# Implementation for Mapping Flood-Risk Areas – Case Study: The Municipality of Viana, Luanda Province (2024–2025).

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**DOI: https://doi.org/ doi.org/10.51244/IJRSI.2026.1306000200**

**Received: 07 June 2026; Accepted: 12 June 2026; Published: 30 June 2026**

## ABSTRACT

The proposal of a Geographic Information System (GIS) for flood mapping and mitigation relies on integrating and analyzing spatial data to identify vulnerable areas and aid preventive decisions. According to Longley, Goodchild, Maguire, and Rhind (2015), GIS is a tool that stores, manipulates, and represents geographic information, clarifying spatial relationships between environmental and human variables. In flood contexts, GIS analyzes relief, drainage, land use, and precipitation, producing thematic maps that indicate risk levels (Burrough & McDonnell, 1998). These maps guide land-use planning, infrastructure projects, and mitigation strategies, and help communicate risk to communities while supporting emergency plans (Smith, 2013). Overall, GIS enables more efficient, sustainable disaster management. and spatial monitoring.

**Keywords:** Floods, geoprocessing, GIS, spatial analysis, flood-risk mapping, Municipality of Viana

## INTRODUCTION

The present text results from a Master's dissertation in Economics, Spatial Planning and Regional Development, submitted at the Methodist University of Angola. The research was supervised by Professor António Afonso Bindanda, PhD. Bibliographic references in English and Portuguese were consulted. Although the dissertation was originally written in English, the article was translated from Portuguese.

This Scientific Dissertation concludes the Master's degree in Economics, Territorial Planning, and Regional Development at the Methodist University of Angola, with the theme: "Implementation of the Geographic Information System (GIS) for Mapping Flood Risk Areas: Case Study – Municipality of Viana, Luanda (2024–2025)," aiming to reduce socio-economic impacts and protect the most vulnerable population. Urban growth without planning is a key factor in flood generation, one of the major urban disasters (TUCCI, 2007). Floods in urban areas result not only from meteorological variables but also from unplanned human activities, leading to unordered land occupation, impermeabilization, and erosion, which aggravate floods in slopes and along riverbanks. This socio-spatial dynamic alters the physical space, impacting several neighborhoods in Viana and requiring safeguarding of areas designated as protections for natural and cultural heritage.

To analyze risks, the concept of flood risk is used according to Sá et al. (2016), considering measures to reduce both the probability of flooding events and their consequences. According to Câmara & Madeiros (2001), GIS (Geographic Information Systems) integrates data from multiple sources, creating georeferenced databases and supporting decisions on land use, spatial planning, urban infrastructures, and environmental monitoring (Mota, 1999). Mapping requires data on land use, slope, morphology, soils, hydrography, geology, and vegetation; these information layers are overlaid in ArcGIS for multifactorial analysis and identification of susceptible areas.

Space technologies, increasingly present, enable space-time analyses with satellite imagery integrated into GIS, boosting productivity gains and cost efficiency. However, intensive exploitation has environmental impacts, highlighting agricultural areas and residential occupations in risk zones.

# DEVELOPMENT

Applicability of GIS: according to Elias (2005) and Fritz (2008), Geographic Information Systems (GIS) are applicable in five broad groups: i) Human Settlement — urban planning, infrastructure networks, urban cleaning, territorial cadastral, and electoral mapping; ii) Health and Education — hospital and education networks, sanitation, and epidemiological control; transportation — supervision of road networks, vehicle routing, traffic control, and tourism information systems; security — control of air, sea, and land traffic, nautical cartography, and emergency services; iii) Land Use — agricultural-larming planning, storage and distribution of production, soil and vegetation classification, watershed management, dam planning, rural property cadastre, topographic and planimetric surveys, and land-use mapping; iv) Environment — fire management, climate studies, monitoring pollutant emissions, and forest management (deforestation/reforestation); v) Economic Activities — marketing planning, socio-economic research, distribution of products/services, and transport of raw materials and inputs.

Ennúrradas, floods, inundations, and inundations: a rush of water is a fast surface runoff caused by intense rainfall; COBRADE (2012) defines it as high-velocity, high-energy surface runoff. Floods are natural phenomena that affect many people, with various designations describing similar processes but distinct. Enchentes occur within a riverbed, especially during heavy rain, and can involve urban areas; alagamentos are water accumulations in streets poorly drained, not directly tied to rivers. The comparative figure shows that floods tend to be more catastrophic, but enchentes also pose risk. A master plan for land use and occupation is essential in cities with a history of floods.

The origin of systemic analysis techniques (thermodynamics, 19th century) and Bertalanffy's general system theory are noted, highlighting open/closed systems, geosystems, and the construction of risk maps through the interaction of physical, natural, and social factors. It is observed that environmental risk results from disorderly occupation and human activities, while natural risk cannot be mitigated by humans. The author emphasizes the current importance of risk areas in light of climate change and the evolution of multivariate techniques in identifying risk zones.

**Urban and peri-urban floods** are historical phenomena that occur when drainage systems overflow, occupying areas of housing, roads, commerce, and industry. They are driven by natural factors (relief, rainfall, soil permeability) and anthropogenic conditioning factors (irregular occupation of floodplains, waste, impermeabilization, changes to watercourse margins). The interaction of these factors explains why floods vary in intensity and frequency. Iconic historical cases (Yellow River 1887, Johnstown 1889, Chinese floods of 1931 and Yangtze 1998) illustrate mass deaths and extensive damage, often exacerbated by inadequate infrastructure. Unplanned urbanization increases vulnerability by channeling rainfall runoff rapidly into urban networks. Highlighted mitigation measures include urban planning with effective drainage and controlled land use, public education about risks, and the adoption of monitoring and flood forecasting technologies. Preserving floodplains and improving water infiltration in basins are key strategies to reduce catastrophic outcomes.

Fig. 3: Flood cases around the world

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Source: Adapted by the author, 2025

**Flood monitoring** methods and techniques involve sensors, hydrological and hydrodynamic models, and early warning systems. Sensor systems include fixed sensors at strategic points to monitor water levels and movable sensors deployed in flood-affected areas to collect real-time data. Flood monitoring also uses remote sensing techniques and hydrodynamic models. Remote sensing (Flood Monitoring by Sensing) collects real-time data to predict flood risk and enable preventive actions. Hydrodynamic models delineate flood hazards and propose mitigation strategies. Structural and preventive measures support flood control.

**Structural measures** include hydraulic works such as dams, levees, and channels, along with reservoirs and infiltration trenches. Preventive measures encompass zoning of flood-prone areas, civil defense-linked alert systems, evacuation from high-risk zones, creation of forest reserves along rivers, and more robust urban planning. Real-time data on water levels and precipitation are analyzed to forecast and monitor flood risk. An advanced technique is Flood Monitoring by Sensing, using sensors and remote sensing tech to gather data. Structural and preventive measures include dams, dikes, urban drainage controls, and drainage network management.

**Preventive measures** also include flood-zone zoning, civil-defense alerts, creating urban green spaces along rivers, and building code criteria. To protect against floods, stay informed about weather forecasts, follow authorities, avoid traveling to affected regions, and avoid contact with floodwaters. Modern city solutions include green and blue infrastructure (green roofs, permeable pavements, floodable parks, rain gardens) and drainage enhancements (inlets, stormwater galleries, reservoirs). Rainwater management systems comprise capture, storage, treatment, drainage, and reuse, yielding benefits like flood prevention, resource conservation, and improved life quality.

**Susceptibility mapping in flood-prone** areas defines susceptibility as a area's predisposition to a given process based on local terrain, excluding temporal probability (return period or frequency). Flood susceptibility relates to the likelihood of inundation, floods, and overflow, and the resulting susceptibility map informs the potential for flood occurrence at a site (Rezende, Marques, de Oliveira, 2017). Producing flood-susceptibility maps is highly important for territorial planning, serving as an effective tool for disaster prevention and control amid urban expansion, and aligning with map types (susceptibility, hazard, risk) and project scales (Barbosa, 2006). Enomoto (2004) views flood-risk mapping as a powerful helper in flood control. Such maps should underlie all damage-reduction programs and often hold legal relevance for zoning and non-structural measures (Friescke, 2004). According to Andjelkovic (2001) these maps enable: building preventive structures, alerting current and future landowners in flood zones, and aiding authorities to develop sustainable development ideas. Marcelino et al. (2006) deem risk mapping one of the most efficient risk-analysis instruments for planning emergencies and fostering community-public sector collaboration. Shidawara (1999) notes that risk maps are crucial in small, resource-limited municipalities where sophisticated monitoring and alert systems are hard to implement.

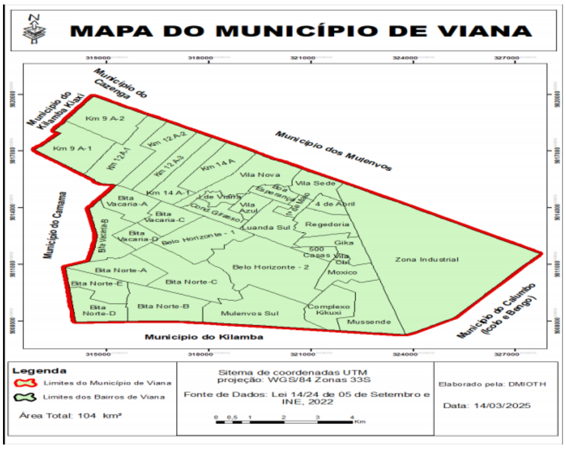
**Volume calculation of flooded water**: determine flooded area and average depth; **Volume = area × depth. Steps:** measure regular or irregular area, average depth from multiple points, multiply, and convert to liters if needed (1 $m^3$ = 1000 L). For irregular areas, use geometric decomposition or advanced methods (integration) for higher accuracy.

**Angolan environmental law** notes the Base Environmental Law (Law 5/98) and Conservation Areas Law (Law 8/20) to protect resources and promote sustainable use; the Constitution recognizes citizens' environmental rights and duties.

SWOT analysis describes internal (Strengths, Weaknesses) and external (Opportunities, Threats) factors for risk management. Strengths include sustainable practices, resilient infrastructure, traditional knowledge; weaknesses include resource gaps and limited information access; opportunities include favorable public policies and international support; threats include extreme climate events and pollution.

**Study Area Location**. According to Law no. 14/24 of 5 September (New Law on Political-Administrative Division), the Municipality of Viana is about 18 km from the national capital. It covers roughly 104.00 $km^2$ and has a population of approximately 865,863 inhabitants (INE, 2024). Geographically, its limits are: north – Cazenga and Mulenvos; south – Kilamba (Luanda Province) and Calumbo (Icolo e Bengo Province); east – Calumbo (Icolo e Bengo); west – Kilamba Kiaxi and Camama. It comprises 24 neighborhoods, as shown on the map.

Figure 10: Physical political map of Viana



Source: Adapted by the author, 2025

### General Information

Lack of growth monitoring in Viana has amplified problems, especially during the rainy season, exposing residents to risks such as floods, particularly in poor communities with few resources, including several neighborhoods in Viana.

### Demography

Fresh INE data (2024–2025) characterize the population as young: about 66% are under 15 years old. Only 1.5% are 65 or older. There are more women than men. Vulnerable children account for 20% of the population, of which 12% are orphans or separated from both parents. The main reasons for migration are war and rural exodus, representing 53.8% of the local demographic profile.

**Socioeconomic Study**. Economic potentials
Recent local priorities to boost development:

- Human resource development
- Poverty reduction
- Infrastructure and social facilities construction
- Public and private investment
  Viana's dominant economic activities are industry (emblematic), trade, and agriculture (traditional and commercial production), anchored by the Viana Industrial Park (PIV).

### Viana Industrial Development Pole

The Industrial Development Pole of Viana was established by Resolution no. 4/98, of 27 March. It emerged to relaunch industrial activity amid deindustrialization, per Angola's PDRA plan. Luanda Province, with about 75% of national productive capacity, was prioritized due to its market, infrastructure, skilled workforce, and proximity to decision centers and financial institutions. At that time, Angola faced electricity, water, roads, rail, ports, airports, and telecoms constraints, plus a shortage of well-equipped industrial land. To focus efforts, "poles de desenvolvimento" were created; Viana's pole was the pilot, initially allocated 6000 hectares for industrial use, later reduced to 1000 ha. Other poles were created later (Catumbela, Fútila, Lucala, Soyo, Dondo).

**Environmental Studies.**

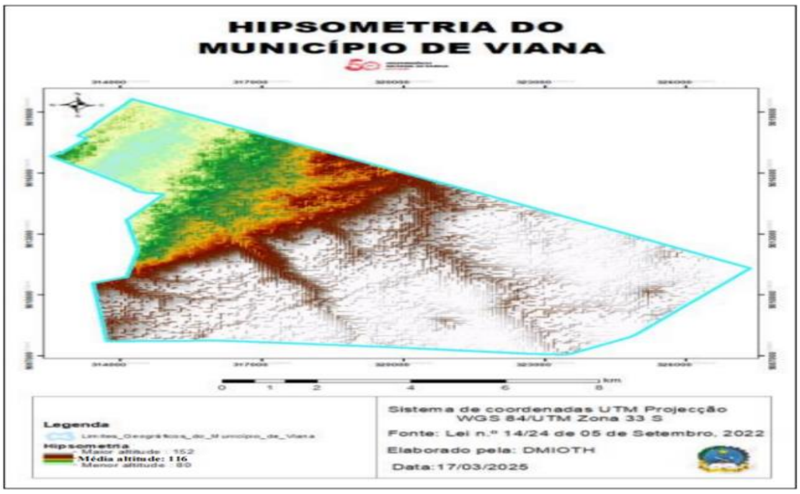
### Elevation

Topographic relief results from endogenous geophysical processes (igneous activity) and exogenous processes (water, wind). Understanding relief is essential for landscape appreciation and territorial planning. Relief comprises altitude (hypsometry), slope (declivity), and concavity. Altitude strongly influences precipitation, vegetation, and fauna, and constrains human occupation by affecting accessibility and urbanization.

### Hypsometry

Hypsometry provides a global view of Viana's relief, using altitude intervals derived from digital topography (10 m contour intervals). MDT is produced from a TIN, contour lines, and digital elevation, using GIS (ArcGIS). Higher elevations reduce flood probability due to gravity-driven water movement.

Figure 11: Hypsometric map of Viana

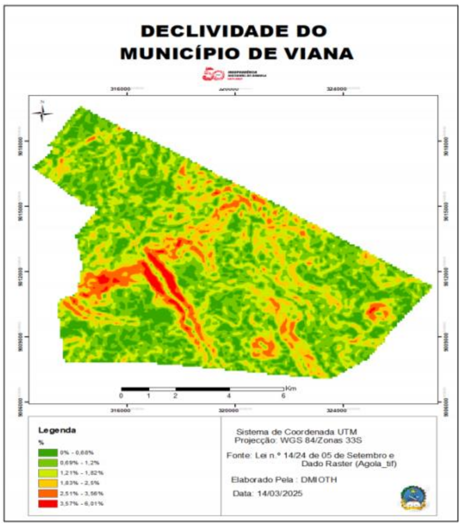


Source: Adapted by the author, 2025

### Slope

Viana's terrain shows moderately gentle to slightly uneven relief. The slope map defines five classes (0–5%, 5–10%, 10–15%, 15–20%, >20%). These classes aid in assessing land use, natural hazard risk, and ecological structure. In urban planning, slopes >45% are rarely present and often considered permanent preservation areas. Flat areas have higher flood risk than steeper areas, and slope influences water runoff and surface storage.

Figure 12: Slope map of Viana



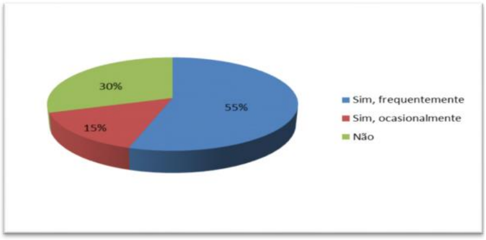
Source: Adapted by the author, 2025 of population growth, mobility pressures, and institutional limitations.

## RESULTS

Questionnaires/Interviews on the degree of social vulnerability to flooding. The following is a selection of seven questions (Appendix 1) developed in the author's questionnaire, applied to 400 citizens, with a brief analysis of social vulnerability to flooding in the neighborhoods of the Municipality of Viana.

**Graph no. 1– Flooding situation in the neighborhoods**

Level of experience: 55% of respondents report frequent floods, 15% occasionally, 30% do not experience flooding.

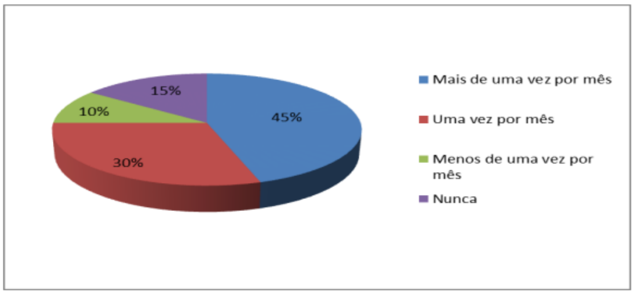


Fonte: Elaborado pelo autor. 2025.

(Source: author, 2025)

**Graph no. 2 – Flood frequency**

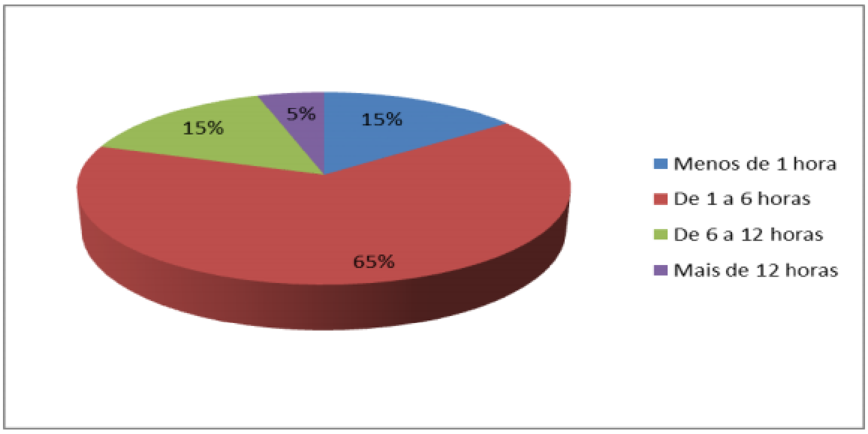
Frequency: 45% occur >1 time/month; 30% occur 1x/month; 10% less than 1 month; 15% do not occur during the rainy season.



(Source: author, 2025)

**Graph no. 3 – Average duration of floods**

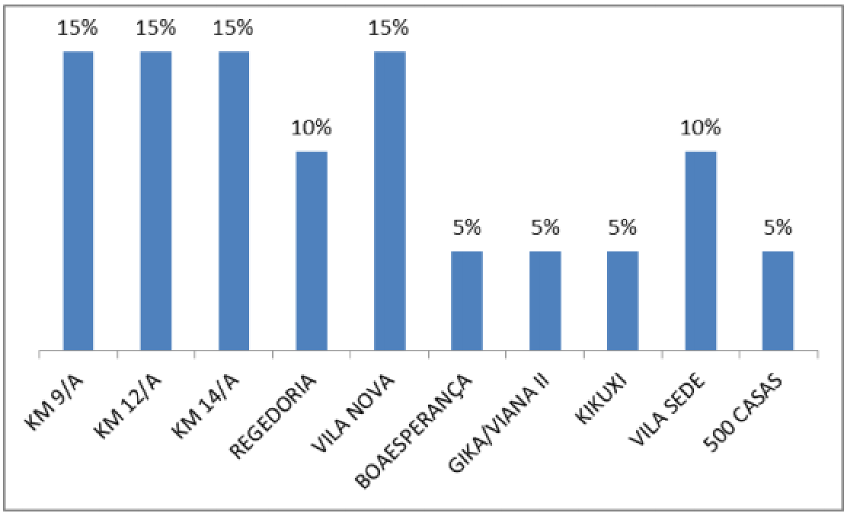
~65% stay flooded 1–6 hours; 5% >12 hours; 15% less than 1 hour and 6–12 hours.



(Source: author, 2025)

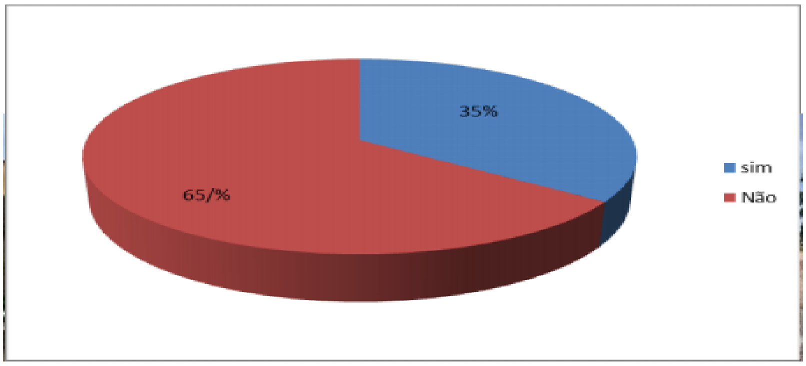
Main neighborhoods: Km 9/A, Km 12/A, Km 14/A, Vila Nova (15%); Regedoria and Vila Sede (10%); 1º de Maio, Gika/Viana II, Kikuxi, and 500 Casas (5%).

**Graph no. 4 – Most affected neighborhoods**



(Source: author, 2025)

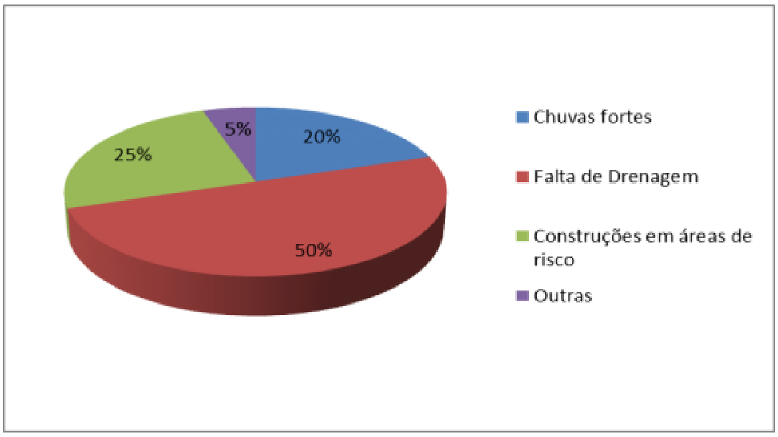
**Graph no. 5 – Abandonment of residences** ~65% abandoned; 35% did not abandon. In situ observations how abandoned houses after heavy rains from September to May.



(Source: author, 2025)

**Graph no. 6 – Main causes**

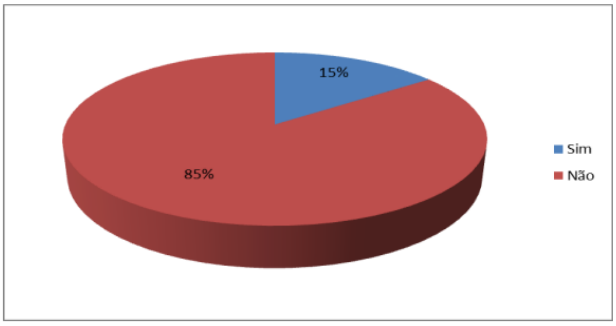
50% cite lack of drainage; 25% indicate housing in risk areas; 15% attribute heavy rains; 5% other causes.



(Source: author, 2025)

**Graph no. 7 Prevention and mitigation by the Administration**

85% perceive no involvement by the local authority; 15% indicate actions of macro-drainage/mitigation during floods.



(Source: author, 2025)

The Geographic Information System (GIS) in mapping flood areas. Data entered into ArcGIS 10.8 (proprietary license) for GIS application, with spatial reference WGS 84/Zone 33, enabling geographic alignment of locations.

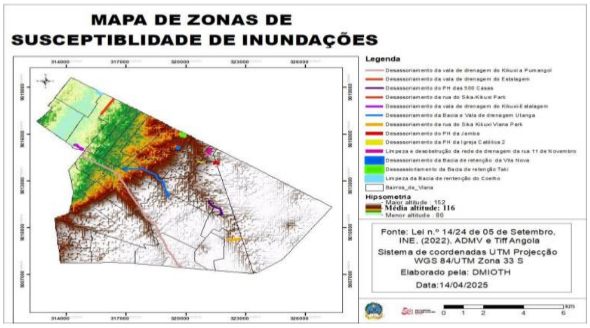
## Hypsometry

Elevation is crucial for identifying flood-prone areas. The Digital Elevation Model (DEM), provided by the Angola Geological Institute (TIFF), generated the hypsometric map of the Municipality of Viana (Figure 12). Elevation ranges from 80 to 152 meters above sea level. Higher-altitude areas appear white; mid-altitude areas brown; low-altitude areas green/greenish. By crossing the hypsometric map (Figure 12) with the location map (Figure 11), it is evident that the Viana Industrial Zone (PIV) and much of Kikuxi lie in higher elevations; neighborhoods such as Boa Esperança, Project Morar, Vila Sede, 4 de Abril, 1º de Maio, and Regedoria show mid elevations. Km 9/A, Km 12/A, Km 14/A, and Vila Nova present low elevations, favoring surface runoff. This fact will be more evident when analyzing the so-called flood susceptibility map in Figure 16. Why these results matter: across multiple studies on this process, the erratic, unplanned construction has radically altered runoff regimes in retention basins and the Municipality's watercourses. Coupled with the lack of proper drainage system structuring in several neighborhoods, this has amplified flood damages and disproportionately affects socially vulnerable communities.

## Key findings:

Figure 15 displays the spatial distribution of land use in the Municipality. It shows that heavy construction dominates the morphology, while green areas become increasingly marginal. Inadequate regulation of land-use and occupation, along with disorderly building in high-risk zones and outdated municipal master plans (PDM), contribute to floods in many bairros of Viana.

Figure 15 Mapa de zonas de susceptibilidade de inundações



(Source: author, 2025)

The flood risk map (Figure 16, in Dissertation) highlights affected zones with multiple color codes, with most of the Municipality impacted when water levels rise. Low-lying zones (below 4 m) are most affected due to proximity to flood-prone areas.

## DISCUSSION

Inequalities in digital terrain models (MDE) used for modeling reduce accuracy, underscoring the need for high-detail surface and bathymetric data. Field records bolster credibility by confirming model-area relationships.

Urban and peri-urban flooding is documented in neighborhoods such as Vila Nova, Vila Sede, Vila Chinesa, and Kikuxi. Some homes flood even in drought periods, reflecting drainage voids and temporary solutions like informal valetas. In urban zones, 90% of the mapped flood footprint aligns with observed inundation areas (Figure 10–11- in Dissertation).

Overall, flood susceptibilities are driven by natural relief, rainfall, drainage inadequacy, and socio-economic factors that promote unordered land occupation and debris in waterways.

## CONCLUSION

The present research demonstrates that the Geographic Information System (GIS) is a highly useful tool for structuring problems, supporting mathematical modeling, and facilitating complex decisions. It stands out for its ability to operationalize qualitative analyses through numerical parameters, resulting in the Map of Flood Susceptibility. This map assists public authorities in exploring urban planning alternatives in the face of environmental issues, adopting both structural and non-structural mitigation measures to revitalize flood-prone areas.

The map was generated by overlaying several layers (Elevation, Slope, Rainfall, Soil Types, and Land Use and Cover) with an appropriate weighted distribution for the variables. Results indicate that flood-susceptible zones are located in flatter, lower-elevation areas, corroborating the GIS's usefulness to guide urban interventions.

The GIS implementation for mapping risk areas represents a significant advance in disaster management, offering a proactive approach to reducing losses. The integration of georeferenced data, spatial analysis, and GIS visualization facilitates understanding of the situation and optimizes decision-making from prevention to response and recovery. The quality of results depends on accurate, up-to-date data on relief, hydrography, precipitation, land use, and historical flood events.

GIS also enables the creation of Digital Elevation Models (DEMs), flood simulations, and vulnerability analyses, supporting planning for risk prevention and mitigation. It is observed that the traditional approach of public authorities has often failed in prevention, preparedness, and response and can even exacerbate impacts. The impermeabilization of the soil and artificialization of the natural drainage network aggravate flood frequency, underscoring the need for risk maps to guide structural and non-structural actions and to prioritize the stages of municipal action, aiming for efficiency of time, resources, and improved quality of life.

### Scope of Objectives

Identify and delimit vulnerable areas; assess disaster probability; subsidize urban and emergency planning; guide prevention and mitigation actions. Additional objectives include protecting the population, avoiding material losses, and increasing community resilience to climatic events.

### Main contributions to science:

- Provide a basis for planning, public policy, and land use planning based on geographic data.
- Tool for integrated analysis of hydrology, relief, land use, and socio-economic dynamics through geotechnologies.

- Support for disaster prevention and mitigation and study of social vulnerability, highlighting inequalities in occupying risk areas.

- Foundation for monitoring and alert systems that anticipate risks.

**Future study topics:**
1) Advanced technologies (AI, Deep Learning, SAR imagery, DEMs) for real-time detection and future scenarios; 2) Long-term climatic projections and urbanization scenarios; 3) Integrated management with urban planning, green infrastructure, and nature-based solutions; 4) Community involvement, participatory mapping, and alert systems; 5) Final recommendations: integrate risk maps into the Municipal Master Plan (PDM) of Viana to guide land use and occupation of risk areas, strengthening resilience and quality of life.

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