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GIS-BASED ANALYSIS OF SLOPE, LANDSLIDE AND FLOOD HAZARDS, AND LAND USE INTEGRATED WITH INDIGENOUS KNOWLEDGE IN *NAGARI* SIJUNJUNG, INDONESIA

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ABSTRACT

This study aims to examine how the traditional settlement of *Nagari* Sijunjung, guided by the Minangkabau philosophy of *Alam Takambang Jadi Guru*, aligns with the area's physical characteristics and functions as an inherent disaster risk reduction system. Specifically, it analyzes the relationship between slope conditions, land use, and hazard potential by integrating indigenous spatial planning with Geographic Information System (GIS)–based risk analysis. The study was conducted in *Nagari* Sijunjung, a 157.1 ha cultural heritage site in West Sumatra, Indonesia, containing 77 traditional *Rumah Gadang*, sacred sites, and diverse clan settlements. Spatial datasets from satellite imagery, Digital Elevation Model (DEM), and official maps were overlaid with indigenous zoning to assess congruence between cultural principles and hazard avoidance strategies. Results show that flat and gentle slopes (0–8%) serve as the core zones for settlements and agriculture, while steeper slopes (8–15%) are preserved as protected forest or rubber plantations, functioning as ecological buffers against landslides. Flood-prone River plains are allocated for seasonal agriculture, while settlements are located on slightly elevated terrain. In conclusion, indigenous zoning closely aligns with physical hazard assessments based on slope, soil, geology, rainfall, and land use analysis, demonstrating that traditional planning offers a culturally grounded and hazard-aware model for community-based disaster risk reduction.

Key-words: *Disaster risk reduction; GIS; Indigenous knowledge; Land use planning; Nagari Sijunjung.*

1. INTRODUCTION

Indonesia ranks among the nations most vulnerable to a wide range of natural hazards, including earthquakes, volcanic eruptions, floods, and landslides. Data from the Indonesian National Board for Disaster Management (BNPB) 2022 indicate a consistent rise in disaster frequency, particularly in areas where land-use changes are misaligned with the physical and ecological characteristics of the landscape (Kegel et al., 2025). While modern, technology-driven mitigation strategies have been widely promoted, they often demand substantial financial, technical, and institutional resources, making them less applicable in communities with limited capacity. In contrast, numerous Indigenous communities across Indonesia have long relied on sophisticated systems of local knowledge as adaptive strategies to manage environmental risks (Asrawijaya, 2024; Karnoto et al., 2025). One prominent example is the customary spatial planning system, which not only regulates the arrangement of settlements, agricultural areas, and conservation zones but also inherently reduces disaster risks through nature-based and culturally embedded mechanisms (Lestari et al., 2025). These systems have evolved over generations, shaped by accumulated experience, continuous observation of environmental cues, and philosophical principles passed down orally or through customary law (Wiersum, 2004; Hiwasaki et al., 2014).

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Administratively, the study focuses on the traditional settlement of *Nagari* (Indonesian: *Nagari*, abbreviated Village) Sijunjung, located in Sijunjung Regency, West Sumatra Province, and traversed by the Batang Kuantan River. The Regency consists of 11 *Nagari*, including Sijunjung, Muaro, Paru, Pematang Panjang, Silokek, and Aie Amo. Topographically, most of the area comprises gentle slopes (2–8%), which are optimal for settlement and agriculture, while steeper slopes (8–15%) are designated as protected forest. This topographical information was obtained from the slope classification generated through the Digital Elevation Model (DEM)/Shuttle Radar Topography Mission (SRTM) analysis conducted in this study.

The traditional settlement of *Nagari* Sijunjung embodies the Minangkabau socio-ecological philosophy of *Alam Takambang Jadi Guru*, literally "Nature Unfolds to Be a Teacher" which guides the community in selecting settlement areas, determining farmland allocation, and designating conservation areas (Heider, 2011; Nasri et al., 2022; Lah et al., 2024). Empirical observations have shown that these settlements are often located on ridge lines or elevated terrain to avoid flooding, with building orientations adapted to prevailing winds and water flow. Traditional *Rumah Gadang* (Indonesian: *Rumah Gadang* abbreviated Big House) houses are built on stilts, providing structural resilience against both inundation and seismic activity.

However, rapid modernization, expanding infrastructure projects, and insufficient legal recognition of customary land rights have gradually altered these spatial configurations. Such shifts risk undermining the embedded disaster-mitigation functions of the traditional system (Sutanta et al., 2013). Consequently, this study integrates spatial slope analysis, indigenous settlement typology, and the Community-Based Disaster Risk Reduction (CB-DRR) framework to examine how the *Nagari* Sijunjung spatial system remains functional, adaptive, and relevant within the context of contemporary, risk-based spatial planning.

This study aims to examine how the traditional settlement of *Nagari* Sijunjung, guided by the Minangkabau philosophy of *Alam Takambang Jadi Guru*, aligns with the area's physical characteristics and functions as an inherent disaster risk reduction system. Specifically, it seeks to analyze the relationship between slope conditions, land use, and hazard potential, integrating indigenous spatial planning principles with modern risk-based spatial analysis using the Geographic Information System (GIS). This study offers a novel integration of GIS–based spatial hazard assessment with indigenous knowledge systems in the context of the traditional settlement of *Nagari* Sijunjung. By directly comparing scientifically mapped hazard zones with customary zoning patterns, the study demonstrates that traditional spatial arrangements can serve as an effective, culturally grounded model for contemporary disaster risk-sensitive land use planning.

2. STUDY AREA

The study was conducted in the traditional settlement of *Nagari* Sijunjung, a designated cultural heritage area that represents a well-preserved example of the traditional Minangkabau spatial arrangement. According to the West Sumatra Cultural Heritage Preservation Office (BPCB), the site covers approximately 157.1 ha and is home to nine major clans, namely Chaniago, Piliang, Malayu, Tobo, Bodi, Panai, Patopang, Bendang, and Malayu Tak Timbago. Within the area, 77 traditional *Rumah Gadang* remain in active use as centers of social, cultural, and customary activities, along with important heritage sites such as *Batu Tabonek* and *Tempat Berkaul Adat*, both of which hold significant spiritual value for the community. The heritage designation follows Law No. 11/2010 on Cultural Heritage, which mandates protection through rescue, security, zoning, maintenance, and restoration.

Nagari Sijunjung is situated in Sijunjung Sub-district, Sijunjung Regency, West Sumatra Province, Indonesia, at coordinates 100°55′30″–101°00′30″ E and 0°42′30″–0°38′30″ S, with elevations ranging from 120 to 930 meters above sea level (MASL). Its strategic location along a network of collector and local roads ensures high accessibility to the Sub-district center and neighboring *Nagari* such as Koto VII, Kamang Baru, and Tanjung Gadang. The Batang Kuantan River flows through the area, serving both as a natural boundary and the primary water source for the community (Prambudi et al., 2023).

Beyond its ecological and economic functions, the river also holds deep cosmological significance in local cultural narratives, influencing settlement placement and land-use decisions. The combination of cultural heritage value, adaptive topography, and abundant natural resources makes *Nagari* Sijunjung an exemplary case for examining how indigenous knowledge systems can be integrated with spatial analysis in the context of disaster risk mitigation and risk-based spatial planning. For more details, see the map in **Figure 1** below.

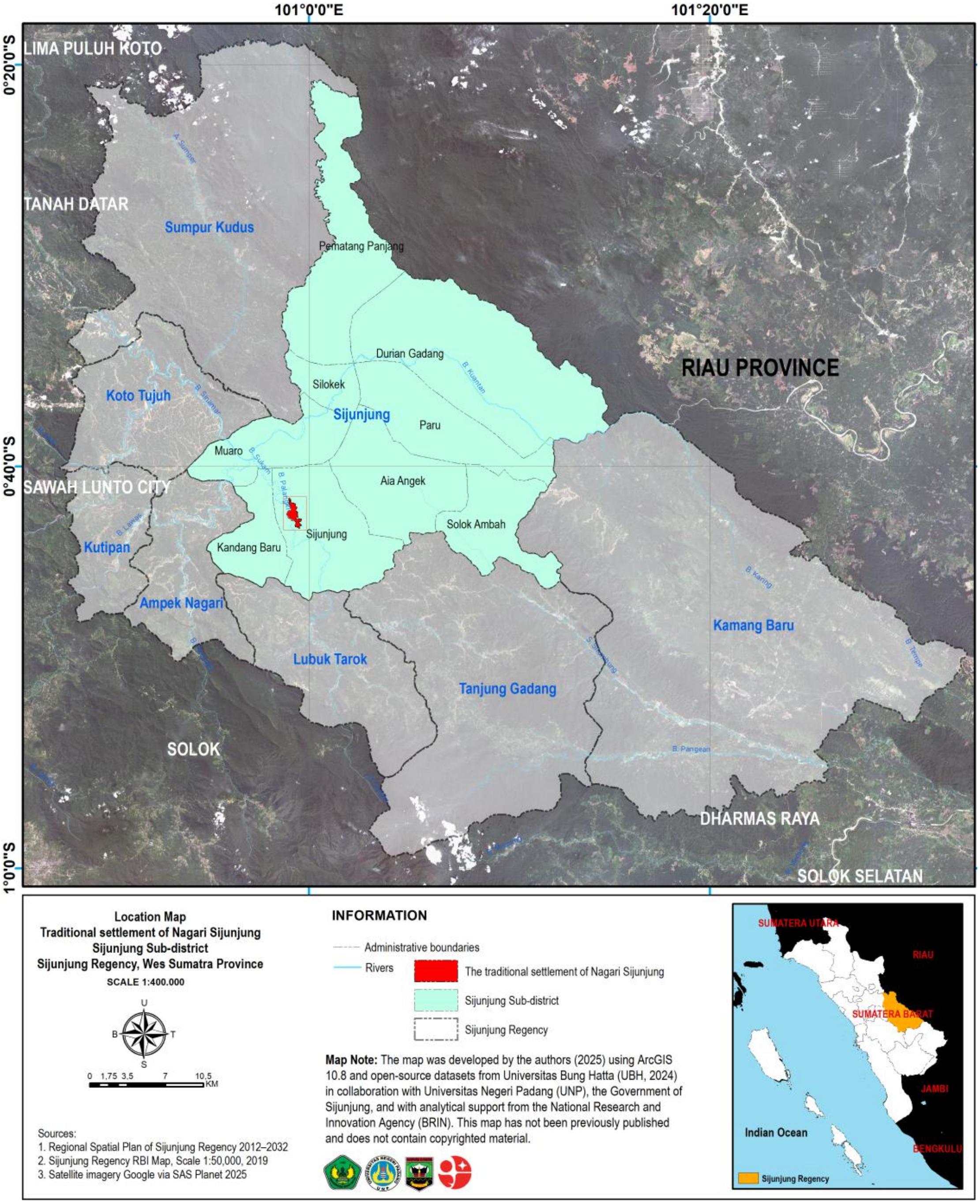

Fig. 1. Location Map of the traditional settlement of *Nagari* Sijunjung.

3. METHODS

3.1. Spatial analysis approach

To ensure analytical accuracy, multiple spatial datasets were obtained from both authoritative and field-based sources. These included 1) High-resolution recent satellite imagery from Google, downloaded via SAS Planet 2025, for land cover mapping and settlement identification; 2) DEM/SRTM data for slope analysis; 3) Land use maps from the Geospatial Information Agency (BIG), used as a baseline for detecting land-use changes and complemented with field verification; 4) Hydrography data from the *Rupa Bumi Indonesia* (RBI) maps by BIG, detailing rivers, streams, and water bodies; 5) Rainfall statistics from the Meteorology, Climatology, and Geophysics Agency (BMKG) for hazard classification; and 6) Administrative boundary maps at the *Nagari*, Sub-district, and Regency levels, sourced from the Regional Spatial Planning (RSP) Sijunjung Regency. Data processing was performed using ArcGIS software. Considering the integration of multiple raster and vector datasets, the use of a GEODATABASE structure is essential to ensure coherent data management and relational analysis (Nicoară & Haidu, 2011).

Data processing was performed using ArcGIS software. Slope classification was generated from DEM/SRTM data, while land use classification was derived from satellite imagery and refined through ground validation. The slope analysis applied a 30 m resolution DEM/SRTM dataset. Overlay analysis was then conducted to assess the spatial relationship between land use and hazard-prone zones, and buffer analysis was applied to delineate protective zones around critical natural features such as rivers, steep slopes, and natural evacuation corridors. Ground checks were carried out at 25 GPS points across settlement, agriculture, forest, and river zones to confirm land use classification. The classification accuracy reached 87%, with a Kappa coefficient of 0.82 (Chahkar et al., 2020), indicating strong agreement between the satellite-derived map and field conditions. Slope data derived from DEM/SRTM were compared with three ground-control transects, showing less than 5% deviation in slope class assignment. These validations ensure that the overlay and buffer analyses are methodologically robust.

For landslide assessment, areas dominated by alluvial and latosol soils with loose texture showed higher susceptibility when combined with steep slopes and high rainfall, while zones underlain by volcanic and igneous formations demonstrated greater stability. For flood assessment, alluvial soils in river plains retained high water content and prolonged inundation, whereas andosol and lithosol soils in elevated zones allowed higher infiltration and reduced ponding. These factors strongly influenced the final hazard maps, explaining why some zones with similar slopes exhibited different hazard levels. Landslide hazard assessment followed the parameter and weighting framework proposed by Paimin et al. (2009). The resulting hazard classifications were then compared with traditional Minangkabau zoning principles to determine the extent to which indigenous. The resulting hazard classifications were then compared with traditional Minangkabau zoning to determine the extent to which indigenous spatial arrangements align with scientific hazard assessments as outlined in **Tables 1 and 2** below.

Table 1

Landslide hazard assessment parameters.

Parameter	Class/Category	Value	Weight
Soil type	Alluvial, Latosol, Grumosol (1); Mediterranean, Podsolic, Glei Humus (2); Regosol, Andosol (3)	1–3	1
Land use	Lake/Pond, River, Fishpond, Brackish Pond (0); Shrubland (2); Rice Field, Dry Field, Plantation, Mixed Garden (4); Settlement, Mining, Open Field (5); Swimming Pool (3)	0–5	2
Rainfall (mm)	2001–2500 (3); 2501–3000 (4); ≥3001 (5)	3–5	3
Slope (%)	0–2% (1); 2–8% (2); 8–15% (3)	1–3	4
Geology	Sedimentary, easily weathered (3); Volcanic, medium strength (2); Igneous/metamorphic, strong (1)	1–3	3

Source: Paimin et al. (2009).

Table 2

Landslide hazard classifications.

Hazard Level	Score Range	Description
Low	1.5–2.3	Requires monitoring during the rainy season
Moderate	>2.3–3.1	Potential hazard during high rainfall or slope disturbance
High	>3.1–3.7	Very prone; requires mitigation and special handling

Source: Paimin et al. (2009).

Following the classification of landslide hazard levels presented in **Table 2** above, the analysis was extended to assess flood hazard potential. This assessment applied a set of parameters that capture the influence of land use, rainfall intensity, elevation, slope, and soil type on flood risk. The criteria and scoring system, adapted from Şen (2018); Nguyen (2019) in **Tables 3 and 4** below.

Table 3

Flood hazard assessment parameters.

Parameter	Class/Category	Value	Weight
Land use	Lake/Pond, River, Mining, Open Land, Settlement, Swamp (5); Swimming Pool, Irrigated/Rain-fed Rice Field, Shrubland (4); Forest Plantation, Primary/Secondary Dryland Forest (3); Mixed Garden, Rubber/Oil Palm (2); Sandbar (1)	1–5	5
Rainfall (mm)	>3500 (5); 3001–3500 (4); 2501–3000 (3); 2001–2500 (2); <2000 (1)	1–5	4
Elevation (m)	0–25 (5); 26–50 (4); 51–100 (3); 101–250 (2); >250 (1)	1–5	3
Slope (%)	0–2% (1); 2–8% (2); 8–15% (3)	1–3	4
Soil type	Alluvial, Latosol, Grumosol (5); Regosol, Andosol (3); Mediterranean, Podsolic, Glei Humus (2); Lithosol (1)	1–5	4

Sources: Şen (2018); Nguyen (2019).

Table 4

Flood hazard classifications.

Hazard Level	Score Range	Description
Very Low	2.4–3.0	Not significant
Low	>3.0–3.6	Light inundation potential
Moderate	>3.6–4.2	Moderate risk during heavy rain
High	>4.2–4.8	Very prone; requires mitigation

Sources: Şen (2018); Nguyen (2019).

3.2. Indigenous knowledge–spatial integration approach

This approach aimed to document, interpret, and integrate local wisdom that guides settlement planning and disaster mitigation in the Minangkabau tradition, with spatial analysis results. The emphasis is on how the philosophy of *Alam Takambang Jadi Guru* is embedded in settlement spatial arrangements and how these customary principles align with scientific hazard mitigation strategies. More details can be seen in **Table 5** below.

By triangulating indigenous narratives, field observations, and mapping, this method not only validates the cultural logic of settlement patterns but also demonstrates their functional role in mitigating risks such as floods and landslides. The outputs, ranging from GIS-based models, offer a framework for integrating cultural heritage into sustainable CB-DRR planning.

Table 5

Description of the indigenous knowledge–spatial integration approach.

Stages	Activities	Purposes
Data collection – indigenous knowledge	Conduct in-depth interviews with *Ninik Mamak* (Indonesian: abbreviated Customary Leaders), *Nan Tuo di Kampuang* (Indonesian: abbreviated Village Elders), Rumah Gadang, and community members to capture traditional norms, decision-making processes, and lived experiences.	Capture and document traditional norms, governance structures, and lived experiences related to settlement planning.
	Carry out participatory observation of building orientation, site selection for houses *Rangkiang* (Indonesian: abbreviated Rice Barns), ommunal facilities, and zoning based on customary land functions.	Document ecological adaptation patterns and local disaster risk mitigation strategies.
	Tambo (Indonesian: abbreviated Customary Manuscripts), historical, and traditional maps to identify the ecological, spiritual, and social values embedded.	Identify the cultural principles guiding spatial arrangements and resource use.
Spatial data analysis	Slope, land use, and hazard maps to assess the physical constraints and hazard exposure of the settlement area.	Understand topographical limitations and hazard.
	Overlay hazard maps with customary zoning patterns to assess spatial congruence with hazard-prone areas.	Compare zoning decisions with mapped hazards.
Integration process	Perform data triangulation between indigenous narratives, field observations, and spatial analysis outputs to validate findings.	Accuracy of insights for both local and scientific.
	Identify effective customary zones for hazard mitigation, such as avoiding settlements at the foot of steep slopes or close to large rivers.	Highlight functional aspects of indigenous knowledge in disaster risk reduction.
	Develop narrative–spatial mapping to the relationship between indigenous principles and physical conditions.	Present integrated evidence of cultural–spatial alignment.
Expected outputs	Produce a spatial model of *Nagari* Sijunjung's traditional settlement functioning as a natural disaster mitigation system	Provide a culturally grounded planning framework.
	Create an integrated model combining local wisdom and spatial data for risk-based planning.	Strengthen evidence-based policy-making.
	Formulate policy recommendations for preserving spatial arrangements within the CB-DRR strategies.	Support sustainable disaster risk reduction.

4. RESULTS

4.1. Slope analysis based on the concept of *Nagari* formation

The slope analysis was conducted to examine how topographical gradients influence the spatial organization of the traditional settlement of *Nagari* Sijunjung. This analysis directly aligns with the Spatial Data Analysis stage outlined in the Indigenous Knowledge–Spatial Integration Approach, where slope data are processed and overlaid with customary zoning maps. Data were derived from a DEM with a resolution of 30 meters. This spatial dataset was then integrated with qualitative insights obtained from in-depth interviews and participatory observation, ensuring that the functional meaning of each slope class was interpreted through the lens of the philosophy of *Alam Takambang Jadi Guru*. More details can be seen in **Table 6** below.

Table 6

Slope classification of the Traditional settlement of *Nagari* Sijunjung area.

Class (%)	Area (Ha)	General function
0–2%	0.7	Fertile lowlands, suitable for wet rice cultivation and core settlement
2–8%	117.5	Gentle: traditional settlement areas, social activities, and agriculture
8–15%	38.67	Steep: protected forest, conservation, water sources, and reserve space

Source: Data analysis, 2025.

Based on **Table 6** above, approximately 118.2 ha (0–8% slope) form the primary settlement and agricultural core of the *Nagari*. These zones host *Rumah Gadang*, *Balai Adat*, and irrigated rice fields, reflecting their suitability for stable structures and intensive farming. In contrast, steeper slopes (8–15%) covering 38.67 ha are reserved for protected forest or shifting cultivation, ensuring watershed protection and preventing erosion. According to interviews with *Ninik Mamak* and *Tuo Kampuang*, settlements are intentionally located away from steep slopes to avoid landslide risk. These practices align with the philosophy *Alam Takambang Jadi Guru*, which dictates that land use should harmonize with natural conditions and maintain the balance of upstream–midstream–downstream spaces.

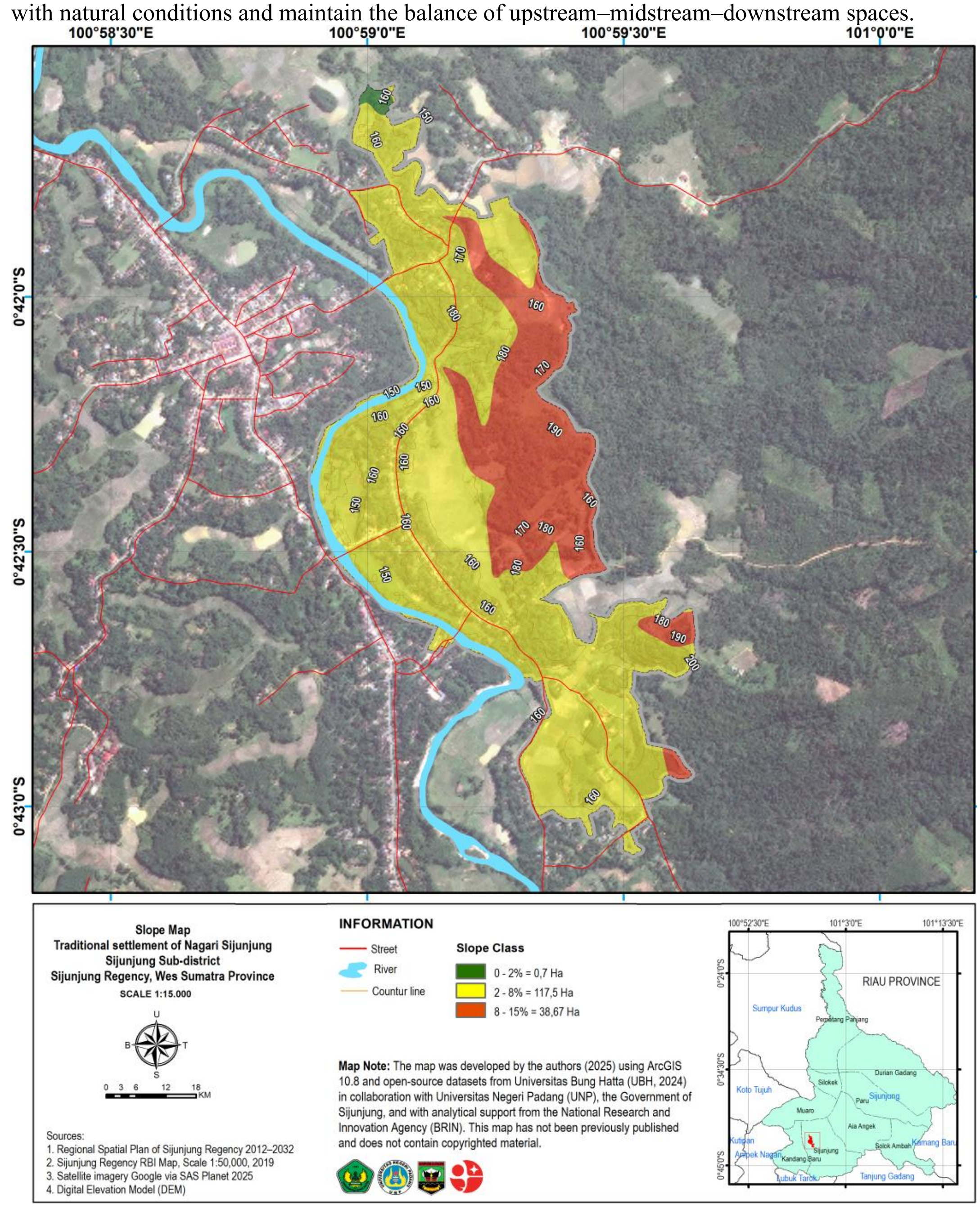

Fig. 2. Slope Map of the traditional settlement of *Nagari* Sijunjung area.

The designation of land functions also reflects a long-standing social consensus, in which customary leaders regulate land allocation to ensure intergenerational resource security and mitigate environmental degradation. For more details, see the map in **Figure 2.**

The analysis results indicate that traditional Minangkabau settlement patterns inherently incorporate disaster risk reduction strategies. The integration of scientific mapping with customary wisdom provides a replicable model for risk-sensitive land use planning in other cultural landscapes. Physically, gentle slopes of 0–8% reduce surface runoff velocity and provide more stable ground for buildings and rice fields, while steeper slopes of 8–15% increase gravitational force and erosion risk (Osman, 2018). This explains why settlements are concentrated in flat to gentle terrain, while forest vegetation is maintained on steeper slopes to prevent landslides and protect water sources.

4.2. Hazard potential analysis for landslides and floods

The hazard potential analysis for the traditional settlement of *Nagari* Sijunjung area was conducted by integrating physical terrain characteristics with indigenous spatial planning principles. The methodology followed Paimin et al. (2009) for landslide hazard assessment, and Şen (2018); Nguyen (2019) for flood hazard assessment. This approach enabled the comparison between scientific hazard mapping and traditional settlement layouts, supporting the research objective of integrating local wisdom into DRR planning.

4.2.1. Landslide hazard potential

Landslide hazard analysis was performed using a weighted method (Paimin et al., 2009). Each parameter was assigned a score based on its class/category, and the cumulative value determined the hazard level classification. More details can be seen in **Table 7** below.

Table 7

Landslide hazard potential and indigenous mitigation strategies.

Hazard levels	Spatial zone	Area (Ha)	Total area %	Indigenous mitigation strategy
High (>8% slope; unstable geology)	Eastern and southern steep slope zones	150.8	24.2%	No permanent settlement; preserved as protected forest to maintain slope stability and water sources
Moderate (2–8% slope, transitional land)	Peripheral mid-slopes near mixed gardens	6.36	4.0%	Seasonal cultivation and erosion-control vegetation planting
Low (0–2% slope, stable soils)	Core settlement and paddy fields	-	71.8%	Settlement use and wet rice agriculture supported by traditional drainage systems
Total		**157.1**	**100%**	

Source: Data analysis, 2025.

The high hazard zones are concentrated in the eastern and southern uplands with steep slopes and weaker geological formations, as identified through GIS-based slope and geology layers. Soil and geological conditions played a significant role in delineating hazard levels. Areas underlain by sedimentary rocks that are easily weathered showed higher susceptibility to mass movement, especially when combined with steep slope gradients (Permana et al., 2020; Triyatno et al., 2020). Similarly, soil types such as alluvial and latosol with relatively loose texture increased surface instability during high rainfall. Conversely, volcanic and igneous formations with stronger structural properties reduced susceptibility, explaining why certain upland zones with similar slopes exhibited different hazard levels (Rahmani et al., 2020). During high rainfall, loose-textured soils such as alluvial and latosol easily absorb water, become saturated, and lose stability, increasing the chance of slope movement (Sjamsiah et al., 2019). Sedimentary rocks that weather quickly also reduce slope strength, while volcanic or igneous rocks remain more stable.

Vegetation, especially rubber plantations, plays an important role by binding the soil with deep roots and reducing runoff, which naturally lowers the risk of landslides. Indigenous practice avoids these zones for settlement, designating them as protected forest, which acts as a natural landslide barrier. The moderate zones are used for mixed agriculture with erosion control measures, while low zones coincide with the core settlement and paddy fields. This alignment confirms that local wisdom inherently incorporates slope stability considerations into spatial planning. For more details, see the map in **Figure 3** below.

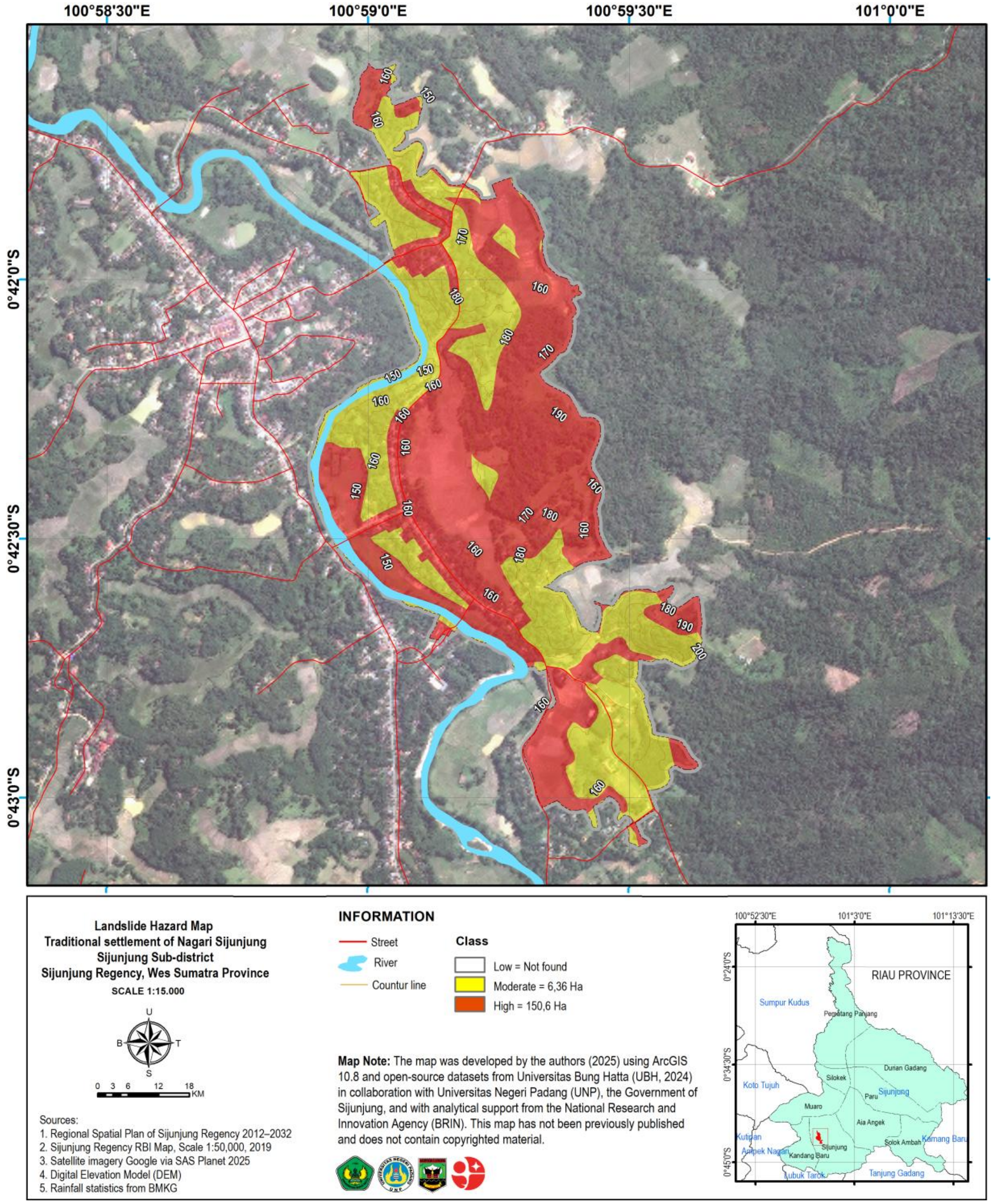

Fig. 3. Landslide hazard map of the traditional settlement of *Nagari* Sijunjung area.

4.2.2. Flood hazard potential

The flood hazard analysis followed the scoring by Şen (2018); Nguyen (2019). Each factor was weighted to generate the flood susceptibility data. More details can be seen in **Table 8** below.

Table 8

Flood hazard potential and indigenous mitigation strategies.

Hazard levels	Spatial zone	Area (Ha)	Total area %	Indigenous mitigation strategy
Very High (<250 m)	River floodplain in northern and central	117.4	74.8%	Avoid permanent housing; use for seasonal farming; preserve vegetation
High (within hydrological catchment)	Transitional areas between river and settlement	39.5	25.2%	Traditional stilt housing (*Rumah Gadang*), community-managed drainage channels
Low–Moderate (>250 m)	Elevated settlement areas	-	<0.5%	Maintain upstream water retention areas (*nan di hulu ditahan*)
Total		**157.1**	**100%**	

Source: Data analysis, 2025.

In higher elevation zones with andosol or lithosol soils, infiltration capacity was greater, reducing flood accumulation despite heavy rainfall (Hermon et al., 2019; Hermon et al., 2024). Heavy rainfall on alluvial plains with low slope (<2%) causes water to accumulate because of low permeability, leading to prolonged inundation. In contrast, areas with andosol or lithosol soils at higher elevation allow faster infiltration, so flooding is less severe (Sjamsiah et al., 2019). Land use, like rainfed rice fields function as temporary water storage during peak rainfall to reduce the spread of floods toward settlements. For more details, see the map in **Figure 4**.

Indigenous settlement patterns avoid this floodplain for permanent housing, instead allocating it for rice cultivation and grazing during the dry season. The high-hazard zones are occupied by traditional elevated housing that reduces flood impact. This approach demonstrates a preventive spatial arrangement embedded in cultural norms. Overlaying the landslide and flood hazard maps reveals that 1) High landslide hazard zones are primarily located in elevated forested areas, while very high flood hazard zones are confined to low-lying river floodplains; 2) Indigenous spatial zoning ensures that core settlements are located in low landslide risk and low–moderate flood risk areas; and 3) The combined hazard-avoidance strategy aligns to integrate indigenous knowledge into CB-DRR frameworks. This spatial congruence between traditional planning and hazard mapping confirms that the philosophy of *Alam Takambang Jadi Guru* has practical risk reduction value and should be preserved in formal planning policies.

4.3. Land Use Analysis of the Traditional settlement of *Nagari* Sijunjung based on Slope Map

An overlay analysis between the land use map and the slope classification map of the Sijunjung Traditional Settlement reveals a strong alignment between spatial utilization and the area's physical characteristics. This pattern reflects the Minangkabau philosophy of *Alam Takambang Jadi Guru*, in which each spatial function is adapted to geographical conditions, resource potential, and disaster risks, such as floods and landslides. The indigenous community has long applied ecological adaptation principles in their spatial planning, ensuring that settlements occupy safe zones, seasonal agriculture is concentrated in lowlands, and steep slopes are preserved with vegetation to prevent soil degradation. More details can be seen in **Table 9.**

Based on **Table 5** above, a spatial configuration of land use in Nagari Sijunjung that closely follows slope contours embodies disaster risk reduction principles rooted in local wisdom. This arrangement reflects a long-standing cultural understanding of how topography, hydrology, and soil stability interact to determine the most suitable allocation of land for settlements, agriculture, and conservation. He et al. (2017) found that communities in mountainous regions of China strategically adapt cropping and vegetation patterns to slope gradients to mitigate erosion and maintain soil productivity.

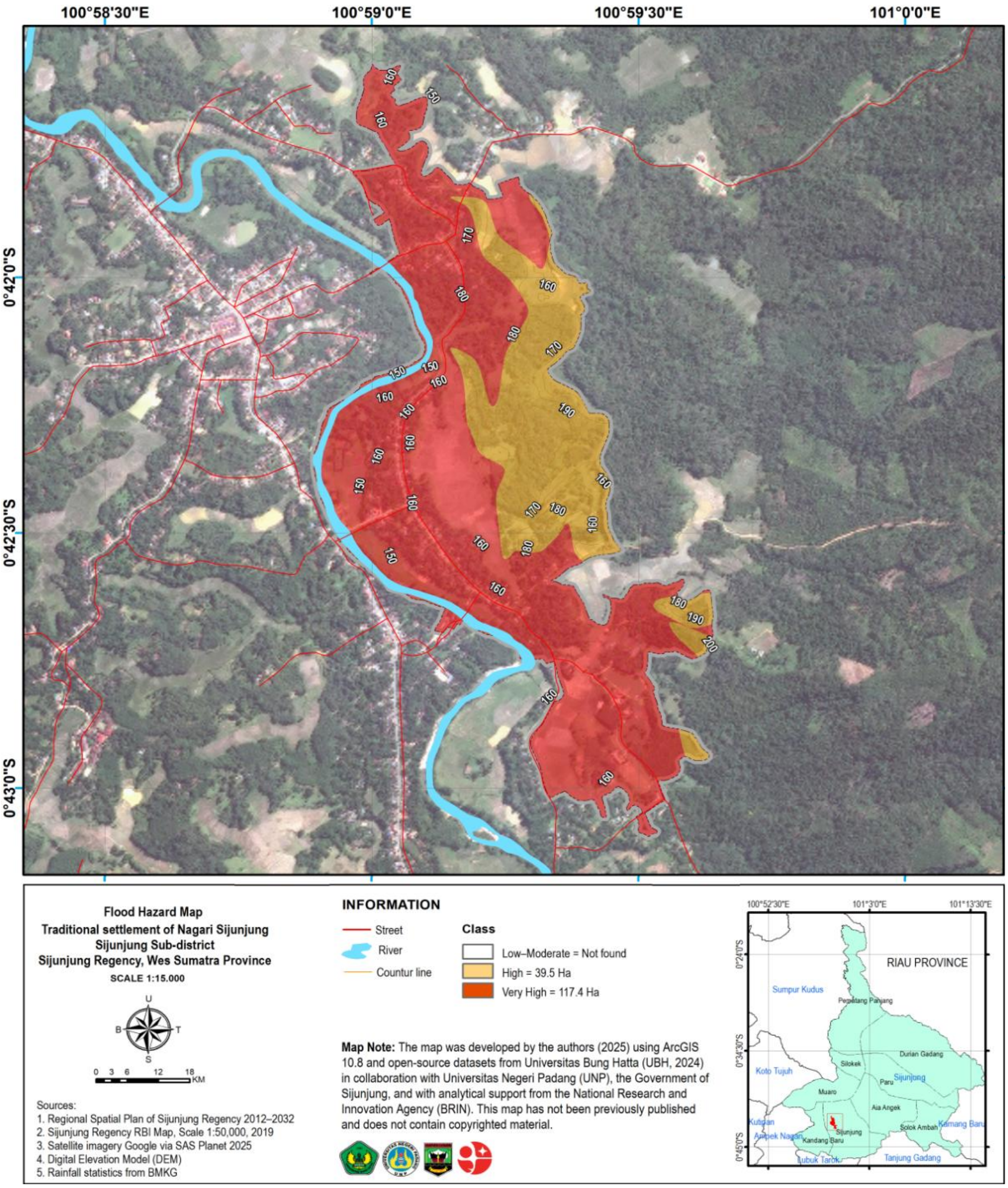

Fig. 4. Flood hazard map of the traditional settlement of *Nagari* Sijunjung area.

Table 9

Flood hazard potential and indigenous mitigation strategies.

Land Use types	Area (Ha)	Notes
Settlement	13.69	Concentrated in central lowland areas and along riverbanks
Rubber Plantation	75.73	Dominates gentle to moderate slope zones
Rainfed Rice Field	46.30	Located in lowland areas adjacent to rivers
Mixed Garden	14.68	Distributed across the midland zones
Swamp	0.92	Situated near river channels
River	5.29	Primary hydrological feature of the landscape
Dry Field/Cropland	0.20	Minor extent, found in small open flat areas
Shrubland	0.14	Minor extent, functioning as natural vegetative cover

Source: Data analysis, 2025.

Putra et al. (2025) similarly noted that agricultural development on gentle slopes is less vulnerable to erosion when combined with basic soil conservation measures.These findings align with Hermon et al. (2019), who demonstrated that perennial vegetation significantly improves slope stability in tropical regions, where perennial cover functions as a bioengineering measure for slope protection. Overall, the land use pattern shows how each element works physically, like rubber plantations on steep slopes stabilize the soil, rice fields in the floodplain act as retention areas to hold excess water, and *Rumah Gadang* on stilts in transitional zones allow communities to adapt to residual flood risk.

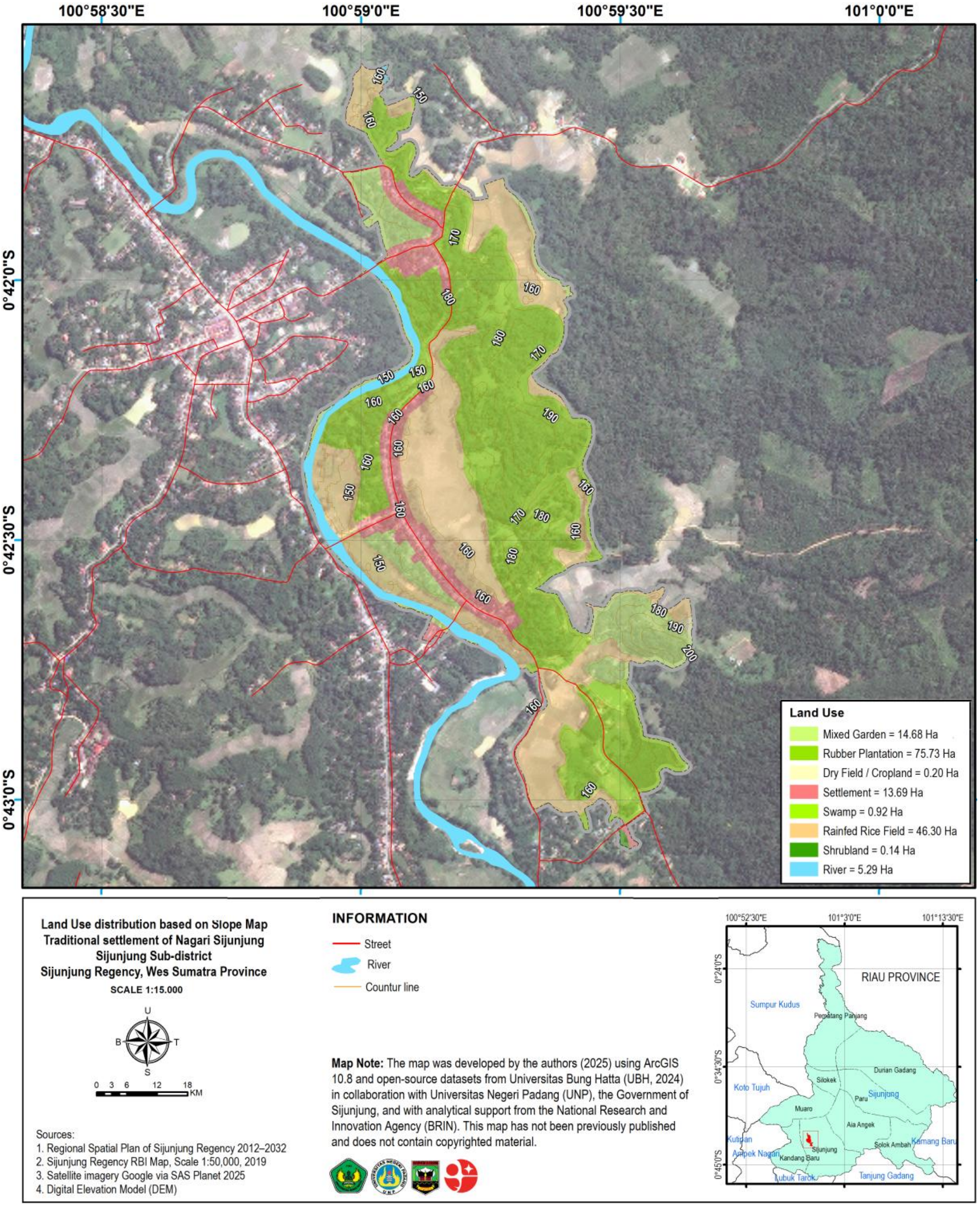

Fig. 5. Land use distribution based on slope map of the traditional settlement of *Nagari* Sijunjung area.

This strategy is consistent with the Minangkabau proverb *"Nan tanah tinggi dipakai rimbo, bukan untuk alun-alun kampuang"*. Flood-prone areas are managed through a combination of zoning and ecological buffers. Settlements and croplands are generally located close to river channels but are set back from the immediate riverbank to reduce inundation risk during peak rainfall events. Swamps (0.92 ha) and low-lying open fields serve as natural buffer zones, absorbing excess surface water and attenuating flood peaks. In the lower plains, rainfed rice fields function as seasonal water retention areas, temporarily storing runoff and preventing prolonged flooding of settlement zones. For more details, see the map in **Figure 5**.

This approach reflects the Minangkabau principle "*Nan di hilia ndak ditabam, nan di hulu ditahan*", which emphasizes source-based water management to safeguard downstream settlements. Barlian et al. (2024) demonstrated that hazard-based zoning and agricultural retention areas effectively reduce flood peaks, while Arora (2023) reported that Himalayan indigenous communities similarly align farmland with hydrological flow paths to retain water and protect villages. Overlay analysis between the land use map and slope map confirms that Sijunjung's indigenous spatial planning is closely aligned with natural conditions. This reflects the Minangkabau philosophy of *Alam Takambang Jadi Guru* as a practical framework guiding: 1) Placement of settlements in safe, stable zones; 2) Allocation of steep slopes for vegetative conservation; 3) Use of lowlands for seasonal agriculture and water storage; and 4) Preservation of rivers, swamps, and riparian vegetation as ecological infrastructure. This spatial logic is reinforced by another local saying, *"Bumi dipijak, langik dijunjuang; alam dibaco, Nagari dibangun"*. The resulting land use pattern represents a socio-ecological equilibrium where environmental processes and cultural norms converge to sustain both community resilience and landscape integrity.

4.4. Analysis of slope, land use, disaster potential, and local wisdom

This study analyzes the relationship between slope conditions, land use patterns, disaster potential, and the application of local wisdom in the traditional settlement of *Nagari* Sijunjung.

Table 10

Results of integrating slope analysis, land use, disaster potential, and local wisdom.

Analysis stage	Field findings	Ecological & social functions	Relation to local wisdom
Slope and land use	The 0–8% slope zone is utilized for settlements and agriculture (rainfed rice fields); the 8–15% slope zone is used for rubber plantations and mixed vegetation.	Optimizes fertile land and accessibility, reduces landslide risk in flat zones.	Principle of land use according to stable slope contours.
Vegetation-based landslide mitigation	Rubber plantations covering approximately 75.73 ha are located on steep slopes.	Deep root systems bind the soil, reduce erosion, and slow surface runoff.	Traditional proverb "*Nan tanah tinggi dipakai rimbo, bukan untuk alun-alun kampuang*".
Flood adaptation	Rice fields and wetlands are located in floodplains; settlements are set back to gentle slope zones.	Provides water absorption areas, reduces inundation risk in settlements.	Traditional proverb "*Nan di hilia ndak ditabam, nan di hulu ditahan*"
Philosophical reflection	Spatial function placement refers to the philosophy of *Alam Takambang Jadi Guru*.	Ensures ecological–social balance, maintains resource sustainability.	Placement of settlements, forests, and agricultural areas follows ecosystem logic.
Integration of modern and local data	Overlaying slope, land, and disaster risk maps with customary zoning.	Strengthens socio-ecological resilience and cultural identity.	Risk-based planning model rooted in local cultural values.

Source: Data analysis, 2025.

The analysis was conducted by overlaying slope maps, land use maps, and disaster risk maps, then comparing them with indigenous knowledge documented through interviews, participant observation, and the review of traditional manuscripts (*Tambo*). The results of the analysis are presented in **Table 10**, formulated based on the indigenous knowledge–spatial integration approach, modified from the framework in **Table 5** (see method).

The synthesis of information shown in **Table 6** reveals that the Sijunjung indigenous community has gradually shaped a land-use system that is both environmentally attuned and hazard-aware. Over time, settlement placement, agricultural zoning, and conservation areas have been organized in a manner that directly corresponds to the area's geomorphology. Flat and gently inclined lands are prioritized for housing and crop cultivation, while steeper slopes are purposefully maintained under protective vegetation cover. This approach supports the view of McDonald (1984) that contour-sensitive land allocation not only reduces ecological degradation but also sustains agricultural yield potential. The decision to utilize rubber plantations within high-susceptibility landslide areas demonstrates a deliberate application of natural slope-stabilization methods. Osman (2018) highlights that deep-rooted perennial crops can enhance slope stability and diminish runoff intensity, thereby lowering landslide risks. Similarly, Lele (2009) describes the dual role of perennial vegetation in watershed management, combining economic value with ecosystem services, which mirrors the function of rubber trees in Sijunjung.

In managing flood hazards, the community adopts a zoning pattern that designates floodplain zones for paddy fields and wetlands, while positioning settlements on slightly elevated ground. This method preserves natural flood absorption capacity and reduces structural vulnerability during peak rainfall. Comparable adaptive zoning practices are documented by Gurung (2024) in rural Nepal, where settlement relocation combined with water flow-aligned agriculture significantly mitigated flood losses. Long et al. (2020) further emphasize that integrating natural buffer zones into spatial plans is a critical element of flood-resilient settlement design. The embedding of the philosophy of *Alam Takambang Jadi Guru* into these spatial decisions reflects the deep interdependence between cultural identity and environmental stewardship. Rani et al. (2025) argue that blending traditional ecological knowledge with modern ecosystem-based planning produces context-specific adaptation strategies that are both sustainable and socially legitimate. The case of Sijunjung also resonates with the CB-DRR framework described by King et al. (2016), wherein community wisdom becomes the cornerstone for hazard-informed land-use policy.

4.5. Hazard potential, land use, and local wisdom in the formation of *Nagari*

This study examines the application of the philosophy *Alam Takambang Jadi Guru* in the spatial planning of *Nagari* Sijunjung, with a particular focus on managing landslide and flood risks. The analysis draws upon slope maps, land-use maps, and field observations, which are then compared with the principles of Minangkabau local wisdom. A summary of the findings is presented in **Table 11**, which is structured based on the indigenous knowledge–spatial integration framework outlined in **Table 5**, but modified to reflect field-based results.

Information shown in **Table 6** above indicates that, despite the accelerating influence of contemporary development, the guiding principles of *Alam Takambang Jadi Guru* still underpin how land is allocated in *Nagari* Sijunjung. Land-use zoning in the area demonstrates a deliberate relationship between terrain characteristics and functional land designation. Steeper slopes are retained under vegetation with protective value, while flatter land is prioritized for settlements and crop production, an arrangement consistent with the ecosystem-based disaster risk reduction model described by Estrella & Saalismaa (2012), where spatial choices are made to reduce hazard exposure while maintaining livelihoods. The use of rubber plantations on slopes classified as highly susceptible to landslides reflects a proactive bioengineering approach to slope stabilization. As noted by Asbjornsen et al. (2014), deep-rooted perennial crops play a vital role in reinforcing soil structure and mitigating erosion in tropical environments. However, where vegetation buffers are reduced or cleared, the stability benefits diminish, increasing vulnerability.

Table 11

Integration of hazard potential analysis, land use, and local wisdom in *Nagari* Sijunjung.

Analysis stage	Field findings	Ecological & social functions	Link to local wisdom
Application of *Alam Takambang Jadi Guru*	Settlements placed on gentle slopes; agriculture follows slope gradient; forest preserved in hazard-prone areas.	Maintains ecosystem balance, minimizes disaster risks.	Proverb "*Alam Takambang Jadi Guru*" as spatial guideline.
Landslide Analysis – Steep Slopes (8–15%)	Dominated by rubber plantations; some areas near settlements; risk increases if vegetation cover is removed.	Rubber roots stabilize soil; vegetation loss heightens landslide susceptibility.	Proverb"Nan tanah tinggi dipakai rimbo".
Flood Analysis – Flat/Gentle Slopes (0–8%)	Main settlements near rivers; high flood risk due to sedimentation and reduced infiltration zones.	Natural floodplains absorb runoff; natural drainage must be maintained.	Proverb "Nan di hilia ndak ditabam, nan di hulu ditahan".
Spatial Suitability	Mostly consistent with customary principles; some modern interventions, such as roads and housing, encroach into hazard zones.	Reduces effectiveness of natural protection if expansion is uncontrolled.	Partial alignment with *Alam Takambang Jadi Guru*.
Spatial Planning Recommendations	Riparian conservation, steep-slope rehabilitation, conservative farming, restriction of expansion into hazard zones.	Enhances disaster resilience and environmental sustainability.	Restores land-use patterns to customary philosophy.

Source: Data analysis, 2025.

In low-lying floodplain areas, settlement placement and agricultural zoning aim to preserve hydrological function. Paddy fields and wetland zones serve as natural retention areas, slowing and absorbing runoff before it reaches settlement areas. This mirrors the floodplain conservation strategies discussed by Hartanto & Rachmawati (2017), who argue that maintaining undeveloped flood storage capacity is critical for both disaster prevention and ecological health. While the prevailing land-use pattern generally aligns with Minangkabau spatial ethics, the encroachment of infrastructure and plantation activities into high-risk zones signals the need for targeted policy control. King et al. (2016) emphasize that such interventions are crucial for ensuring that community-based hazard knowledge is effectively translated into enforceable land-use regulation. The proposed measures, namely riparian zone preservation, reforestation of steep slopes, and adoption of soil-conserving agricultural practices, offer dual benefits of ecological sustainability and cultural continuity. Geetha et al. (2025) underscore that combining indigenous environmental knowledge with appropriate modern tools enhances adaptive capacity, creating spatial systems that are both risk-informed and locally grounded.

5. CONCLUSIONS

The spatial organization of *Nagari* Sijunjung reflects a deep integration of geomorphological realities, ecological functions, and Minangkabau local wisdom, particularly the philosophy of *Alam Takambang Jadi Guru*. Slope analysis shows that flat and gently sloping areas (0–8%) are primarily used for settlements, social infrastructure, and intensive agriculture, while steeper slopes (8–15%) are preserved under vegetation, mainly rubber plantations and customary protected forest. This configuration minimizes landslide risks, optimizes fertile land use, and safeguards upstream water resources. Hazard mapping confirms that indigenous land allocation inherently avoids high-risk zones.

Landslide-prone areas with unstable geology are excluded from permanent settlements, serving instead as ecological buffers. Rubber plantations on these slopes function as natural bioengineering systems, stabilizing soil and reducing runoff. In flood management, river floodplains are reserved for seasonal agriculture and grazing, while settlements are strategically placed on slightly elevated terrain. These arrangements preserve natural flood absorption capacity, reduce structural vulnerability, and maintain hydrological balance. Overlaying slope, land use, and hazard maps demonstrates a high degree of spatial congruence between indigenous zoning and scientific disaster risk assessments. Such alignment indicates that traditional planning is not only culturally rooted but also hazard-aware, offering a practical framework for CB-DRR.

Despite this resilience, modern development pressures such as road construction and plantation expansion into hazard-prone zones pose emerging threats to ecological stability and cultural integrity. Targeted interventions, including riparian conservation, steep-slope rehabilitation, and soil-conserving agricultural practices, are essential to maintain both environmental sustainability and socio-cultural identity. The *Nagari* Sijunjung case illustrates how integrating indigenous knowledge with modern spatial analysis can produce adaptive, risk-sensitive land use models. Preserving and formalizing these practices within planning policy can strengthen resilience, protect ecosystems, and ensure that cultural values remain central to sustainable landscape management.

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