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GIS BASED FLOOD VULNERABILITY MAPPING IN THE BATANG KURANJI WATERSHED, PADANG CITY DUE TO LAND CONVERSION

*M. Fauzan[1,4], Aaron Kristian[2], Ratna Wilis[3], Triyatno[3], Cahyadi Nugroho[5], L Sukardi[6]

[1]Regional Disaster Management Agency, Pariaman City, Indonesia
[2]Mangrove and Coastal Research Center, New Zealand
[3]Department of Geography, Universitas Negeri Padang, Indonesia
[4]Master Program of Geography Education, Universitas Negeri Padang, Indonesia
[5]Department of Geography Education, Universitas Negeri Manado, Indonesia
[6]Department of Environmental Science, Universitas Mataram, Indonesia
Email: muhaamadfauzan07@gmail.com

*Corresponding Author, Received: February 01, 2026. Revised: May 07, 2026. Accepted: May 27, 2026

ABSTRACT: Flood is one of the most frequent hydrometeorological disasters in Padang City, closely related to land use change and the degradation of watershed functions. Rapid urban development in the Batang Kuranji Watershed has led to the expansion of built-up areas, which reduces land infiltration capacity and increases surface runoff, thereby intensifying flood risk, especially in downstream areas. The advancement of remote sensing technology and Geographic Information Systems (GIS) enables comprehensive spatial analysis to assess land use dynamics and flood hazard distribution at the watershed scale. This study aims to analyze land use changes in Padang City during the 2017–2025 period and to identify flood hazard and vulnerability levels in the Batang Kuranji Watershed based on multiple physical and hydrometeorological parameters. The analysis utilizes Landsat 8 imagery, CHIRPS rainfall data, DEMNAS-derived slope data, soil type information, river buffer analysis, and spatial planning data, which are processed using scoring and overlay methods within a GIS environment. The results indicate a continuous increase in built-up areas accompanied by a reduction in agricultural land and natural vegetation, particularly in the middle to downstream sections of the watershed. Flood hazard analysis shows that most of the watershed area falls into the low to moderate hazard classes; however, areas categorized as high hazard are concentrated in lowland regions and river corridors with dense settlements. These critical zones have limited water absorption capacity and are highly susceptible to flooding and inundation during periods of high rainfall. Therefore, spatial monitoring of land use change and flood hazard distribution is essential as part of an integrated flood mitigation strategy to support sustainable watershed management and spatial planning in Padang City.

Keywords:, Flood hazard; Land use change; Geographic Information System (GIS); Remote sensing; Batang Kuranji Watershed; Padang City.

1. INTRODUCTION

Flood disasters are events that threaten and disrupt people's lives and livelihoods, which are generally caused by river water overflows due to natural factors, including damage to the buffer zone of upstream watersheds [1].

Floods are one of the most frequent natural disasters in Indonesia and have a major impact on the environment, social, and economic community [2]. This phenomenon is generally caused by high rainfall as well as uncontrolled hydrological conditions and land use, especially in densely populated and rapidly developing areas [3].

In various regions of Indonesia, floods are also often exacerbated by the degradation of watersheds and decreased land absorption due to changes in land use that are not in accordance with conservation rules [4].

Changes in land function are one of the dominant factors causing increased flood vulnerability in urban areas. The conversion of land from water catchment areas to built-up areas results in a decrease in the capacity of the soil to absorb rainwater, thereby increasing the volume of surface runoff [3], [5]. The imbalance between the pace of development and spatial control narrows the river boundary and reduces the quality of the environment due to low community participation in maintaining the cleanliness of the river [6].

This condition also occurs in Padang City, West Sumatra Province, which is geographically located on the West Coast of Sumatra Island with a coastline of ±84 km. The area of Padang City reaches ±694.96 km², of which about 60% or ±434.63 km² is hilly areas overgrown with protected forests, while the rest is lowlands that are the center of urban activities [7]. Topographic variations between lowlands and hilly areas make the region vulnerable to hydrometeorological disasters, such as floods and landslides [8].

One of the areas with a high level of flood vulnerability in Padang City is the Batang Kuranji Watershed, which covers an area of ±22,469 hectares and consists of five sub-watersheds [7][9]. This area plays an important role in the hydrological system of Padang City, but it is under pressure due to uncontrolled land conversion. The change of vegetation land into residential areas and built-up areas has disturbed the balance of the Kuranji watershed ecosystem and increased the potential for flood and erosion disasters [10].

Batang Kuranji is a river that divides the city of Padang in West Sumatra Province. This river flows upstream around Bukit Barisanantara in Solok Regency with Padang City, and empties into the Indian Ocean. Land-use changes in the Batang Kuranji watershed, particularly the increase in settlements and built-up land, have significantly altered the region's hydrological characteristics, increasing surface runoff and the frequency of flooding events [7] [11].

In addition, land degradation and damage to the hydrological function of watersheds are often caused by land use that deviates from the regional spatial plan and the low application of soil and water conservation techniques on steeply sloped land [12]. Therefore, spatial analysis based on Geographic Information Systems (GIS) is an important method to identify areas with potential flooding and evaluate the impact of land-use changes on the carrying capacity of the environment. Through an overlay approach and scoring various physical parameters of the land, GIS can be used to determine priority areas for control and more sustainable spatial planning [13].

2. METHODS

2.1. Changes in Padang City Land Use in 2017-2025

The formulation of land use changes in Padang City for the 2017–2025 period uses the applied classification method combining *the Object-Based Image Analysis* (OBIA) approach with supervised classification, allowing for more accurate classification results because it considers spatial elements such as shapes, textures, and patterns of objects. All analyses are limited to the administrative area of Padang City so that the results obtained are spatially relevant[14].

2.2. Land Use (Existing) of Padang City in 2025

To analyze land use in Padang City in 2025, an overlay was carried out between existing land use data and the Regional Spatial Plan (RTRW) of Padang City for the period 2025–2045. This approach allows identifying the compatibility between real conditions on the ground and the spatial planning that has been determined, as well as looking at potential land use changes that occur due to urbanization, infrastructure development, and settlement expansion [15].

2.3. Flood Vulnerability and Danger Level in Kuranji Watershed

The data used for each indicator was obtained from various sources, including: CHIRPS dataset for rainfall, Padang City Land Use 2025 map, RBI base map of Padang City, DEMNAS data for topography and slopes, as well as information from BBSDLP related to hydrological and spatial conditions[7].

Table 1. Indicators of Vulnerability and Danger of Flooding in the Batang Kuranji Watershed

Indicator	Sub indicator	Rank	Score
Rainfall	<1500	1	0,25
	1500 – 2000	2	0,50
	2000 – 2500	3	0,75
	2500 – 3000	4	1,00
	>3000	5	1,25
Slope	Datar	5	1,25
	Sloping	4	1
	A bit steep	3	0,75
	Curam	2	0,5
	Very Steep	1	0,25
Land Use	Water bodies	5	1,25
	Forest	1	0,25
	Wetland Vegetation	2	0,50
	Agriculture & Plantation	3	0,75
	Woke Areas	4	1,00
	Vacant Land	5	1,25
	Awan	5	1,25

	Grasslands	3	0,75
Buffer Sungai	0–50	5	1,25
	51–100	4	1,00
	101–150	3	0,75
	151–250	2	0,50
	251–500	1	0,25
Soil Type	Entisols	1	0,1
	Histosols	1	0,1
	Ultisols	2	0,2
	Inceptisols	3	0,3
	Oxisols	4	0,4

Source: Data analysis results, 2025

3. RESULT AND DISCUSSION

3.1. Changes in Padang City Land Use in 2017-2025

The city of Padang has experienced an increase in built-up areas such as housing, public facilities and consistent infrastructure. The development of this built-up area is reported as a positive/upward trend in several studies that examined Landsat/Sentinel imagery and land use mapping in Padang City [16].

Table 2. Land Use 2017-2025

No	Remarks	Area 2017 (ha)	Area 2021 (ha)	Area 2025 (ha)
1	Water bodies	410,13	397,70	392,30
2	Forest	49.300,05	48.983,99	49.385,99
3	Wetland Vegetation	6,40	8,14	2,02
4	Agriculture and Plantations	4.977,05	5.138,15	4.564,49
5	Woke Areas	13.411,06	14.124,01	14.434,62
6	Vacant Land/Land	70,16	41,24	49,17
7	Awan	2,79	0,03	7,69
8	Grasslands	1.243,83	728,36	585,12

Source: Data analysis results, 2025

Based on table 2, Padang City's land use changes during 2017–2025 show a real shift due to rapid development and human activities. The built-up area increased from 13,411.06 hectares to 14,434.62 hectares, reflecting the expansion of settlements and infrastructure, especially in downstream areas. In contrast, agricultural land and plantations decreased to 4,564.49 hectares, accompanied by reduced grasslands and wetland vegetation due to land conversion and changes in water systems. However, the forest area showed stability with a slight increase to 49,385.99 hectares, which indicates that there are still conservation efforts in the upstream part of the watershed. The land use of Padang City is analyzed using a map of land use results from 2017-2025 as shown in figure 2.

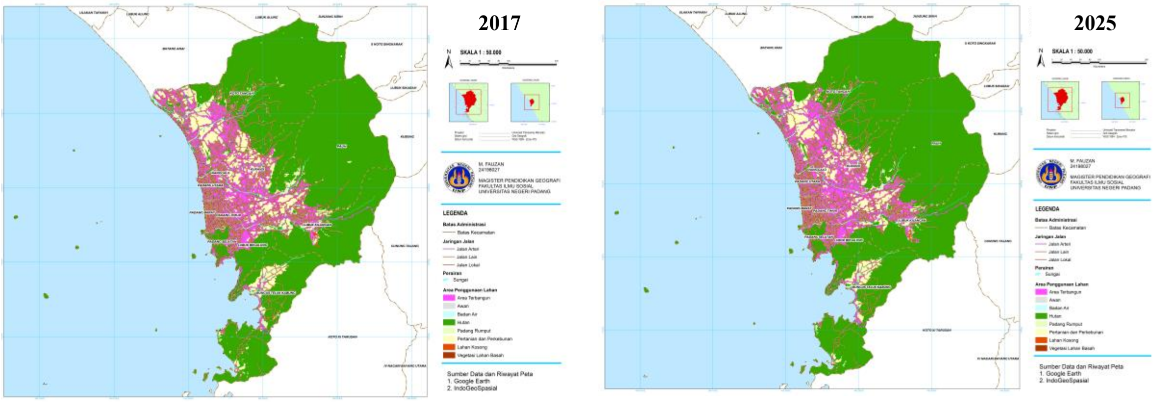

Fig 1. Padang City Land Use in 2017-2025

Analysis of the map of land use change in Padang City from 2017-2025 identifies that the comparison of land cover area shows significant dynamics in several land classes. The built-up area continues to increase from 13,411.06 ha in 2017 to 14,434.62 ha in 2025, indicating an intensive urbanization process. This often occurs in urban areas and is usually influenced by population growth and expansion of space requirements [17].

Various factors contribute to the change in land cover in Padang City. [17] It was stated that these dynamics were influenced by several main aspects, namely: (1) population growth, (2) anthropogenic activities, (3) natural disaster events, (4) natural succession processes, (5) technical constraints such as variations in resolution and image position, and (6) changes in cloud cover conditions in the observation area. In line with this, research [18] on settlement dynamics and factors driving land cover change in Padang City shows that the main factors affecting land cover change in the period 1998–2008 are WATER, RENT, and GARAP factors.

3.2. Existing Land Use of Padang City in 2025

The projected land use of Padang City in 2025 shows significant spatial dynamics, especially related to the development of built-up areas and changes in other land functions [11]. This phenomenon is largely triggered by rapid population growth, which drives an increase in the need for settlements and supporting infrastructure, often at the expense of other productive land [16]. The gap between spatial planning and implementation in the field often leads to massive land conversion, exceeding the carrying capacity of the area and potentially causing new environmental problems[19].

The existing land use of the city of Padang is analyzed based on several aspects related to land use obtained from the overlay of the Padang City RDTR data with the elaboration in table 1.

Table 3. Existing Land Use of Padang City in 2025

No	Remarks	Area 2025 (ha)
1	Water bodies	392,30
2	Forest	49.385,99
3	Wetland Vegetation	2,02
4	Agriculture and Plantations	4.564,49
5	Woke Areas	14.434,62
6	Vacant Land/Land	49,17
7	Awan	7,69
8	Grasslands	585,12

Source: Data analysis results, 2025

Based on Table 1, it shows the condition of land use in Padang City in 2025, where forest areas dominate with an area of 49,385.99 hectares, indicating that the ecological function of the area is still strong. The built-up area occupies the second position with 14,434.62 hectares, illustrating the rapid development of settlements and human activities. Meanwhile, agriculture and plantations cover 4,564.49 hectares, followed by pastures covering an area of 585.12 hectares and water bodies of 392.30 hectares. The bare land, wetland vegetation, and clouds have a relatively small area, namely 49.17 hectares, 2.02 hectares, and 7.69 hectares, respectively. Overall, the dominance of forests still maintains the ecological balance of the Batang Kuranji watershed, although the increase in built-up area indicates that there are development pressures that need to be controlled so as not to interfere with the hydrological function of the area. Supervised land use analysis map (cliff calcification) using lane 8 in the overlay using the intersec method between the RDTR of Padang City and the existing land use of Padang City which can be seen in figure 2.

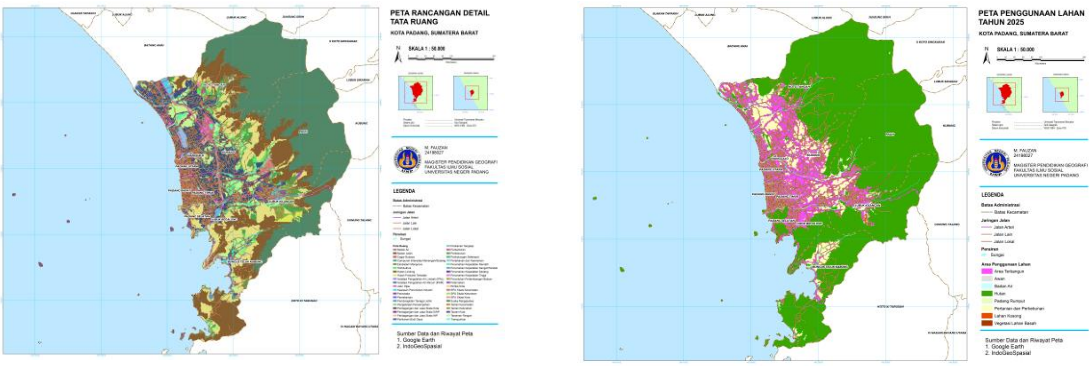

Fig 2. Map of RDTR Space Patterns and Suitability of Existing Conditions of Padang City in 2025

Analysis of the suitability of the spatial pattern in the Regional Spatial Plan (RTRW) with the condition of existing land in Padang City shows that the majority of the area, which covers an area of 41,703.94 ha, has been in accordance with the stipulated spatial planning provisions. However,

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there is a significant area that is not suitable, namely 1,690.40 ha. This inconsistency is clearly identified, among others as an invasion of built-up areas that enter the function of protected areas, which include Water Bodies covering an area of 448.77 ha and Protected Forests covering an area of 137.21 ha. The land use incompatibility that occurred highlights the existence of serious problems in the control of existing spatial planning.

Globally, land-use change has affected about 32% of land area over six decades, with significant regional variations. The Global North has seen the greening and abandonment of farmland, while the Global South has seen deforestation and agricultural expansion. This trend highlights the complex interplay between global trade, agricultural production, and land-use dynamics [20].

3.3. Flood Levels and Flood Hazards of the Batang Kuranji Watershed

The level of vulnerability and flood danger in the Batang Kuranji watershed is determined through a combination of several biophysical and hydrometeorological parameters, namely rainfall, soil type, slope slope, distance to the river (buffer), and land use.

The flood phenomenon in the Batang Kuranji Watershed (DAS) area is one of the environmental issues that has received increasing attention in recent years. Increasing rainfall intensity, land conversion, and settlement growth around riverbanks have increased the potential risk of disasters, especially in areas that are geomorphologically vulnerable to surface runoff.

The analysis of vulnerabilities and hazards was carried out using the CHIRPS method obtained from several indicators.

Table 4. Flood Vulnerability in Kuranji Watershed

Vulnerability Categories	Total Area (ha)
Not Prone	12.090,53
A Bit Prone	2.762,45
Quite Prone	5.594,27
Prone	1.363,41
Highly Vulnerable	478,62
Total	22,289.28 ha

Source: Data analysis results, 2025

Table 5. The Danger of Sub-district Flooding in the Kuranji Watershed

Hazard Class	Total Area (ha)
Low	14.389,59
Medium	6.813,53
Height	1.077,05
Overall Total	22,280.17 ha

Source: Data analysis results, 2025

The results of the analysis in Table 4 show that the level of flood vulnerability in the Kuranji watershed is dominated by the non-vulnerable category with an area of 12,090.53 ha, which reflects the relatively stable physical condition of the area in terms of topography, soil infiltration, and distance to the main river channel. However, the existence of the category of moderately vulnerable (5,594.27 ha) and somewhat vulnerable (2,762.45 ha) indicates that there are transition areas that are beginning to be affected by changes in land use and increased surface runoff. Areas with vulnerable (1,363.41 ha) and very vulnerable (478.62 ha) categories, although in a smaller area, are critical zones because they are generally located in lowlands and densely populated areas, so they have the potential to experience repeated inundation. This pattern is in line with the approach of flood vulnerability analysis based on GIS scoring and overlay as applied to the Antokan watershed, where the determination of danger zones is carried out through weighting of indicators and subindicators of the physical environment to produce low, medium, and high hazard classes [21].

Furthermore, table 5 shows the level of flood danger in the Kuranji watershed which is dominated by the low hazard class with an area of 14,389.59 ha, followed by the medium hazard class with an area of 6,813.53 ha, and the high hazard class with an area of 1,077.05 ha. This pattern suggests that most areas of the Kuranji watershed are at low to moderate flood hazard levels, with relatively limited high-hazard areas but with a large risk of impact. These findings are in line with the results of a study in the Tarusan watershed, West Sumatra, which showed the distribution of flood danger zones of 22% high hazard, 58% medium hazard, and 20% low hazard, thus confirming that the geomorphological characteristics, land use, and hydrological dynamics of the watershed greatly influence the variation in flood hazard levels between regions [22]. The similarity of these patterns reinforces that although the proportion of each class is different, watershed areas in West Sumatra generally show moderate hazard predominance with high-hazard pockets that require priority flood mitigation based on spatial approaches and sustainable watershed management.

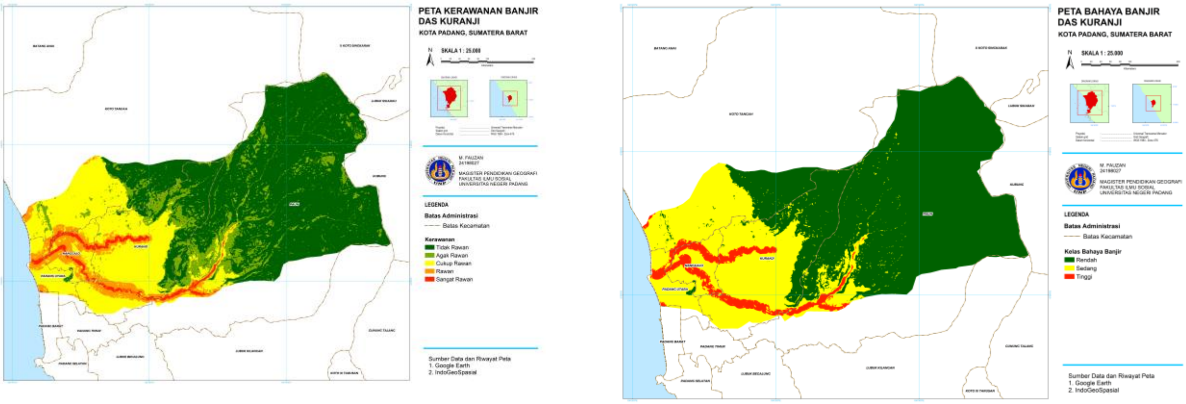

Fig 3. Vulnerability and Danger of Flooding in the Batang Kuranji Watershed

4. CONCLUSION

The results of this study show that the Batang Kuranji Watershed is predominantly characterized by low flood hazard areas, mainly located in the upstream and hilly regions with higher elevations, steeper slopes, dense forest cover, and good soil infiltration capacity, which collectively contribute to maintaining hydrological stability and reducing surface runoff; however, flood-prone and highly flood-prone areas are increasingly concentrated in the middle to downstream parts of Padang City, particularly in lowland zones and along river corridors, where rapid land use change toward built-up areas has significantly reduced water absorption capacity and increased surface runoff, thereby elevating the risk of flooding and inundation during high rainfall events; consequently, areas classified as moderate to high flood hazard can be considered critical zones with high potential flood risk, requiring priority mitigation measures, while continuous monitoring of land use dynamics and flood hazard patterns using GIS-based spatial analysis is essential to support effective flood mitigation, strengthen spatial planning control, conserve upstream forest areas, and ensure sustainable watershed management in the Batang Kuranji Watershed.

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