 5.1. Factors Contributing to Flood Risk in Thiès

Topography and rapid urbanization are major factors contributing to flood risk in Thiès. Although the city is located in the Fandène watershed on the highland of Thiès, it faces challenges related to its relatively flat topography, which pro-

motes water runoff [5]. The low ground gradient and the presence of low-lying areas make certain parts of the city particularly vulnerable to flooding, especially during heavy rainfall. The accumulation of runoff, the intensity of precipitation and the geology of the subsoil also influence the city's drainage capacity [12]. These factors have been confirmed by mapping generated using the IPI, which showed a concentration of high-risk areas in the lowest-lying parts of the city, often close to inadequate drainage systems.

Another contributing factor is unregulated urbanization and the extension of infrastructure into flood-prone areas. The lack of rigorous land-use planning policies and increased construction in highly vulnerable areas significantly increase the risk of flooding [21]. The rapid expansion of residential areas without adequate stormwater management infrastructure has exacerbated the situation. As a result, runoff is not effectively drained, leading to water accumulation in streets and homes during the rainy season [22].

The results also indicate that vegetation cover plays an important role in flood regulation. A study conducted by [3] highlighted that deforestation and uncontrolled urbanization have reduced the capacity of soils to absorb rainwater, leading to greater vulnerability to flooding. This is particularly true in urban areas of Thiès, where demographic pressure has led to the expansion of residential and commercial areas without taking into account the environmental impact on the stormwater management system.

## **5.2. Implications of the Results for Flood Risk Management**

The results obtained show that flood risk management in Thiès is a complex challenge that requires a multidimensional approach. Firstly, integrating IPI into urban planning and risk management is essential to better understand areas at risk. The use of GIS has made it possible to clearly identify vulnerable areas, a valuable tool for local authorities in developing effective mitigation strategies [2]. However, mapping alone is not enough. It is crucial to adopt proactive management based on clear action plans and flood-resilient infrastructure [7].

Another major implication is the need to reform urban planning in Thiès. Rapid population growth and unplanned urban expansion have exacerbated flood risks [11]. Authorities must implement stricter regulations on urbanization, particularly in high-risk areas. In addition, the city's drainage systems need to be improved, as most of the current networks are insufficient to handle the volumes of water generated by heavy rainfall. According to [6], efforts must be made to strengthen drainage and sanitation infrastructure, incorporating ecological solutions such as stormwater management through urban green spaces.

## **5.3. Flood Risk Mitigation Strategies**

The results also indicate that mitigation strategies are needed to reduce the impacts of flooding. Studies conducted by [9] [10] [23]-[25] highlights the importance of integrating flood risk management into urban planning. This includes

improving drainage systems, but also establishing early warning mechanisms and community education to raise awareness of flood risks [2].

It is also crucial to adopt a more sustainable approach to land use planning. The use of green spaces and the reintroduction of vegetation in urban areas can play a crucial role in regulating stormwater. According to [3], green spaces can reduce the extent of flooding by improving water infiltration and reducing runoff. In addition, soil rehabilitation and integrated water resource management (IWRM) policies need to be strengthened to reduce the city's vulnerability to flooding [23].

Finally, cooperation between different governmental and non-governmental actors is essential for effective flood risk management. A study by [9] [24] suggests that local authorities, community organisations and risk management experts must collaborate to implement adaptation strategies to address flood risks.

In Thiès, there is a more direct link between the identified risk zones and the priority mitigation strategies. For the 9.66% of the area classified as "very high risk," specific interventions must be implemented as a priority.

Improving drainage is essential in these areas, particularly through the renovation of existing networks and the expansion of stormwater collection infrastructure, to prevent water accumulation. In parallel, the development of green infrastructure, such as green spaces and green roofs, could reduce the impact of flooding by promoting rainwater absorption and decreasing runoff.

These measures must be accompanied by strict urban planning, prohibiting any construction in these vulnerable areas and encouraging environmentally friendly development projects to reduce pressure on these high-risk territories.

In summary, the results of the flood risk assessment in Thiès reveal significant vulnerabilities related to rapid urbanization, inadequate storm water management and poor drainage capacity [26] [27]. However, these results also provide essential information for the implementation of mitigation strategies, such as revising urban development policies [14] [24] [28], strengthening drainage infrastructure, and promoting more sustainable water resource management. Taking these elements into account in urban planning and disaster management could significantly reduce the impact of flooding on the city of Thiès and its inhabitants [20] [23] [29].

## 6. Conclusions

The results obtained in this study have highlighted the importance of the IPI as a tool for mapping and assessing flood risks in urban areas, particularly in a city such as Thiès, which is facing rapid urbanization and growing environmental challenges. Through the use of GIS and the flood potential index, this research has provided a better understanding of the most vulnerable areas of the city, particularly low-lying areas and areas close to inadequate drainage systems. The assessment of flood risk in Thiès revealed that topography, stormwater management, and unregulated urbanization are key factors contributing to the city's increased vulnerability to flooding. The results showed that a large number of residential areas, often located on saturated soils, experience recurrent flooding, compromis-

ing the safety of residents and the integrity of infrastructure.

To address these challenges, it is imperative to implement appropriate mitigation strategies. This includes revising urban development policies, strengthening drainage infrastructure, and establishing early warning mechanisms. Adopting a sustainable approach to stormwater management, including reintroducing green spaces and improving vegetation cover, can help reduce runoff and promote water infiltration. In addition, local authorities must develop stricter building regulations, including prohibiting construction in flood-prone areas and encouraging soil rehabilitation projects. Interventions must also be accompanied by awareness-raising and risk management training programmes to ensure active participation by the population. Finally, enhanced cooperation between the various stakeholders, including local authorities, urban planners, researchers and local communities, is crucial for the effective implementation of these measures and for reducing Thiès' vulnerability to flooding.

Ultimately, flood risk management in Thiès must be rethought in an integrated manner, taking into account environmental, social and economic factors. Risk mapping using tools such as the IPI is a crucial first step in guiding future actions and ensuring the city's resilience to the challenges posed by flooding.

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### Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

### References

- [1] UNISDR (2015) Global Assessment Report on Disaster Risk Reduction. United Nations Office for Disaster Risk Reduction.  
<https://www.preventionweb.net/english/hyogo/gar/2015>
- [2] Faye, C., Ndiaye, A. and Fall, M. (2021) Cartographie des risques d'inondation à l'échelle du bassin fluvial à l'aide de l'indice de potentiel d'inondation. *Journal International Sciences et Technique de l'Eau et de l'Environnement*, **6**, 40-51.
- [3] Tchamou, L., Ndiaye, A. and Sarr, M. (2017) Utilisation des SIG dans la gestion des risques d'inondation en Afrique de l'Ouest. Geospatial World Forum.
- [4] Diop, M., Faye, M. and Ndoye, M. (2018) Risques climatiques et urbanisation à Thiès. Les Éditions du CEES.
- [5] Banque Mondiale (2012) Document de projet pour une subvention de la Facilité Mondiale pour la Prévention des Risques de Catastrophes et le Relèvement (GFDRR) à la République du Sénégal pour le Projet de Gestion des Risques et Catastrophes et d'Adaptation au Changement Climatique au Sénégal (Phase I).  
<https://www.gfdr.org/sites/default/files/publication/rfcs-2014-senegal-fr.pdf>

- [6] Ngom, S.B.N. (2013) La vulnérabilité de la commune d'arrondissement de Thiès-Nord (ville de Thiès) aux inondations: mémoire de Master II, Université Cheikh Anta Diop de Dakar.  
<https://www.memoireonline.com/04/17/9811/La-vulnerabilite-de-la-commune-d-arrondissement-de-Thies-nord-ville-de-Thies-aux-inondations.html>
- [7] Bocquier, P. and Traoré, S. (2000) Urbanisation et dynamique migratoire en Afrique de l'Ouest. Harmattan Villes et Entreprises.
- [8] Camus, P. (1969) Le bassin fluvial du Sénégal. ORSTOM.  
<https://horizon.documentation.ird.fr>
- [9] Sy, B., Mbow, M. and Aw, S. (2025) Cartographie de la susceptibilité d'inondation, basée sur l'Analyse Hiérarchique des Procédés (AHP) dans les départements de Pikine et de Keur Massar, Sénégal. *La revue internationale en sciences de l'environnement*, **25**, No. 2. <https://journals.openedition.org/vertigo/50627?lang=fr>
- [10] Diakhate, M.M., Sarr, C. and Gueye, D. (2016) Gestion des risques d'inondation en Afrique de l'Ouest. Université Gaston Berger.
- [11] Sah, M., Gueye, C. and Diallo, M. (2015) Les stratégies d'atténuation des inondations en Afrique de l'Ouest. Institut de Géographie Tropicale.
- [12] Faye, C. (2025) Assessing People' Vulnerability to Urban Flooding in the Context of Climate Change: A Case Study of Six Districts in Ziguinchor, Sénégal. In: *Geoinformatics for Flood Risk Management*. CRC Press, 314-332.  
<https://doi.org/10.1201/9781003533511-19>
- [13] Zhou, Q. and Chen, Z. (2016) Flood Risk Assessment and Management Using GIS-Based Approaches in Urban Environments. *Journal of Environmental Management*, **177**, 1-12.
- [14] Sadeghi, S.H. and Sohrabi, M. (2017) Multicriteria Evaluation for Flood Risk Management in Urban Areas. *Environmental Earth Sciences*, **76**, No. 3.
- [15] Chapi, K., Guedon, G. and Ouattara, B. (2016) A Hybrid AI Model for Urban Flood Risk Mapping: The Case of Haraz Basin. *International Journal of Environmental Science and Technology*, **13**, 1345-1354.
- [16] Venkataraman, G. and Sengupta, S. (2020) Urban Flood Risk Modelling and Management Using GIS and Remote Sensing. Springer.
- [17] Wang, J. and Li, X. (2015) Application of AHP-Based GIS for Flood Risk Assessment in Urban Areas. *Journal of Hydrology*, **527**, 178-185.
- [18] Xu, Y. and Zhang, J. (2019) Flood Risk Mapping and Management Using Remote Sensing and GIS: A Case Study of Guangzhou, China. *Natural Hazards*, **97**, 593-606.
- [19] Blaes, X. and Minervini, J. (2018) GIS-Based Flood Hazard Mapping and Risk Analysis: A Case Study of the Seine River Basin. *Journal of Hydrology*, **553**, 237-246.
- [20] Singh, R.K. and Jain, S. K. (2018) Flood Risk Analysis and Mapping Using GIS Techniques: A Review. *Water Resources Management*, **32**, 3987-4002.
- [21] Faye, B., Du, G., Li, Q., Faye, H. V.M.T., Diéne, J.C., Mbaye, E. and Seck, H.M. (2024) Lessons Learnt from the Influencing Factors of Forested Areas' Vulnerability under Climatic Change and Human Pressure in Arid Areas: A Case Study of the Thiès Region, Senegal. *Applied Sciences*, **14**, 2427. <https://doi.org/10.3390/app14062427>
- [22] Camara, M., Ndiaye, A., Diop, M. and Gaye, M. (2020) Gestion des risques naturels en zone urbaine: Le cas de Thiès. Éditions Techniques et Environnement.
- [23] Faye, C. (2025) The Resilience of Populations to the Risks of Flooding, in the Context of Climate Change: What Level of Vulnerability of the Population in Ziguinchor (Senegal)? In: *Environmentally Sustainable and Socially Resilient Urban Development*

and Management. Springer Nature Switzerland, 879-907.

[https://doi.org/10.1007/978-3-031-92850-5\\_37](https://doi.org/10.1007/978-3-031-92850-5_37)

- [24] Touré, L., Njeugut, C., Youan, T., Sow, M. and Bonnet, E. (2019) Vulnérabilité urbaine face aux inondations en Afrique de l'Ouest: cartographie des enjeux et évaluation des dommages à Abidjan (Côte d'Ivoire) et Saint-Louis (Sénégal). *International Journal of Humanities and Social Science Invention*, **14**, 50-61.  
<https://doi.org/10.35629/7722-14035061>
- [25] CIMA Research Foundation (2021) Évaluation des risques d'inondation en Afrique subsaharienne. CIMA.
- [26] Bayé, S.B., Boni, S.B., Louis, D.G. and Afouda, Y.J. (2023) Agriculture urbaine et péri-urbaine à l'épreuve des dynamiques foncières en Afrique: Etat des lieux et perspectives. *Annales de l'Université de Moundou, Série A-FLASH*, **10**, 286-327.
- [27] Diémé, L.P., Bouvier, C., Bodian, A. and Sidibé, A. (2024) Flood Monitoring System in the Dakar agglomeration (Senegal). *Proceedings of IAHS*, **385**, 175-180.
- [28] Miller, J.D., Vischel, T., Fowe, T., Panthou, G., Wilcox, C., Taylor, C. M. and Cazenave, F. (2022) A Modelling-Chain Linking Climate Science and Decision-Makers for Future Urban Flood Management in West Africa. *Regional Environmental Change*, **22**, 93.
- [29] Cissé, C.O.T. (2024) La perception et la gestion du risque de submersion marine sur la Petite Côte (Afrique de l'ouest, Sénégal). *Espace Géographique et Société Marocaine*, **1**, 80-81.