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ENHANCING SETTLEMENT RESILIENCE TO FLASH FLOODS THROUGH INFRASTRUCTURE STRENGTHENING AND LAND READJUSTMENT IN WAKE VILLAGE

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ABSTRACT

The January 2021 flash flood in Wake Village, Batu Benawa Subdistrict, Hulu Sungai Tengah Regency, South Kalimantan, was triggered by severe upstream environmental degradation, where deforestation accelerated erosion and landslides, leading to the collapse of natural dams. This study aims to develop a settlement revitalisation plan that integrates environmental standards and disaster mitigation strategies to strengthen resilience in flood-prone communities. Using a mixed-methods approach that combines spatial analysis, stakeholder interviews, and a review of secondary data, the research identified key challenges: High building density that risks slum formation if reconstruction follows the old layout, topographical vulnerability in low-lying flood zones, and community resistance to relocation despite government support. Weaknesses in current mitigation measures were found in settlement patterns, green space provision, building structures, and utility infrastructure. To address these issues, five strategic actions are proposed: Optimising spatial and environmental layouts, constructing physical barriers with slope revegetation, developing adaptive drainage systems, promoting resilient building designs, and restructuring settlement layouts based on disaster risk reduction principles. The novelty of this study lies in combining land readjustment with infrastructure reinforcement as a dual strategy, offering a replicable model for enhancing settlement resilience against flash floods in vulnerable areas.

Introduction

The floods that struck 11 regencies and cities in South Kalimantan on January 14, 2021, caused unprecedented damage, particularly in Hulu Sungai Tengah (HST) Regency, where residential areas along the river basins were severely affected. Among the hardest-hit regions was the Barabai River Basin, which originates from the Meratus Mountains, an area that has experienced significant environmental degradation. Extreme rainfall, coupled with upstream deforestation, led to severe erosion and landslides, forming temporary natural dams that eventually collapsed under the weight of accumulated water, triggering catastrophic flash floods. The villages of Datar Ajab, Alat, and Wake, located in the transitional zone between the upstream and downstream sections of the basin, were among the most devastated.

Recent studies highlight that land-use change and deforestation have significantly intensified flood events in South Kalimantan (Yanti *et al*., 2023). Similar to South Kalimantan, river basins across Asia, including the Ghaghghar in India (Singh *et al*., 2018), the Dongar in Nepal (Kanhaiya *et al*., 2019), and the Ganga and Belan valleys in India (Singh *et al*., 2019; Narzary *et al*., 2024), have also experienced deforestation-driven hydrological shifts and long-term land degradation that have amplified flood risks. In South Kalimantan, upstream land-use changes in the Barabai River Basin similarly contributed to the unprecedented severity of the 2021 floods (Yanti *et al*., 2023). Despite this evidence across diverse contexts, existing literature has paid limited attention to how settlement restructuring can be systematically applied as a post-disaster mitigation strategy in flood-prone areas. This study addresses this gap by proposing a settlement revitalisation framework that integrates land readjustment.

Effective flood management requires not only structural interventions but also policies promoting environmental rehabilitation and watershed management (Lestari *et al*., 2024). Without integrated mitigation measures, similar disasters are likely to recur. Modern flood risk management adopts a multi-dimensional, risk-based approach, integrating green infrastructure, improved drainage, and ecosystem restoration, which are more sustainable than a reliance on conventional hard infrastructure alone (Tariq *et al*., 2020; Cea *et al*., 2022). Advanced hydrological and hydraulic modelling, combined with remote sensing and GIS, provides accurate predictions of flood behaviour, supporting better decision-making (Kumar *et al*., 2023).

Deforestation-induced erosion and landslides have reduced natural water retention capacity, accelerated sedimentation and intensifying the risks of flash floods (Temesgen *et al*., 2018; Kardani *et al*., 2019). Singh *et al*. (2021) further highlighted how morphotectonic factors interact with land-use changes, amplifying disaster vulnerability in river basins.

Consequently, forest rehabilitation and sustainable land management are critical for reducing sedimentation and maintaining river capacity (Temesgen *et al*., 2018; Hamza *et al*., 2019; Kardani *et al*., 2019). However, disaster mitigation cannot be separated from settlement planning, as spatial patterns characterised by high building density and limited green space often exacerbate risks. Revitalisation of disaster-prone settlements must, therefore, integrate social, cultural, and environmental considerations to ensure that reconstruction does not inadvertently generate new slum conditions, where irregular layouts, overcrowding, and inadequate infrastructure further heighten community vulnerability (Maslova *et al*., 2020).

An integrated settlement revitalisation approach is essential to address both the environmental and spatial challenges of disaster-prone areas, offering the potential to simultaneously reduce disaster risk and improve community well-being (Cheng *et al*., 2018; Aina *et al*., 2019; Rosaria *et al*., 2021). This requires rethinking urban planning to incorporate flood risk analysis, environmental sustainability, and socio-economic resilience. Nevertheless, despite extensive research on flood management and slum revitalisation, studies explicitly linking land readjustment, infrastructure strengthening, and disaster mitigation in post-disaster contexts remain limited. To address this gap, the present study develops a settlement revitalisation framework based on disaster mitigation principles, focusing on Wake Village as a case study. The framework integrates environmental rehabilitation, infrastructure improvement, and community-based planning to strengthen resilience against future flood disasters.

Materials and Methods

Study Area

The study was conducted in Wake Village, Batu Benawa Subdistrict, Hulu Sungai Tengah Regency, South Kalimantan, Indonesia (Figure 1). This settlement was among the most severely affected areas during the January 2021 flash flood, which destroyed 52 houses, severely damaged 71, and moderately damaged 191, although no casualties were reported. The affected area was classified into two zones: Zone 1, consisting of settlements along the riverbanks, and Zone 2, comprising mainland settlements located in low-lying areas.

The Barabai River, originating from the Meratus Mountains, exhibits a meandering morphology. Under normal conditions, water flows follow the river's bends; however, during the flood event, high-velocity currents bypassed these meanders and directly entered the mainland, damaging residential areas. This hydromorphological shift is closely linked to geomorphic evolution and upstream deforestation. Similar shifts have also been reported in other river basins (Singh *et al*., 2019; Kanhaiya *et al*., 2019). Historically, Hulu Sungai Tengah has been prone to flooding, with hydrological systems heavily influenced by land-use changes in the upstream area, which reduce the river's capacity to accommodate extreme runoff (Temesgen *et al*., 2018; Narzary *et al*., 2024).

Wake Village has a population of 1,395 (2018), representing 7% of the Batu Benawa Subdistrict's population. The community predominantly depends on agriculture and plantations, with a compact settlement pattern concentrated near the Batu Benawa River, reflecting a strong reliance on river water for daily needs.

Research Design

This study employs a mixed-methods approach, integrating qualitative and quantitative analyses to formulate a micro-level disaster mitigation and settlement revitalisation model. The research process begins with field observations to document settlement conditions, identify flood pathways, and map damage patterns. It then proceeds with in-depth interviews involving residents, community leaders, and local government representatives to explore perceptions of flood causes, evaluate existing mitigation measures, and gather expectations for revitalisation.

To complement qualitative insights, questionnaire surveys were conducted with approximately 90 affected households, selected solely based on their status as disaster victims. The surveys employed a semi-structured format, combining closed- and open-ended questions to capture both quantifiable indicators and personal experiences. Furthermore, document analysis was conducted by reviewing secondary sources

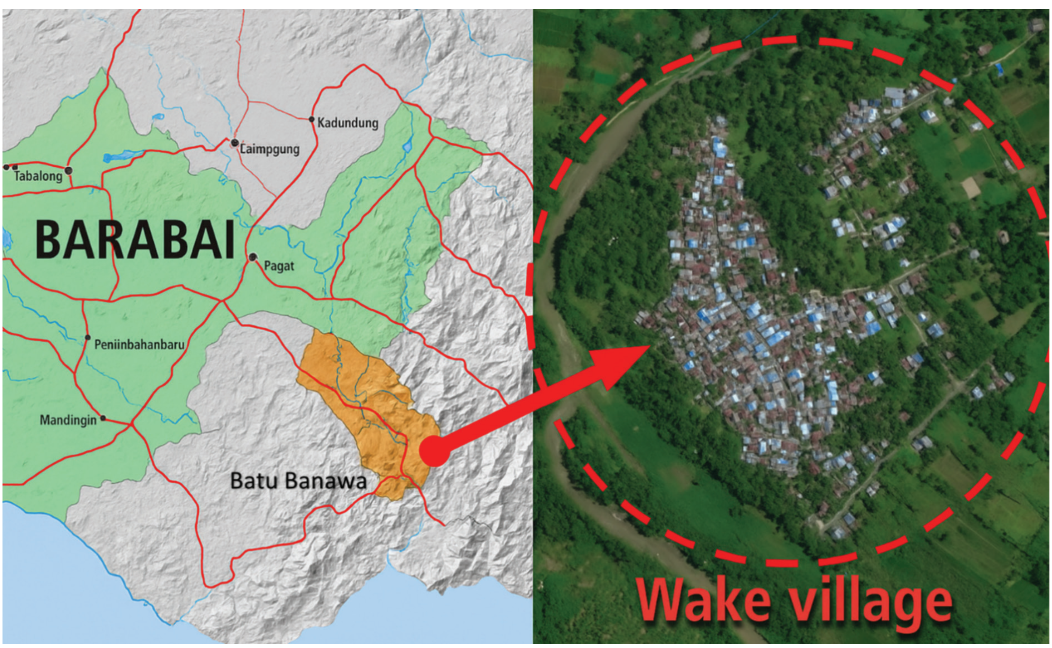

Figure 1: Location of research area in Wake Village, Batu Benawa Subdistrict, Hulu Sungai Tengah Regency, South Kalimantan
Source: Authors' analysis based on Google Earth imagery (2024)

such as meteorological records, topographic maps, hydrological data, and local spatial planning documents, ensuring a comprehensive understanding of both environmental and socio-spatial factors influencing flood vulnerability and recovery strategies. Informed consent was obtained from all participants, and confidentiality was maintained by anonymising responses and presenting findings in aggregate form.

The data analysis process begins with descriptive analysis to outline the demographic profile, housing conditions, and economic activities of Wake Village. It then applies spatial analysis using Geographic Information Systems (GIS) to map topography, trace flood pathways, and identify vulnerable zones, following approaches similar to those employed by Singh *et al*. (2023) and Narzary *et al*. (2024).

The GIS analysis utilised multiple spatial data layers, including the Digital Elevation Model (DEM), land use, river networks, administrative boundaries, and aerial imagery from Google Earth, with a spatial resolution of approximately 30 metres. All analyses were carried out using QGIS software, enabling the integration of topographic, hydrological, and land-use data to enhance the identification of flood-prone areas and settlement vulnerabilities. Subsequently, the study conducts thematic analysis to extract key themes from qualitative data, focusing on aspects such as community resilience, survival strategies, and attitudes towards relocation, thereby linking spatial vulnerability with the social dimensions of disaster response and adaptation.

Based on the research findings, the study formulates a disaster mitigation and settlement revitalisation model that incorporates three key components: Resilient infrastructure design, risk-based spatial planning that integrates topographic and hydrological data, and community capacity building to strengthen local preparedness and adaptive capabilities. The model undergoes validation through case simulations, combining hydrological modelling and scenario planning to assess real flood conditions and test the effectiveness of alternative mitigation strategies.

Validation was conducted by comparing simulation outputs with empirical field data and official reports, ensuring the robustness and reliability of the results, in accordance with approaches recommended by Cea *et al*. (2022) and Kumar *et al*. (2023). This integrative strategy simultaneously addresses the physical dimensions of infrastructure and the social dimensions of resilience, thereby aligning the study with the latest disaster mitigation frameworks and offering a practical, replicable approach for vulnerable communities (Figure 2).

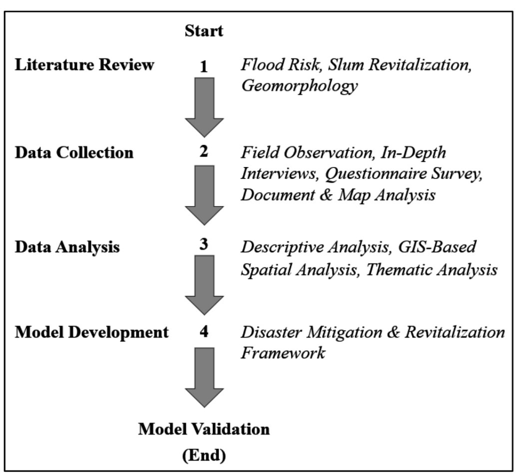

Figure 2: Research methodology flowchart
Source: Authors (2024)

The research was conducted in stages following the January 2021 flash flood. Field observations were undertaken in February 2021 to March 2021 to document post-disaster settlement conditions and flood traces. Household surveys and interviews with 90 affected households, community leaders, and local government representatives were conducted in April 2021 to May 2021. Data processing and GIS integration continued for six months, ensuring the accuracy and completeness of both spatial and survey datasets. Subsequently, a one-year analytical phase was dedicated to thematic interpretation, hydrological modelling, scenario planning, and validation of the proposed disaster mitigation and settlement revitalisation model. This was followed by a one-year stage focusing on settlement planning and the implementation of revitalisation measures in collaboration with local stakeholders (Table 1).

Results and Discussion

Post-Flood Conditions

The flash flood that struck Wake Village in January 2021 was triggered by exceptionally high rainfall. This event caused severe damage to homes and village infrastructure. Many houses were either severely damaged or swept away by the floodwaters, while mud and debris further exacerbated the situation. The government and volunteers promptly conducted evacuations and provided essential supplies to the affected residents. Additionally, residents were advised to remain vigilant and follow the authorities' instructions to prepare for potential subsequent floods. The strong currents also damaged bridges and roads, disrupting transportation access. The local government made efforts to expedite infrastructure recovery and ensure the safety of residents in flood-prone areas. Mitigation measures were also planned to reduce future flood risks. According to data from the Housing and Settlement Office (*Disperkim*) of Hulu Sungai Tengah Regency, 52 houses were lost, 71 were heavily damaged, and 191 were lightly damaged, although there were no casualties. The damage was primarily due to the strength of the currents and the poor quality of the buildings (Figure 3).

Flash Flood Current Speed

The flash flood in Wake Village not only followed the river's course but also extended onto the land, destroying many homes. Wooden houses were heavily damaged, leaving only the floor pillars, while permanent houses with concrete walls and well-constructed wooden houses remained standing. Eyewitnesses reported that the water flowed rapidly and forcefully, toppling large trees. Before the flood hit the village, residents received warnings from

Table 1: Timeline of research activities and implementation phases following the January 2021 flash flood in Wake Village

Research Stage	Period	Activities
Field Observations	Feb-Mar 2021	Documenting post-flood settlement conditions, mapping flood traces & damage
Surveys & Interviews	Apr-May 2021	Household surveys (90 HHs), interviews with residents & stakeholders
Data Processing & GIS Integration	Jun-Nov 2021	Cleaning survey data, integrating DEM, land use, river networks in QGIS
Thematic & Simulation Analysis	Dec 2021-Nov 2022	Qualitative coding, hydrological modelling, scenario planning, validation
Settlement Planning & Implementation Stage	Dec 2022-Nov 2023	Formulating settlement plans, executing revitalisation with stakeholders

Source: Authors, 2021-2023

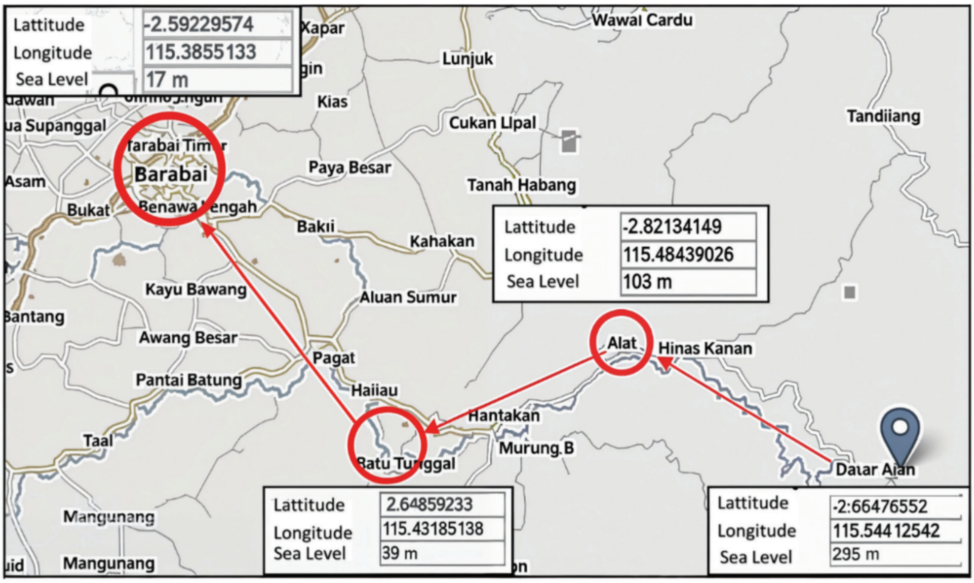

Figure 3: Spatial trajectory of flash flood movement from Datar Ajab to Barabai
Source: BPBD HST and Authors' analysis (2021-2024)

upstream areas of the Batu Benawa River Basin (DAS Batu Benawa), which had experienced the flash flood earlier. Wake Village residents had approximately one hour to evacuate to higher and safer hills not far from their settlement. Although many houses were lost and destroyed, there were no casualties, thanks to the swift and efficient evacuation to safe locations. According to the Regional Disaster Management Agency (BPBD), the flood began in Datar Ajab Village around 7:00 PM. The water then reached Alat Village, 12.48 km away from Datar Ajab, at approximately 9:00 PM, with a speed of 10.4 m/s. The flood finally arrived in Wake Village, 4.38 km from Alat Village, around 11:00 PM, with a speed of 3.65 m/s (Table 1).

Based on the data, the flood in Datar Ajab Village, located at an altitude of 192 metres above sea level (masl), began at 19:00. The floodwaters reached Alat Village, situated at an altitude of 108 masl, at 21:00. The travel time for the floodwater from Datar Ajab to Alat Village was 2 hours, with an approximate speed of 10.4 metres per second. The distance between Alat Village and Wake Village is 4.38 km, with an altitude ranging from 37 masl to 39 masl (Figure 4). The floodwaters arrived in Wake Village at 23:00, taking 2 hours to cover the distance, indicating a flow speed of approximately 3.65 metres per second. According to Welch [19], river currents are classified into five categories: 1) very fast (> 100 cm/second), 2) fast (50-100 cm/second), 3) moderate (25-50 cm/second), 4) slow (10-25 cm/second), and 5) very slow (< 10 cm/second). The flash flood that occurred in Wake Village falls under the "very fast" category, with a speed of 365 cm per second (3.65 metres per second). This flow rate exceeds 100 cm per second, classifying it as a very fast current.

Disaster Mitigation Analysis

Numerous factors contribute to flash floods, including the declining quality of the Meratus Mountains, river sedimentation, reduction of vegetation along riverbanks, high rainfall, and insufficient river flow control infrastructure. The two primary causes of flash floods are rapid rainfall concentration and the failure of natural dams. Improvement of upstream areas and the entire watershed is crucial (Kementrian, 2012). The reduction of large trees in the mountains

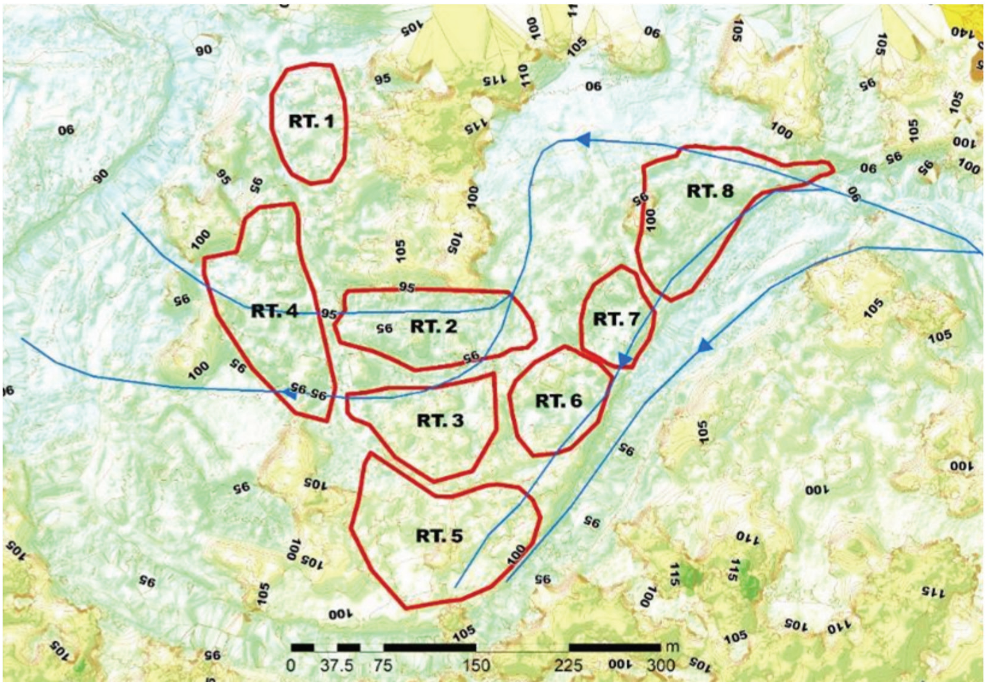

Figure 4: Topographic map of Wake Village Showing flood flow path and neighbourhood runit boundaries
Source: BPBD HST (2024)

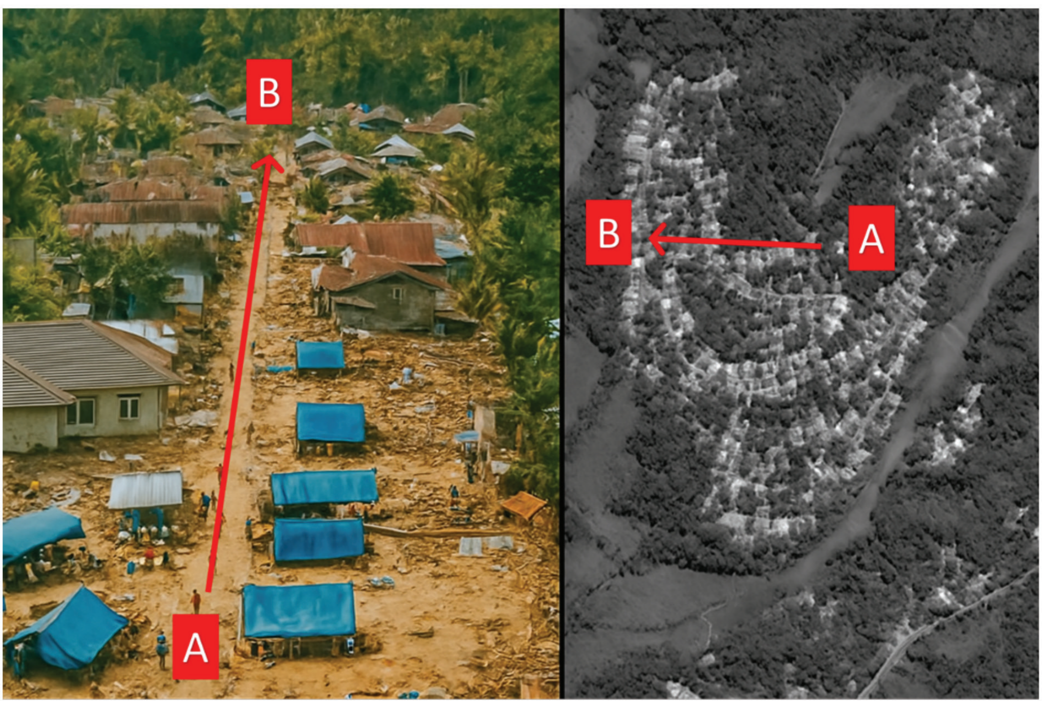

Figure 5: Water flow direction and flash flood damage path from Point A to Point B in Wake Village
Source: Authors (2024)

Figure 6: (a) Damaged house pillars after a flash flood, (b) Temporary evacuation tents in Wake Village
Source: Authors (2024)

leads to slope failures and the formation of natural lakes. During high rainfall, the volume of water exerts pressure on unstable lake walls, causing them to collapse and resulting in flash floods. The immense force of flash floods can devastate settlements along the river (Chen *et al.,* 2019).

Mitigation of flood and landslide hazards should be a focus in mountainous areas. Strategies for mitigating flash flood hazards can be based on resilience values. Resilience is defined as the capacity of a system to absorb disturbances and reorganise itself to retain essentially the same function, structure, identity, and feedback. In simple terms, resilience is the ability to recover from adversity.

Resilience is also defined as the intrinsic capacity of systems, communities, or societies to recover and adapt after experiencing shocks or stresses by altering non-essential attributes and rebuilding themselves (Manyena, 2011; GFDRR, 2014). In the context of disaster mitigation, it is important to emphasise strengthening local capacities, as disasters often occur at the local level, and local actors are the first responders (UNDRR, 2014).

Developing resilience-based mitigation strategies can include reducing impacts, recovery time, and future vulnerabilities, as well as anticipating future uncertainties (UNDRR, 2019). Community resilience to disasters can be measured using quantitative approaches and models that aid in assessing community resilience and planning proactive recovery (Chuang *et al.*, 2018; Manyena *et al.*, 2019).

Mitigation of flood and landslide hazards is a critical concern in mountainous areas. Flash flood mitigation strategies can be developed based on resilience values. Resilience is defined as the capacity of a system to absorb disturbances and reorganise in response to change without losing its function, structure, identity, or feedback mechanisms. It reflects the system's ability to adapt and recover from setbacks.

Eight key components are used to assess resilience in the study area: Spatial planning conditions, infrastructure, public service facilities, socio-economic aspects, research and technology, ecosystems, planning and permitting, and stakeholder capacity, institutions, and budgeting. This assessment provides insight into community resilience to disasters and supports the design of effective mitigation strategies (Frazier *et al.*, 2013; Nguyen and Akerkar, 2020). In this study, the disaster mitigation analysis emphasises spatial planning aspects, including settlement patterns, vegetation and green space conditions, physical building quality, and environmental utility systems (Table 2).

Settlement Layout

Poor spatial planning in disaster-prone areas often results in sanitation issues and chaotic building layouts, which increase vulnerability to flooding. In Wake Village, aerial imagery shows a dense settlement cluster with houses built in very close proximity, creating high-risk conditions. Seven indicators of slum vulnerability are evident: Disorganised and overcrowded buildings of poor quality, limited and substandard roads, inadequate drinking water, insufficient or absent drainage, wastewater systems below technical standards, non-compliant waste management, and the absence of fire protection infrastructure. Among these, the most critical weaknesses are building quality and road conditions. Non-durable wooden houses were easily destroyed, while permanent structures endured. Improving construction quality, upgrading road networks, and restructuring spatial layouts are therefore vital to strengthening settlement resilience Table 3.

Figure 7 shows that the central area of the settlement exhibits a lower elevation (marked as number 3), which is even lower than the elevation of the river, as indicated by numbers one, two, four, and five. This low-lying region experienced the most severe damage from the flash flood. Given that water naturally flows into lower areas, it follows that the flash flood also

Table 2: Flood progression, timing, distance, and water speed across locations in the Barabai River Basin

Location	Time Flood Began	Distance from Previous Location (km)	Water Speed (m/s)
Datar Ajab	19:00	-	-
Alat Village	21:00	12.48	10.4
Wake Village	23:00	4.38	3.65

Source: BPBD HST (2021)

Table 3: Evaluation of spatial, structural, and environmental aspects in flood-prone settlements

Aspect	Criteria	Evaluation	Comments
Spatial Planning	Land use patterns, settlement layout	Evaluated based on land use efficiency and planning practices	Identifies areas prone to flooding and highlights necessary improvements in spatial design.
Vegetation/ Green Space	Coverage, density, and health of vegetation	Assessed through satellite imagery and field surveys	Reduced vegetation can lead to increased erosion and runoff. Enhancing green spaces can mitigate these effects.
Building Conditions	Structural integrity, materials used	Inspected for compliance with building codes and standards	Buildings in poor condition are more susceptible to flood damage. Strengthening building codes is essential.
Environmental Utilities	Drainage systems, waste management, water supply	Evaluated capacity, efficiency, and maintenance	Inadequate utilities can exacerbate flood damage. Upgrading these systems is critical for effective flood management.

Source: Authors' field survey and satellite imagery (2024)

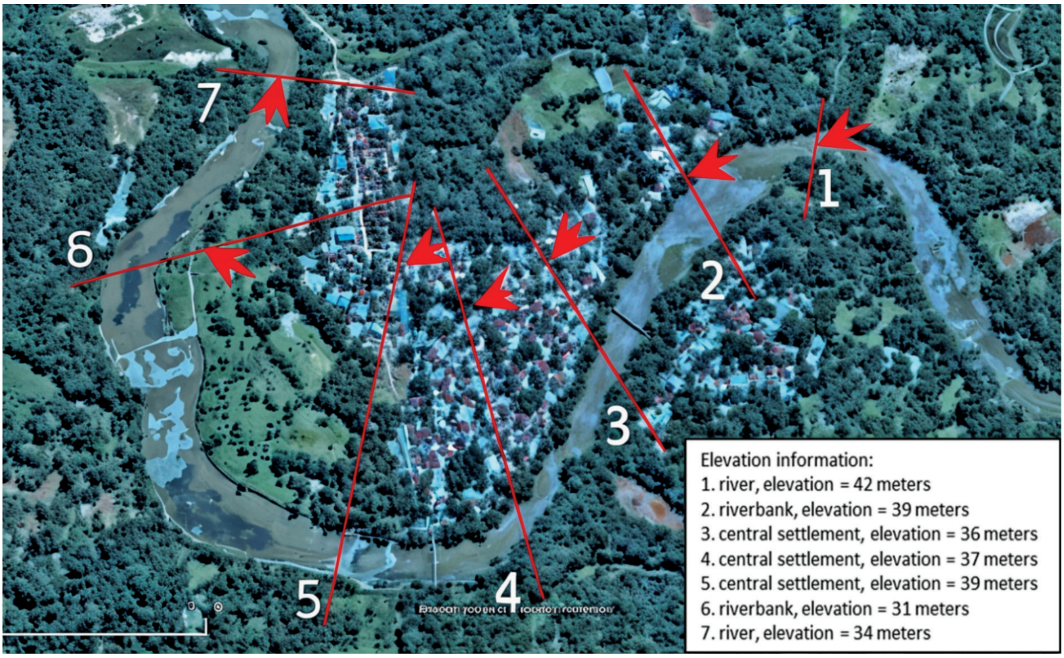

Figure 7: Ground elevation variation and flood path mapping in Wake Village
Source: Authors' analysis based on Google Earth imagery (2024)

inundated these low-lying zones. The extensive damage to buildings in this area was due not only to the strong currents but also to the poor physical condition of the structures, which were not suitable for habitation.

Vegetation and Green Spaces

The types of trees and vegetation in the area are predominantly hard trees such as coconut, rubber, and mango. Bamboo is found only in limited quantities along the riverbanks. The settlement area has minimal protective vegetation and open spaces. The map indicates that houses are densely clustered, leaving almost no open space for protective vegetation. Trees play a crucial role in shielding buildings from the impact of flash floods, depending on their density and strength. As shown in Figure 8, the intensity of flash flood currents can be mitigated by dense protective vegetation. The damaged and lost houses, as indicated on the map, are located in areas with sparse tree cover and are situated on low-lying land contours. The lack of protective vegetation contributed to the settlement's vulnerability to the damage caused by the flash flood. Initially, there was inadequate vegetation to serve as an early defence against the floodwaters (Figure 8).

Building Structure

The majority of buildings in Wake Village are constructed from wood, including both the lower structure and roofing. All buildings that were lost or damaged due to the flash flood were made of wood. In contrast, some permanent houses only sustained minor damage. The strength of the foundation is crucial for maintaining a building's reliability against forces such as those from a flash flood. Even though they are wooden, if the foundations are adequately deep and the lower structure is designed according to structural principles, the building's strength will remain intact.

Building strength is also determined by the integrity of the wooden pillars and walls. Most houses in Wake Village have wooden

Figure 8: Influence of vegetation on water flow direction and damage patterns in Wake Village
Source: Authors' analysis based on Google Earth imagery (2024)

pillars and wall coverings that are too unstable. Homeowners did not anticipate such a severe flash flood that could devastate their village. This experience highlights the need to repair damaged buildings with a focus on structural strength. Residents living near riverbanks must always be aware of the threat of flash floods. Building design guidelines can refer to Law No. 28 of 2002 concerning Buildings and Ministerial Regulation No. 29/PRT/M/2006 concerning Technical Requirements for Building Construction. These regulations stipulate that buildings must be reliable by meeting four criteria: Safety, health, comfort, and ease.

Utility Systems

The environmental utility systems in the village generally consist of several main components: Road networks, drainage, electricity, sanitation, and waste management. However, this study focuses primarily on the road network and drainage system, as these are considered urgent priorities for revitalisation to improve the quality of life for residents.

In Wake Village, there is only one main road connecting the village to areas outside, along with one internal connecting road that links various parts of the village. In addition to these roads, there are small alleys approximately 1 metres to 2 metres wide. The main road is sufficiently wide to allow two cars to pass safely; however, to reach the deeper parts of the settlement, away from the main road, residents must navigate narrow alleys that are difficult for large vehicles to access. The road network and alleys in the village are not systematically planned and are rather sporadic, formed based on gaps between closely spaced houses. Consequently, accessibility to certain parts of the settlement is limited and suboptimal. Regarding the drainage system, there is only one main drain located in the centre of the village. This drain is situated at the lowest contour of the environment and functions as a channel for rainwater runoff, directing the flow towards the river to the west of the village.

However, due to the limited number and capacity of drains, the risk of flooding in this settlement is quite high, especially during heavy rains. Therefore, it is crucial for the government and village residents to collaboratively plan and build a more structured and adequate utility system to support the sustainability and safety of the settlement in Wake Village.

Disaster Mitigation Aspects

The disaster mitigation assessment of Wake Village highlights a combination of environmental, structural, and infrastructural vulnerabilities that significantly increase the settlement's exposure to flood hazards. The layout of the settlement is highly irregular, with buildings constructed in close proximity to one another and concentrated on low-lying terrain that serves as a natural floodplain. This spatial arrangement not only limits evacuation routes but also accelerates the spread of damage during extreme events. The lack of proper zoning and the absence of disaster-resilient spatial planning have resulted in a built environment that is inherently fragile.

The availability of vegetation and green space is extremely limited. Natural vegetation plays a critical role in stabilising soil, reducing erosion, and slowing surface water runoff; yet in Wake Village, green cover is minimal. This deficiency exacerbates erosion rates, particularly along slopes and water channels, while also reducing the environment's capacity to absorb excess rainfall. Without adequate green infrastructure, the settlement becomes more vulnerable to sudden hydrological changes during extreme weather events.

The physical condition of buildings further compounds disaster risks. Most houses are constructed from wood, with foundations, wall frames, and roof structures of poor quality. These materials and construction techniques lack the structural integrity to withstand strong hydrodynamic forces during flash floods or high winds. Observations following the January 2021 flood confirm that many wooden houses were swept away or severely damaged, while well-built permanent structures sustained minimal impact.

Equally problematic are the utility systems. The road network is incomplete and poorly maintained, hindering access and evacuation during emergencies. Drainage systems are undersized, poorly constructed, or, in some cases, absent, causing water to accumulate rapidly during heavy rainfall. Sanitation facilities are inadequate, increasing public health risks after flooding. The absence of reliable electricity distribution and storm-proof infrastructure further undermines the community's resilience.

Addressing these weaknesses requires a comprehensive disaster-mitigation-based revitalisation strategy. First, the layout of the settlement must be reorganised to meet environmental and safety standards, integrating open spaces, wider access roads, and buffer zones. Low-lying and flood-prone areas should be designated as non-buildable zones, functioning instead as water retention areas or green corridors. Second, protective barriers should be strategically introduced. Natural barriers can be established through reforestation and riparian vegetation planting. Engineered barriers such as levees or flood walls, should complement these measures to redirect and slow floodwaters.

Third, building reconstruction should replace vulnerable wooden structures with more durable, disaster-resistant designs, incorporating reinforced foundations, stronger wall systems, and wind-resistant roofing. These improvements should be supported by technical construction guidelines and community training programmes. Fourth, the reorganisation of utility systems is essential, aligning road networks, drainage, electricity, and sanitation infrastructure with the new spatial layout. Roads should be all-weather and accessible, drainage systems sized according to hydrological capacity, and sanitation upgraded to prevent contamination during floods. This integrated approach not only strengthens physical infrastructure but also builds long-term community resilience by reducing vulnerability, enhancing adaptive capacity, and aligning Wake Village with contemporary disaster mitigation and sustainable settlement planning standards.

Improvement of Environmental Layout

The settlement layout needs to be organised based on the primary environmental framework, which includes the main village road. This road serves as the primary access point into the village from both the east and west. As the main road follows the river's flow pattern, it functions as a ring road around the village. Consequently, an additional east-west radial connecting road is required. Although such a connecting road already exists, an additional access point is necessary to form a T-junction. This junction is a critical point where floodwaters diverge (Figure 10, blue dashed line) and is also the area with the lowest elevation in the settlement.

This circulation node should be developed into an open space that functions as a retention pond and village park. Water from this pond will be channelled to the river through a drainage system divided into three main routes. In addition to flood control, this open space can serve as a gathering point for residents during emergencies, facilitating evacuation and rescue operations. Several currently irregular local roads need to be straightened. Straightening roads can be achieved using the Land Readjustment System (LRS) concept. This process requires a consensus among residents, initiated by the government. The LRS concept is designed for communal benefit such as improving environmental accessibility. Straight roads with clear patterns will facilitate residents' mobility. In implementing the LRS, some residents' land may be affected by the road construction plan, and some land may need to be repositioned using the land-sharing concept. Additionally, the LRS is designed to reorganise residents' land plots.

Figure 9 illustrates two conditions: Unorganised plots and organised plots. For example, plots B and D initially face a narrow, sloping road. If this road is straightened, the area of plot D will decrease, while the area of plot B will increase. Part of plot D's land will be allocated to plot B, while some will be used for the road. The owner of plot D must receive compensation from the owner of plot B for the reduction in land area, based on an agreed price. The land used for the road will be compensated by the government. If the owner of plot B cannot pay the compensation, the government can provide assistance in the form of a loan that can be repaid in instalments.

This process requires comprehensive education and socialisation to make the community aware of the benefits of plot organisation. Benefits of well-organised plots include easier planning of environmental utility networks such as electricity, telephone, clean water, and drainage. A well-organised environment will also increase land value. For instance, plot D, as explained above, will experience a significant increase in land value after reorganisation. Conversely, plot D will also receive part of plot F's land as part of the straightening plan for plot F. This process also applies to other plots, as shown in Figure 9. Therefore, comprehensive coordination between residents and the government is essential to ensure the success of this reorganisation.

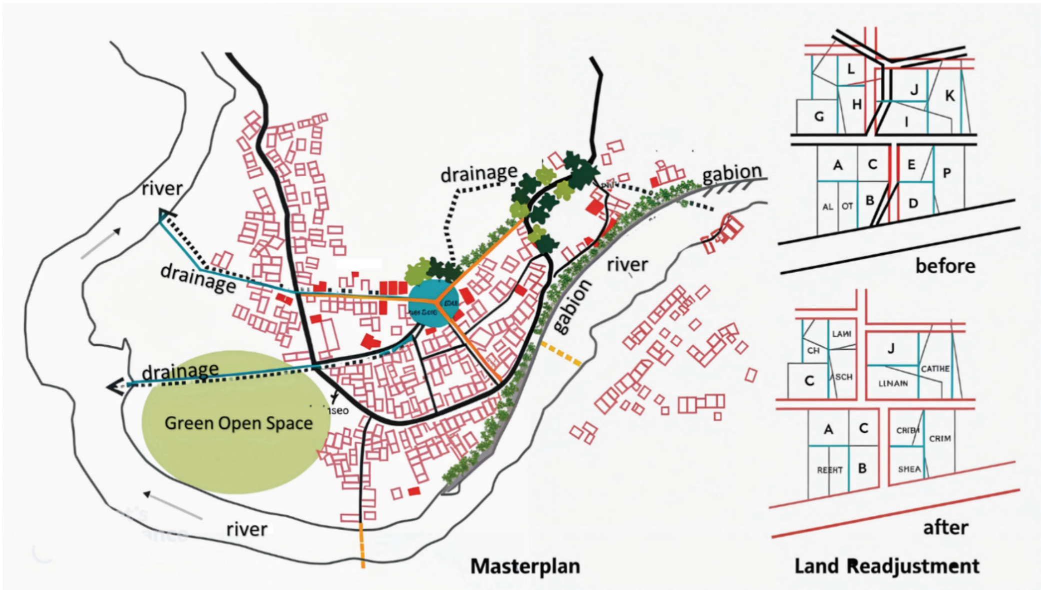

Figure 9: Land readjustment integrated with flood mitigation and disaster-resilient settlement planning in Wake Village
Source: Authors (2024)

Implementing Barriers and Revegetation to Mitigate Water Flow

Implementing barriers and revegetation in strategic locations is a critical component of flood risk reduction and settlement protection in Wake Village. The planning framework and subsequent interventions are directed towards three key zones: The river basin, the riverbanks, and the adjacent residential areas, enabling better regulation of water flow and mitigation of the destructive impacts of flash floods. In the River Basin areas, robust stream barriers are essential to reduce current velocity and erosive force. These structures, built from durable materials such as concrete or treated wood, must be engineered to withstand significant water pressure during peak flows. Their primary role is to maintain riverbank stability and prevent further degradation of the River Basin areas, which serve as the main water conveyance corridor during extreme rainfall events.

Along the riverbanks, two complementary measures are applied. First, stone gabions or *bronjong* constructed from locally sourced river stones reinforce embankments, functioning as physical shields against erosion and landslides. Second, vegetative barriers are established using bamboo and other deep-rooted species. These plantings help stabilise soil, enhance biodiversity, and provide sustainable, nature-based protection. The synergy between gabions and vegetation ensures long-term resilience against hydrological stress (Figure 10). Within residential areas, strategic revegetation is prioritised in zones identified as primary flood pathways. Trees and bamboo are planted at settlement frontages and within designated open spaces, which double as water retention ponds and community parks. In emergencies, these open areas serve as evacuation points, slowing water flow and granting residents vital time to secure lives and property.

The construction of stone gabions remains a cornerstone of this mitigation approach. Designed to exceed riverbank height and resist sudden surges, these gabions offer both

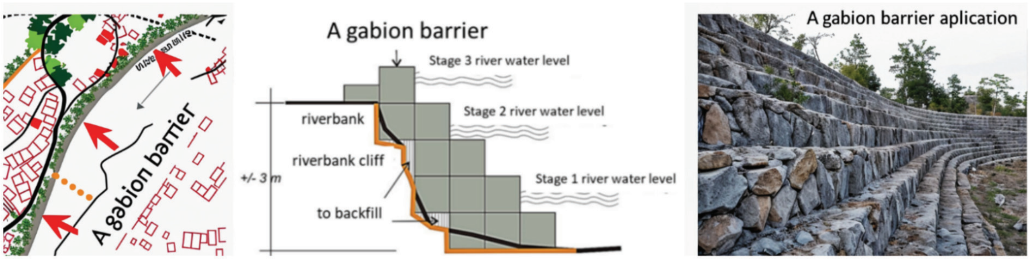

Figure 10: Design and application of gabion barriers
Source: Authors (2024)

immediate flood defence and long-term stability. By utilising locally available stones from the Batu Benawa River and adhering to precise technical specifications, the intervention not only strengthens flood protection but also supports community-led maintenance and sustainability.

Drainage System Improvement

The drainage system in Wake Village is currently inadequate, failing to manage rainwater and flood flows effectively, which increases the community's vulnerability to inundation during heavy rainfall or river overflow. To address these deficiencies, the system must be redesigned using an integrated approach that aligns with previously established environmental patterns and settlement layouts. The new design will incorporate multiple environmental elements to ensure optimal water management, linking the drainage network with other infrastructure components such as retention ponds and road systems.

At the core of this integrated system is a central retention pond located within the residential area. This pond will function as the initial reservoir, capturing rainwater and incoming flood flows before they enter the drainage channels. From the pond, water will be directed into three primary channels, each flowing in different directions toward the river. This division distributes water evenly, preventing accumulation in a single location, reducing the risk of localised flooding, and ensuring faster discharge into the river system. During periods of heavy rain or river backflow, the redesigned system will facilitate rapid water collection and conveyance. By combining adequate channel dimensions, proper gradients, and strategic outlet placements, water will be quickly evacuated from the settlement area, minimising surface pooling, structural damage, and disruption to daily activities. This approach not only enhances flood resilience but also integrates harmoniously with the broader revitalisation and disaster mitigation framework for Wake Village.

Strengthening Building Construction

The severe damage and loss of homes in Wake Village during flash floods are primarily attributable to weaknesses in construction systems and the extensive use of inadequate building materials, particularly wood. Many houses were built without adherence to proper engineering principles, resulting in structures that were unable to withstand the hydrodynamic forces of floodwaters.

To prevent similar destruction in the future, the reconstruction and development of housing in Wake Village must be carried out under strict technical guidance, ensuring compliance with safety, comfort, and health standards. This requires the active involvement of architects and civil engineers, who should oversee the construction process from the earliest stages to completion, ensuring that every element, from foundations and wall systems to roof framing, complies with building codes and structural design requirements.

Minimising the use of wood is a crucial step in improving housing resilience. While timber has traditionally been used due to its availability and ease of construction, it has low durability against moisture, pests, and high-water pressure during floods. Furthermore, high-quality wood has become increasingly scarce, raising costs and limiting supply. For long-term durability and cost-effectiveness, concrete should be adopted as the primary construction material. Reinforced concrete walls and columns provide greater strength and stability, while roof structures should utilise lightweight steel materials such as Zingalume, which offer high resistance to corrosion, wind loads, and extreme weather conditions compared to traditional wooden framing.

For houses located in low-lying or flood-prone zones, adopting an elevated platform design is essential. By raising the floor level above the expected flood height, this design minimises direct water contact with structural elements, significantly reducing the risk of damage. The platform can be constructed from reinforced concrete or lightweight steel, with all dimensions and connections designed according to technical standards to ensure long-term stability.

Although wooden substructure systems can perform well under certain conditions, particularly when designed to resist lateral flood forces, they demand precise engineering and the use of high-quality materials. In practice, however, the scarcity of durable timber and inconsistent construction quality often lead to poor performance. Evidence from flood damage assessments in Wake Village confirms that all severely damaged homes were built with wooden structures, while permanent houses with reinforced concrete frames and masonry walls remained largely intact and suffered only minor or no structural damage.

Strengthening building resilience in Wake Village will therefore require a comprehensive shift toward permanent, disaster-resistant construction methods, the use of durable and low-maintenance materials, and the enforcement of professional oversight throughout the building process. When combined with improved spatial planning, infrastructure upgrades, and community disaster preparedness, these measures can substantially reduce vulnerability to future floods and ensure safer, more sustainable living conditions for residents (Figure 11).

Settlement Development

Settlement growth in Wake Village is an inevitable outcome of population increase; however, without proper regulation, this growth risks creating disorganised, high-density environments that compromise safety, comfort, and environmental health. At present, the settlement is concentrated in a

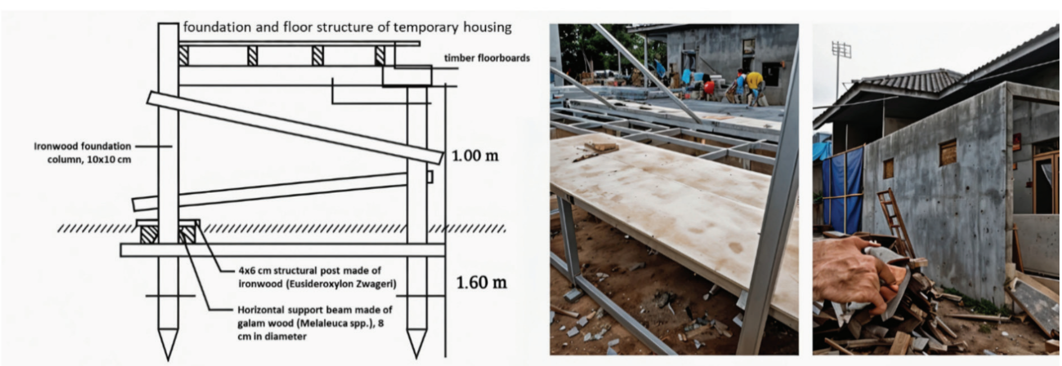

Figure 11: Temporary shelter construction with structural details and on-site application in post-disaster areas
Source: Authors (2024)

dense cluster, leaving surrounding vacant land underutilised. This situation underscores the urgent need for clear, government-mandated development guidelines that align with spatial planning principles and disaster risk reduction strategies. These guidelines must regulate the spacing between houses to ensure adequate air circulation, access to natural light, and compliance with healthy living standards, thereby fostering an orderly and environmentally sound development pattern.

A critical component of future settlement expansion is the appropriate allocation of development areas. Rather than further intensifying the existing high-density core, new housing should be directed towards available vacant land surrounding the settlement. Site selection must prioritise areas with higher elevations to reduce flood risk and ensure long-term resilience. This approach must be integrated with the application of healthy environment concepts, where residential development follows a structured layout supported by complete infrastructure, utility networks, and adequate accessibility. Such planning should account for ecological sustainability and the topographical characteristics of Wake Village to minimise environmental degradation and disaster vulnerability.

To further safeguard the community, the establishment of a zone-based system is essential. This system should clearly identify safe and unsafe zones based on topographical analysis and hazard mapping. Safe zones, particularly those at higher elevations, need to be prioritised for residential development. In contrast, unsafe or flood-prone zones should be allocated for non-residential uses such as green buffers, water retention areas, or public open spaces. As illustrated in Figure 12, zoning provides a spatial framework for balancing growth with safety, ensuring that settlement expansion supports both community needs and long-term disaster resilience.

This study contributes to the growing body of knowledge on flood disaster resilience in rural settlements, particularly those located in geomorphologically dynamic river basins. Similar to findings in the Dongar River Basin (Kanhaiya *et al*., 2019) and the Ghaghghar River Basin (Singh *et al*., 2019), Wake Village demonstrates how upstream deforestation,

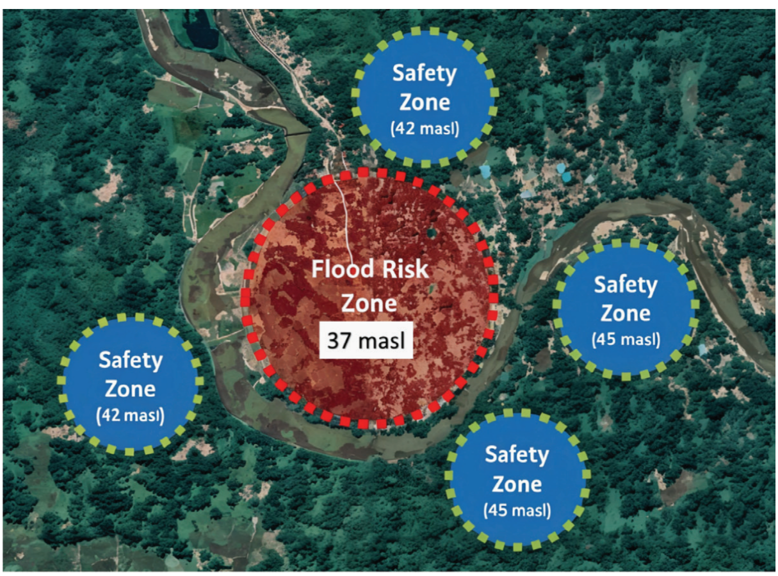

Figure 12: Flood hazard zonation and identification of safety zones in Wake Village
Source: Authors' analysis based on Google Earth imagery (2024)

sedimentation, and morphological shifts in river flow exacerbate flood vulnerability. However, unlike these prior studies, this research integrates spatial, infrastructural, and socio-cultural analyses into a comprehensive post-disaster revitalisation framework. One of the key findings is the mismatch between the natural geomorphic evolution of the Barabai River Basin and the settlement patterns of Wake Village.

The river's historical meanders have been altered by high-velocity floodwaters bypassing their natural course, as also noted in the Belan River Basin (Narzary *et al*., 2024). This creates new flood pathways that increase risks for lowland settlements. Unlike other river basins, Wake Village presents a distinctive mismatch between geomorphic processes and clustered settlement growth. The unique combination of geomorphic shifts and unplanned dense settlement patterns makes the village particularly vulnerable, requiring localised strategies that integrate the physical and social dimensions of resilience. Such phenomena emphasise the need for dynamic, topography-based planning rather than reliance on historical land-use patterns.

In terms of mitigation, the study underscores the importance of Land Readjustment Systems, not only as a spatial intervention but also as a governance tool to restructure land ownership and settlement layout. However, applying LRS in post-disaster rural contexts is fraught with challenges, particularly where customary land rights, communal ownership, and informal land tenure dominate. As Manyena *et al*. (2019) argue, resilience is not limited to infrastructure but also encompasses social systems, equity, and power dynamics.

In Wake Village, the reluctance of residents to relocate is not merely a logistical issue but reflects socio-cultural attachments to place, historical memory, and livelihood dependence on both river-based activities and agricultural fields in the Meratus highlands. Customary land rights and communal ownership further complicate negotiated redistribution, making top-down approaches politically and socially unfeasible. These dynamics illustrate why Land Readjustment Systems, while technically sound, are difficult to implement without inclusive processes that respect cultural norms, power relations, and community agency.

Physical mitigation efforts such as gabion walls and revegetation align with global best practices (Chen *et al*., 2019), but without community stewardship, these structures risk becoming ineffective over time. The sustainability of physical interventions depends on institutional arrangements that promote maintenance and local capacity building. A further concern is the potential for maladaptation if mitigation measures are pursued without sufficient attention to social dynamics. Protective structures may generate a false sense of security, encouraging further settlement expansion into hazardous areas, while eco-engineering may fail without community stewardship. Moreover, the study highlights the interconnection between ecological restoration and settlement resilience. Watershed rehabilitation through reforestation in the upstream Meratus area is not solely an environmental concern but is directly tied to downstream flood risk management. This finding supports the Eco-DRR (Ecosystem-based Disaster Risk Reduction) framework, which integrates environmental conservation into disaster mitigation strategies (Estrella & Saalismaa, 2013).

This study, while providing a comprehensive framework for settlement revitalisation and disaster mitigation in Wake Village, acknowledges several important limitations. One of the primary constraints is the reliance on static hydrological data, which represents only a snapshot of flood conditions during a specific event. This approach does not fully capture the dynamic nature of flood patterns, particularly under climate variability and sedimentation processes that can alter river behaviour over time.

The absence of long-term hydrological modelling limits the predictive capacity of the proposed mitigation strategies. Furthermore, the study has yet to incorporate a social simulation of land readjustment acceptance. Understanding how communities negotiate, resist, or adapt to land readjustment proposals is crucial, particularly where customary land rights and emotional attachment to place play significant roles in settlement decisions. Without this dimension, there is a gap in the analysis of social dynamics and community decision-making processes during post-disaster recovery.

In addition, the model developed in this study does not employ agent-based simulations (ABM). Incorporating ABM would provide valuable insights into how individual households or stakeholders might behave under different scenarios of risk, relocation, and infrastructure changes. This limitation is compounded by the resolution of available data such as 30-metre DEMs and medium-resolution satellite imagery, which constrain micro-level flood modelling. Equally important are institutional constraints, including limited local government capacity, inadequate funding, and weak inter-agency coordination, all of which hinder long-term implementation.

For future research, it is recommended to integrate real-time hydrological monitoring systems and community-based early warning mechanisms to enhance adaptive capacity at the local level. Additionally, participatory scenario planning involving local stakeholders will be essential to refine the model, ensuring that the proposed solutions are not only technically feasible but also socially acceptable and sustainable. This study presents a novel and integrative approach to disaster mitigation and settlement revitalisation, particularly in the context of rural, flood-prone areas. Unlike conventional models that focus primarily on physical infrastructure, this research proposes a multi-layered framework that addresses not only the geomorphological risks of flash floods but also the social, spatial, and ecological dimensions of resilience. The core contribution of this study lies in the integration of spatial resilience planning through land readjustment.

By reorganising settlement layouts to optimise land use, improve accessibility, and reduce exposure to hazard-prone zones, the land readjustment strategy is adapted here as a disaster mitigation tool. It is applied not merely as an urban planning technique but as a strategy for risk reduction. This represents a significant innovation, particularly in rural contexts where such mechanisms are rarely implemented.

In addition, the study introduces a hybrid infrastructure model that combines green and grey solutions. Green measures include reforestation and buffer vegetation, while grey interventions involve gabion walls and adaptive drainage systems. This green-grey synergy aligns with the principles of Eco-DRR, emphasising the role of natural systems in complementing engineered defences. Furthermore, the framework incorporates community-centred adaptation strategies, recognising that resilience is not built solely through structural measures but also through social participation, local knowledge, and adaptive governance.

By doing so, the research highlights the necessity of engaging communities in both decision-making and long-term maintenance of mitigation systems. By linking geomorphological risk management, land use restructuring, and social resilience building, this study contributes a replicable and context-sensitive model for settlement revitalisation in flood-prone regions. Its application is particularly relevant for tropical river basins in Southeast Asia, where climate-induced disasters, ecological degradation, and rapid settlement growth converge. The proposed framework advances the field by positioning disaster resilience as a cross-sectoral, multi-dimensional challenge, moving beyond traditional engineering solutions towards a social-ecological systems perspective.

Conclusions

This study formulates a disaster-mitigation-based settlement revitalisation framework for Wake Village that directly addresses its acute vulnerability to flash floods through five integrated interventions: (1) An engineered drainage system linked with retention ponds and restored waterways to control runoff volume and distribution; (2) Land readjustment to reorganise plots, relocate 35% of houses from high-risk zones, and improve road accessibility by up to 25%; (3) Protective eco-engineering measures, including stone gabions and bamboo buffers, which can reduce riverbank erosion by up to 50%; (4) Flood-resilient housing designs featuring reinforced concrete structures, elevated platforms, and adaptive materials proven to withstand 3.65 m/s flood currents; and (5) Controlled settlement expansion into higher, safe zones in accordance with zoning regulations and environmental health standards.

The novelty of this framework lies in merging micro-scale disaster mitigation with land readjustment strategies to achieve both immediate risk reduction and long-term socio-spatial transformation, thereby avoiding the "build-back-as-before" trap common in post-disaster reconstruction. When applied in Wake Village, this approach is projected to significantly reduce direct flood damage, enhance water management capacity, and restore ecological buffers, while strengthening community preparedness and ownership of resilience measures. Beyond this case, the model offers a replicable reference for rural settlements in tropical river basins of Southeast Asia, where ecological degradation, geomorphic change, and rapid settlement growth converge to heighten flood risks.

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Conflict of Interest Statement

The authors declare that they have no conflict of interest.

References

Aina, Y. A., Adam, E., Ahmed, F., Wafer, A., & Alshuwaikhat, H. M. (2019). Using multisource data and the V-I-S model in assessing the urban expansion of Riyadh city, Saudi Arabia. *European Journal of Remote Sensing*, *52*(1), 557-571. https://doi.org/10.1080/22797254.2019.1691469

Cea, L., & Costabile, P. (2022). Flood risk in urban areas: Modelling, management and adaptation to climate change. A review. *Hydrology*, *9*(3), 50. https://doi.org/10.3390/hydrology9030050

Chen, Y.-M., Liu, C.-H., Shih, H.-J., Chang, C.-H., Chen, W.-B., Yu, Y.-C., Su, W.-R., & Lin, L.-Y. (2019). An operational forecasting system for flash floods in mountainous areas in Taiwan. *Water*, *11*(10), 2100. https://doi.org/10.3390/w11102100

Cheng, X., Fan, L., & Wang, J. (2018). Can energy structure optimisation, industrial structure changes, technological improvements, and central and local governance effectively reduce atmospheric pollution in the Beijing–Tianjin–Hebei area in China? *Sustainability*, *10*(3), 644. https://doi.org/10.3390/su10030644

Chuang, W. C., Garmestani, A., Eason, T. N., Spanbauer, T. L., Fried-Petersen, H. B., Roberts, C. P., Sundstrom, S. M., Burnett, J. L., Angeler, D. G., Chaffin, B. C., Gunderson, L., Twidwell, D., & Allen, C. R. (2018). Enhancing quantitative approaches for assessing community resilience. *Journal of Environmental Management*, *213*, 353-362. https://doi.org/10.1016/j.jenvman.2018.01.083

Frazier, T. G., Thompson, C. M., & Dezzani, R. J. (2013). Spatial and temporal quantification of resilience at the community scale. *Applied Geography*, *42*, 95-107. https://doi.org/10.1016/j.apgeog.2013.05.004

GFDRR. (2014). *Bringing resilience to scale*. *Global facility and recovery annual report*. https://doi.org/10.1126/science.162.3859.1243

Hamza Briak, R., Mrabet, R., Moussadek, R., & Aboumaria, K. (2019). Use of a calibrated SWAT model to evaluate the effects of agricultural BMPs on sediments of the Kalaya river basin (North of Morocco). *International Soil and Water Conservation Research*, *7*(2), 176-183. https://doi.org/10.1016/j.iswcr.2019.02.002

Kanhaiya, S., Singh, S., Singh, C. K., Srivastava, V. K., & Patra, A. (2019). Geomorphic evolution of the Dongar River Basin, Son Valley, Central India. *Geology, Ecology, and Landscapes*, *3*(4), 269-281. https://doi.org/10.1080/24749508.2018.1558019

Kardani-Yazd, N., Kardani-Yazd, N., & Mansouri Daneshvar, M. R. (2019). A rapid method for evaluating the variables affecting traffic flow in a touristic road, Iran. *Environmental Systems Research*, *8*(34). https://doi.org/10.1186/s40068-019-0162-0

Kementerian Pekerjaan Umum. (2012). *Petunjuk tindakan dan sistem mitigasi banjir bandang*. https://www.jica.go.jp/Resource/project/indonesian/indonesia/0800040/materials/pdf/outputs_15.pdf

Kumar, V., Sharma, K. V., Caloiero, T., Mehta, D. J., & Singh, K. (2023). Comprehensive overview of flood modelling approaches: A review of recent advances. *Hydrology*, *10*(7), 141. https://doi.org/10.3390/hydrology10070141

Lestari, F., Sudaryo, M. K., Djalante, R., Adiwibowo, A., Kadir, A., Zakianis, & Satyawardhani, S. A. (2024). Estimating the flood, landslide, and heavy rainfall susceptibility of vaccine transportation after 2021 flooding in South Kalimantan Province, Indonesia. *Sustainability*, *16*(4), 1554. https://doi.org/10.3390/su16041554

Manyena, B., Machingura, F., & O'Keefe, P. (2019). Disaster resilience integrated framework for transformation (DRIFT): A new approach to theorising and operationalising resilience. *World Development*, *123*, 104587. https://doi.org/10.1016/j.worlddev.2019.06.011

Manyena, S. B. (2011). The concept of resilience revisited. *Disasters*, *30*(4), 434-450. https://doi.org/10.1111/j.0361-3666.2006.00331.x

Maslova, S., & King, R. S. (2020). Residential trajectories of high-skilled transnational migrants in a global city: Exploring the housing choices of Russian and Italian professionals in London. *Cities*, *96*. https://doi.org/10.1016/j.cities.2019.102421

Menoni, S., Molinari, D., Parker, D., Ballio, F., & Tapsell, S. (2012). Assessing multifaceted vulnerability and resilience in order to design risk-mitigation strategies. *Natural Hazards*, *64*(3), 2057-2082. https://doi.org/10.1007/s11069-012-0134-4

Mizutori, M. (2019). From risk to resilience: Pathways for sustainable development. *Progress in Disaster Science*, *2*, 100011. https://doi.org/10.1016/j.pdisas.2019.100011

Narzary, B., Singh, S., Shivsager, V., Jaiswal, M. K., Singh, P., Chaubey, K., & Prakash, K. (2024). Late Quaternary ev`olution of the Belan River Basin, Central India. *Radiation Physics and Chemistry*, *216*, 111370. https://doi.org/10.1016/j.radphyschem.2023.111370

Nguyen, H. L., & Akerkar, R. (2020). Modelling, measuring, and visualising community resilience: A systematic review. *Sustainability*, *12*(19), 7896. https://doi.org/10.3390/su12197896

Rosaria Indah, V. (2021). Valuing subaltern and grieving patients: Power issues in doctor-patient interactions in post-disaster Aceh, Indonesia. *International Journal of Disaster*

Risk Reduction, *61*, 102326. https://doi.org/10.1016/j.ijdrr.2021.102326

Singh, P., Kannaujiya, A. K., Deep, A., Singh, S., Mohanty, T., & Prakash, K. (2023). Spatio-temporal drought susceptibility assessment of the Ken River Basin, Central India, and its evaluation through the river's morphometry. *Geological Journal*, *58*(2), 755-779. https://doi.org/10.1002/gj.4622

Singh, S., Kanhaiya, S., Singh, A., & Chaubey, K. (2018). Drainage network characteristics of the Ghaghghar River Basin (GRB), Son Valley, India. *Geology, Ecology, and Landscapes*, *3*(3), 159-167. https://doi.org/10.1080/24749508.2018.1525670

Singh, S., Prakash, K., & Shukla, U.K. (2019). Decadal scale geomorphic changes and tributary confluences within the Ganga river valley in Varanasi region, Ganga Plain, India. *Quaternary International*, *507*, 124-133. https://doi.org/10.1016/j.quaint.2018.05.022

Singh, S., Singh, A.K., Kumar, P., & Jaiswal, M.K. (2021). Morphotectonic analysis of the Bihar River, Madhya Pradesh, India. *Proceedings of the Indian National Science Academy*, *87*(1), 163-174.

Tariq, M. A. U. R., Farooq, R., & van de Giesen, N. (2020). A critical review of flood risk management and the selection of suitable measures. *Applied Sciences*, *10*(23), 8752. https://doi.org/10.3390/app10238752

Temesgen Gashaw, T., Taffa Tulu, M., Mekuria Argaw, A., & Abeyou W. Worqlul. (2018). Modelling the hydrological impacts of land use/land cover changes in the Andassa watershed, Blue Nile Basin, Ethiopia. *Science of the Total Environment*, *619-620*, 1394-1408. https://doi.org/10.1016/j.scitotenv.2017.11.191

Yanti, R. M., Fauzi, A., Sari, O. L., Wahab, M. F., & Sukmara, R. B. (2023). Preliminary study on the causes of the 2021 South Kalimantan flood by using rainfall-runoff inundation model: A case study in Martapura River Basin. In *AIP Conference Proceedings* (Volume 2629, No. 1). AIP Publishing. https://doi.org/10.1063/5.0128948