Mapping The Physical Vulnerability Level of Residential Fires in Alalak Tengah Urban Village, North Banjarmasin Sub-district

Pemetaan Tahap Kebakaran Fizikal Penempatan Di Daerah Alalak Tengah Daerah Banjarmasin Utara

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ABSTRACT *Indonesia is an area that is vulnerable to various disasters, one of which is residential fires. Banjarmasin City has the highest population density and fire frequency in South Kalimantan. Alalak Tengah Urban Village is the urban village with the highest area of slums in North Banjarmasin Sub-district. Slums are often accompanied by a decline in the quality and facilities of settlements, making them areas that allow settlement fires to occur. Mapping vulnerability levels is necessary for disaster risk management. This research uses qualitative analysis based on Geographic Information System (GIS). The parameters used in this study are the density of residential buildings, type of residential buildings, settlement layout pattern, distance from water source location, distance from fire extinguisher location, distance from main road, and width of driveway. The research shows that the level of physical fire vulnerability in Alalak Tengah Village is divided into three levels with a low vulnerability level of 8.2 Ha, a medium vulnerability level of 11.7 Ha, and a high vulnerability level of 16.4 Ha. The high vulnerability level dominates with areas that have limited access, with dense settlements, and flammable building materials. The results of the physical vulnerability map of residential fires are reliable, with map accuracy test results ≥80%.*

***Keywords**: Settlement Fire, Geographic Information System (GIS), Disaster, Vulnerability*

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ABSTRAK *Indonesia merupakan wilayah yang terdedah kepada pelbagai bencana, salah satunya kebakaran perumahan. Kota Banjarmasin merupakan kawasan yang mempunyai kepadatan penduduk dan kekerapan kebakaran tertinggi di Kalimantan Selatan. Kecamatan Alalak Tengah merupakan sebuah kecamatan dengan kawasan permukiman kumuh terluas di Kabupaten Banjarmasin Utara. Kawasan setinggan sering disertai dengan penurunan kualiti dan kemudahan penempatan, menjadikannya kawasan yang terdedah kepada kebakaran petempatan. Pemetaan tahap kerentanan adalah perlu untuk pengurusan risiko bencana. Kajian ini menggunakan analisis kualitatif berdasarkan Sistem Maklumat Geografi (GIS). Parameter yang digunakan dalam kajian ini ialah kepadatan bangunan kediaman, jenis bangunan kediaman, corak susun atur penempatan, jarak dari sumber air, jarak dari lokasi alat pemadam api, jarak dari jalan utama, dan lebar jalan masuk. Penyelidikan menunjukkan bahawa tahap kerentanan fizikal terhadap kebakaran di Kampung Alalak Tengah terbahagi kepada tiga tahap dengan tahap kerentanan rendah 8,2 Ha, tahap kerentanan sederhana 11,7 Ha, dan tahap kerentanan 16,4 Ha yang tinggi. Tahap kerentanan yang tinggi mendominasi kawasan yang mempunyai akses terhad, penempatan padat dan bahan binaan mudah terbakar. Keputusan peta kelemahan fizikal untuk kebakaran kediaman boleh dipercayai, dengan keputusan ujian ketepatan peta ≥80%.*

Kata Kunci : *Kebakaran Kediaman, GIS, Bencana, Keterdedahan*

1. Introduction

Indonesia is an area prone to various disasters, both natural and non-natural disasters. Non-natural disasters include social and political unrest, industrial accidents, disease outbreaks, and various other events (Kartika et al., 2023). Residential fires and residential buildings are one of the non-natural disasters. Settlement fires in Indonesia often occur, especially in urban areas that are densely populated, dense residential buildings and high economic activity (Muzani, 2020).

Banjarmasin City is a densely populated city in South Kalimantan. The population density in Banjarmasin City reached a population density of 6,779 people/km^2 in 2022 (BPS, 2023). This population density, Banjarmasin City is categorized as a high-density city, but not to an extreme level ranging from 5,000 to 20,000 people square kilometers (Brezzi et al., 2012; Sihombing & Utami, 2023). This population density leads to increased space requirements, while the availability of space is limited and decreasing, causing the quality of buildings to decline. Dense settlements often cause fires in urban areas (Sagala et al. in Adyatma et al., 2024). The dense population in the city of Banjarmasin is the reason this research focuses on one of the urban villages, which has a high slum area. Alalak Tengah urban village has the highest area of slums in the North Banjarmasin sub-district with an area of 20.02 Ha (Decree No. 215 of Banjarmasin City Government, 2022).

Geografi Vol.13 (2), 88-114
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Slums are usually accompanied by a decline in settlement quality, which can lead to various problems in the lives of city residents. In the context of disasters, physical vulnerability refers to the characteristics of the built environment and other physical elements that are susceptible to damage or destruction due to a threat, in this case fire. This includes aspects such as building density, types of combustible construction materials, accessibility for firefighters, and availability of water sources. This concept is crucial because, vulnerability is one of the key components of disaster risk, where the higher the physical vulnerability of an area, the greater the potential impact of a fire (Saputra et al., 2023). The vulnerability of an area to fire is highly dependent on location and area factors. Because of this need, a comprehensive data presentation is required to provide information on the spatial distribution of fire vulnerability. The spatial presentation of data is intended to provide an understanding of the level of vulnerability of an area. Analysis of fire vulnerability distribution can be an important foundation in disaster mitigation planning and the development of effective fire management strategies in a region or area. Maps are one of the data media presentations that can be used to simplify and provide a visual impression that makes it easy to communicate and transmit spatial information (Salampessy et al., 2023). Mapping the level of physical vulnerability in this study intends to focus the research on the physical elements of buildings and infrastructure that impact the causes of fire. The physical environment plays an important role in shaping the impact and recovery process after a disaster (Brown, 2024). Information on these physical vulnerabilities is essential for urban planning and policy development. Mapping using Geographic Information Systems (GIS) and Remote Sensing (RS) is a solution in providing physical vulnerability information. Mapping is a method used in providing mathematical information about the effect of a phenomenon on the earth's surface on spatial or area phenomena (Pratiwi et al., 2018; Widodo, 2014).

This research focuses on determining the level of physical vulnerability of residential fires in Alalak Tengah urban village. Mapping the level of physical fire vulnerability is the objective of this research. This research examines physical vulnerability with 7 parameters, namely the density of residential buildings, the type of residential buildings, the layout pattern of residential buildings, the location of settlements from water sources, the distance of fire-fighting locations, the distance of settlements from roads, and the width of driveways. Although many fire vulnerability studies have been conducted in large cities, mapping of physical fire vulnerability in small urban villages such as Alalak Tengah is still minimal, even though these areas often have unique characteristics that contribute to high risk. This study aims to fill this gap by providing detailed mapping specific to densely populated areas at the urban village level.

Geografi Vol.13 (2), 88-114
ISSN 2289-4470 /eISSN 2462-2400

2. Literature Review

2.1 Understanding and causes of fire hazards

A fire is an event involving uncontrolled flames, which can cause significant damage to property and the environment, and can endanger human lives. Fires can occur in various places such as forests, residential buildings, vehicles, and open land. A fire occurs when the flames that form cannot be controlled and generate continuous heat, beyond human ability and desire (Seni et al., 2023). A fire starts as a small flame and grows larger if it is not extinguished immediately. Three interrelated elements are necessary for a fire to occur: oxygen, combustible material (fuel), and a heat source (fire, embers, sparks, short circuits, hot metals, and exothermic reactions) (Musadek et al., 2021). In general, the causes of fires can be divided into five categories: limited information and knowledge about fires themselves, human negligence, animals such as rats and others, intentional acts, and natural causes (Musadek et al., 2021).

3. *Urban fire vulnerability in Indonesia*

A city commonly used in Indonesia is an area with a higher population density than the surrounding areas, due to the concentration of various functional activities related to the activities of its residents. (Kustiwan, 2014). Cities are usually economic, social, and cultural centers, where many people gather to work, live, and participate in various activities that support daily life. (Undang-Undang Republik Indonesia Nomor 26 Tahun, 2007). Cities usually have a much higher population density than surrounding areas (Mardiansjah et al., 2018). The trend of population growth in a city, which is often accompanied by densification and a decline in the quality of housing, can cause various problems in the lives of city residents. Densely populated neighborhoods often cause fires in urban areas (Sagala et al. dalam Adyatma et al., 2024). The potential for residential fires and the lack of firefighting facilities make residential areas vulnerable to fires (Yaskinul Anwar & Lukas, 2019).

4. *Concept and dimensions of vulnerability (physical, social, environmental)*

Vulnerability is a condition of a community or society that leads to or causes an inability to cope with disaster threats (BNPB,2012). Vulnerability is divided into three categories: physical, social, and economic vulnerability. Physical vulnerability refers to physical conditions that lack resilience, are damaged, lost, or destroyed, such as residential buildings, structures, and other physical structures such as infrastructure, when certain factors cause or result in damage (Noson dalam Fitria et al., 2019). Social vulnerability is a multifaceted concept that encompasses the vulnerability of social groups to the adverse effects of external stresses, such as natural disasters, economic downturns, and pandemics. It is characterized by a combination of factors, including

Geografi Vol.13 (2), 88-114
ISSN 2289-4470 /eISSN 2462-2400

economic instability, lack of access to resources, and social exclusion, which collectively place individuals and communities at higher risk of harm and slower recovery from crises ("Social Vulnerability A Qualitative Research on the Reasons behind Social Vulnerability in Erbil City," 2023). Environmental vulnerability refers to the degree to which a system or area of the environment is susceptible to damage, degradation, or negative impacts from specific pressures or disturbances. It reflects the potential for damage that could affect ecosystem balance, quality of life, and the sustainability of natural resources.

2.4 Physical vulnerability factors in urban areas

Physical vulnerability to fire in residential areas is a major concern, especially in densely populated urban areas and areas with traditional housing structures. The unique characteristics of these environments contribute to high risk during fire incidents. Table 1 shows parameters in determining the level of physical vulnerability to residential fires include the level of residential fire triggers, the rate of residential fire spread, the availability of water sources, and the accessibility of firefighting equipment (Suvek, 2021).

Table 1.
Parameters in determining the level of physical vulnerability

Research	Research Variables	Parameters
Vulnerability to Residential Fires	Fire Spread Rate in Residential Areas	• Residential building density
		• Types of residential buildings
		• Residential layout patterns
	Availability of Water Sources	• Distance from water sources
	Firefighting Accessibility	• Distance from fire stations
		• Distance of residential areas from main roads
		• Width of access roads

5. Methods

This research adopts a mixed-methods approach, combining quantitative and qualitative spatial analysis. Quantitative research method is an approach that uses or is expressed in the form of numbers (Ramdhan, 2021). The data used is a collection of data obtained from GIS analysis sourced from fire department agencies, primary data from *Open Street Maps*, *google earth* images and field data. The population in this study are all objects including residential buildings, roads, water sources and fire extinguisher locations in Alalak Tengah Village. This study divides Alalak Tengah Village into 1078 grids with an area of 97.02 Ha, a grid size of 30 x 30 meters, with each grid covering an average of 3-5 residential buildings.

Geografi Vol.13 (2), 88-114
ISSN 2289-4470 /eISSN 2462-2400

This grid division aims to facilitate the distribution of samples at each level. The grid size of 30 x 30 meters refers to the length of a fire hose which is generally 30 meters long (Yuniarto & Bhiwara in Rosyidiin et al., 2023).

The sample for this study comprised 50 samples for each parameter, totaling a robust dataset for analysis. This sample size aligns with common practices in spatial mapping, particularly for studies involving multiple categories, where a minimum of 50 samples per category is often recommended to ensure statistical validity and representativeness (Roger M. McCoy in Forsythe, 2006). Such a sample size is deemed sufficient to achieve reliable spatial mapping accuracy, providing adequate data points across the study area for robust analysis. Sampling in this study used the *Proportional Stratified Random Sampling technique. The Proportional Stratified Random Sampling technique* is used when the population has stratified members / elements whose samples are proportionally stratified (Sugiyono in Amin et al., 2023). To ensure the integrity and reliability of the data, ethical considerations and stringent validation procedures were implemented.

All primary data collection in the field adhered to ethical guidelines, ensuring privacy and minimizing disruption to residents. Furthermore, data validation was systematically performed through direct field observations and cross-referencing with high-resolution satellite imagery (Google Earth) and existing official records (fire department agencies). This multi-source validation approach helps to minimize errors and enhance the credibility of the spatial data used in the analysis. The parameters selected for accuracy testing—settlement density, settlement type, settlement layout pattern, and road width—were prioritized based on their direct impact on physical fire vulnerability. Other essential parameters, such as water body locations (rivers), fire station locations, and main roads, were verified through direct field checks to confirm their correctness and consistency with the tentative maps. Map accuracy was deemed acceptable if it exceeded 80% (≥80%), a widely recognized and acceptable threshold in spatial mapping and GIS applications (Kevin, 2023; Kusuma et al., 2023; Putri et al., 2024; Wulansari Harvini, 2017). This threshold signifies a high level of confidence in the map's ability to accurately represent real-world features, making it suitable for informed decision-making in disaster mitigation and urban planning. The determination of settlement vulnerability classes uses a scoring method by assigning a value. The smallest value or 1 is for each parameter that has no effect on creating fire-prone conditions, while the value of 3 is the class for each parameter that has an effect on causing high fire-prone conditions. The value of each parameter is shown in the following table 2 until table 8 below:

Geografi Vol.13 (2), 88-114
ISSN 2289-4470 /eISSN 2462-2400

Table 2.
Parameter Scoring Density of residential buildings

Class	*Description*	*Value Score*
Not Solid	≤40% of residential buildings from the total area	*1*
Somewhat Solid	40% - 75% residential buildings of the total area	*2*
Solid	*>75% residential buildings of area*	*3*

Source: (DITJEN Cipta Karya, 1980; Suharyadi 1980 in Rahmaddani & Sari, 2024)

Table 3.
Parameter Scoring Types of residential buildings

Class	Description	Value Score
Non-flammable	>75% permanent residential building types	1
Somewhat flammable	40%-75% permanent residential building types	2
Flammable	< 40% permanent residential building type	3

Source: (DITJEN Cipta Karya, 1980; Suharyadi 1980 in Rahmaddani & Sari, 2024)

Table 4.
Parameter Scoring of Settlement Layout Patterns

Class	Description	Value Score
Regular	>75% of residential buildings are parallel to the road	1
Somewhat Organized	40% - 75% of residential buildings are parallel to the road	2
Irregular	≤40% of residential buildings are parallel to the road	3

Source: (DITJEN Cipta Karya, 1980; Suharyadi 1980 in Rahmaddani & Sari, 2024)

Table 5.
Parameter Scoring of Settlement Location from Water Source

Class	Description	Value Score
Near	>75% <100 meters away	1
Medium	40%-75% within 100-200 meters	2
Deep	<40% spaced > 200 meters	3

Source: (DITJEN Cipta Karya, 1980; Suharyadi 1980 in Rahmaddani & Sari, 2024)

Table 6.
Parameter Scoring of Extinguisher Location Parameters From Location

Class	Description	Value Score
Near	>75% spaced< 1,500 meters away	1
Medium	40%-75% 1,500-2,500 meters away	2
Deep	<40% distance > 2,500 meters	3

Source: (DITJEN Cipta Karya, 1980; Suharyadi 1980 in Rahmaddani & Sari, 2024)

Table 7.
Parameter Scoring Distance of Settlements from Main Roads

Class	Description	Value Score
Near	>75% spaced< 50 meters	1
Medium	40%-75% within 50-100 meters	2
Deep	<40% spaced > 100 meters	3

Source: (DITJEN Cipta Karya, 1980; Suharyadi 1980 in Rahmaddani & Sari, 2024)

Geografi Vol.13 (2), 88-114
ISSN 2289-4470 /eISSN 2462-2400

Table 8.
Parameter Scoring of Driveway Width

Class	Description	Value Score
Width	>75% Driveway width more than 6 meters	1
Somewhat Wide	40%-75% Driveway width 3 - 6 meters	2
Narrow	<40% Driveway width < 3 meters	3

Source: (DITJEN Cipta Karya, 1980; Suharyadi 1980 in Rahmaddani & Sari, 2024)

After calculating the value of each parameter, a total value of all parameters can be generated for classification into fire and settlement vulnerability levels. The fire vulnerability map is the final result that will be produced from this research. The map produced by in this research contains information about the location of fire vulnerability in Alalak Tengah Village based on the total value of the parameters. To get these results, an overlay is done between variables or parameters. The results of the overlay that have been calculated will get a total score or total value so that it can be classified in the fire vulnerability class with the formula and table below:

$$I = \frac{R}{K}$$

I= Interval
R= Range (Maximum *Value-Minimum Value*) K= Class (Number of Classes 3)
K= Class (Number of Classes 3)

6. Results and Discussion

6.1 Accuracy Test Results of Residential Fire Parameters

Analysis of the accuracy of residential building density maps shows excellent classification performance. The producer accuracy for the dense class reaches 100%, indicating the model's perfect ability to identify areas with high building concentrations. Meanwhile, the medium and non-dense classes show strong producer accuracy, at 88.2% and 85%, respectively. User accuracy levels also confirm this reliability, with the dense class reaching 92.8%, the non-dense class 89.4%, and the moderate class 88.2%. The overall accuracy of the settlement density map of 90% not only exceeds the minimum threshold of ≥80% set in this study but also indicates that the spatial data used is highly representative of field conditions (Figure 1). This high reliability is vital because settlement density is a crucial factor in determining the rate of fire spread and accessibility for firefighting.

Geografi Vol.13 (2), 88-114
ISSN 2289-4470 /eISSN 2462-2400

Therefore, this map serves as a robust and valid tool for further fire vulnerability analysis. While the model shows high accuracy in certain classes, it is essential to consider the potential biases introduced by imperfect ground truth data, which can affect the perceived accuracy of classifications (Foody, 2024).

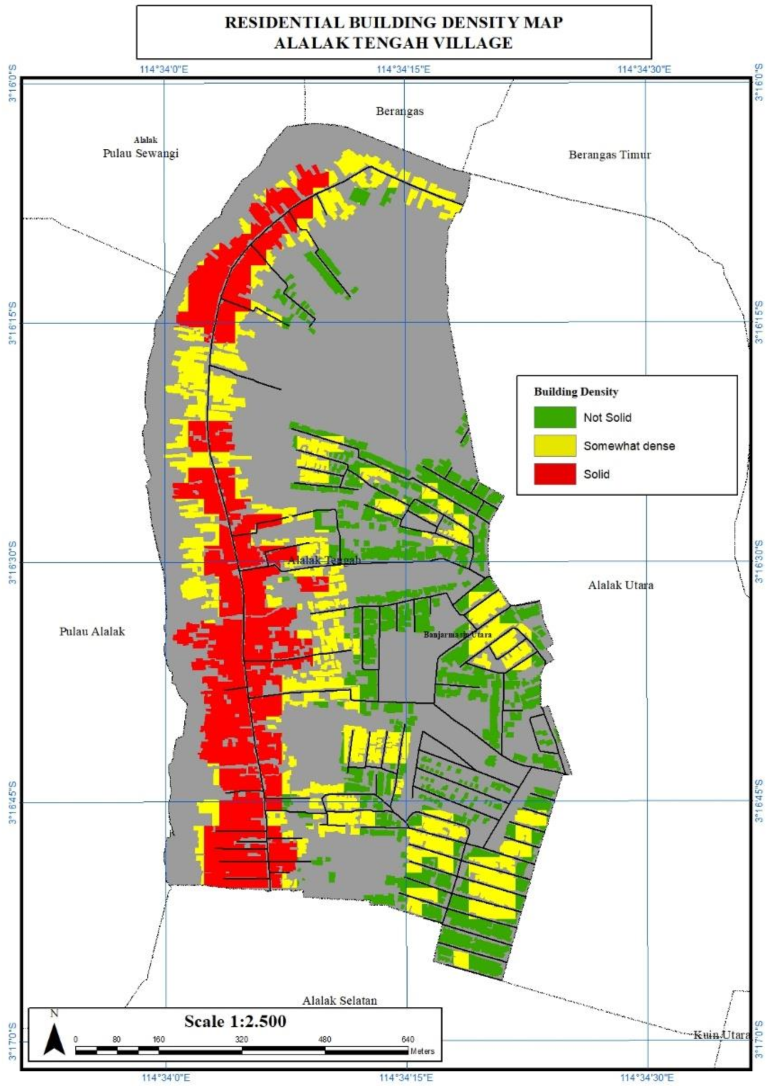

Figure 1. *Residential Building Density Map*
Source: Research Results 2025

Geografi Vol.13 (2), 88-114
ISSN 2289-4470 /eISSN 2462-2400

Figure 2. *Field Check Photos of Dense Settlements*
Source: Research Results 2025

Table 8.
Accuracy Test of Residential Building Density Map

			Field Survey Results (Producer)				Commission	Producer Accuracy
			Residential Building Density			Total		(%)
	Class		Solid	Somewhat Dense	Not Solid		(%)	
Interpretation Result (Maker/Producer)	Residential Building Density	Solid	13	0	1	14	0	100
		Somewhat Dense	0	15	2	17	11,7	88,2
		Not Solid	0	2	17	19	15	85
	Total		13	17	20	50	***Overall* Accuracy**	
Omissions (%)			7,1	11,7	10,5		**90%**	
Accuracy of Users (%)			92,8	88,2	89,4			

Source: Research Results 2025

4.12 *Accuracy Test Results of Road Width Map*

The overall accuracy for road width classification reached 90%, indicating a generally high level of accuracy for the entire map. This figure easily exceeds the minimum threshold of ≥80% for the study, making the map reliable enough to be used directly in further analysis (Figure 3).

While the overall accuracy is commendable, the identified weaknesses in specific classes, particularly the very low accuracy for the "width" class, underscore the importance of delving into individual class accuracy. This disaggregation reveals areas requiring focused refinement to ensure complete map representation. Poor road conditions can hinder emergency response, necessitating regular maintenance and repair to ensure optimal functionality (At Taufan et al., 2025).

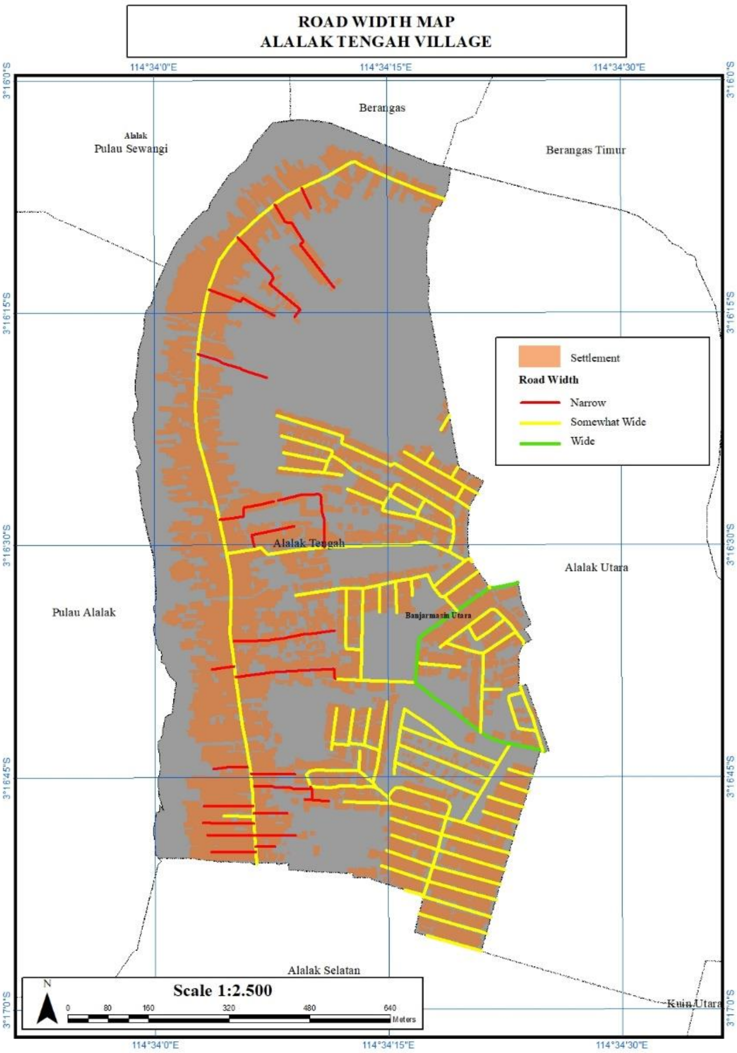

Figure 3. *Road Width Map*
Source: Research Results 2025

The high overall accuracy of 90% for road width classification is consistent with similar spatial mapping studies that use remote sensing and GIS for urban infrastructure analysis. Many urban mapping projects, especially those focused on accessibility for disaster management, generally achieve overall accuracy above 80% when ground-truthing is performed rigorously. Strong performance on narrow and moderately wide roads is particularly valuable in contexts such as Alalak Tengah, where complex and often unpaved paths are common.

Geografi Vol.13 (2), 88-114
ISSN 2289-4470 /eISSN 2462-2400

However, the unique issue with the "wide" class due to limited samples highlights challenges that can arise in GIS classification, especially when certain feature categories are rare or underrepresented in the sample data. This contrasts with the ideal classification scenario where all classes are adequately represented, reminding us that data scarcity for specific features can indeed impact accuracy metrics, even if the underlying model is robust.

The findings from this road width map have profound implications for urban disaster management in cities with similar structures throughout Southeast Asia. In many urban areas in this region, road networks are often complex, consisting of a mix of main roads and many narrow, often informal lanes. Accurate road width maps are essential for emergency access planning, evacuation route identification, pre-disaster route assessment, and infrastructure prioritization.. The results of the field check are presented in the following table 9 below:

Table 9.
Road Width Map Accuracy Test

			Field Survey Results (Producer)			Total	Commission (%)	Producer Accuracy (%)
	Class		Road Width					
			Narrow	Somewhat Wide	Width			
Interpretation Result (Maker/Producer)	Road Width	Narrow	13	1	0	14	0	100
		SomewhatWide	0	31	0	31	13,9	86,1
		Width	0	4	1	5	0	100
Total			13	36	1	50	***Overall* Accuracy**	
Omissions (%)			7,1	0	80		**90%**	
Accuracy of Users (%)			92,8	100	20			

Source: Research Results 2025

4.13 *Accuracy Test Results of Building Types Map*

Validating the accuracy of building type maps is crucial because building materials play a direct role in vulnerability and potential fire spread during a fire. Our analysis revealed varying levels of accuracy among building type classes, demonstrating the strength of the model in some areas and the need for improvement in others. The overall accuracy for the settlement type parameter reached 80%. This figure meets the minimum threshold set in this study, indicating that the classification has acceptable reliability and the map results can be used. However, in this study, researchers continued to make improvements to the tentative map based on field results, especially for classes with high omission or commission errors.

Geografi Vol.13 (2), 88-114
ISSN 2289-4470 /eISSN 2462-2400

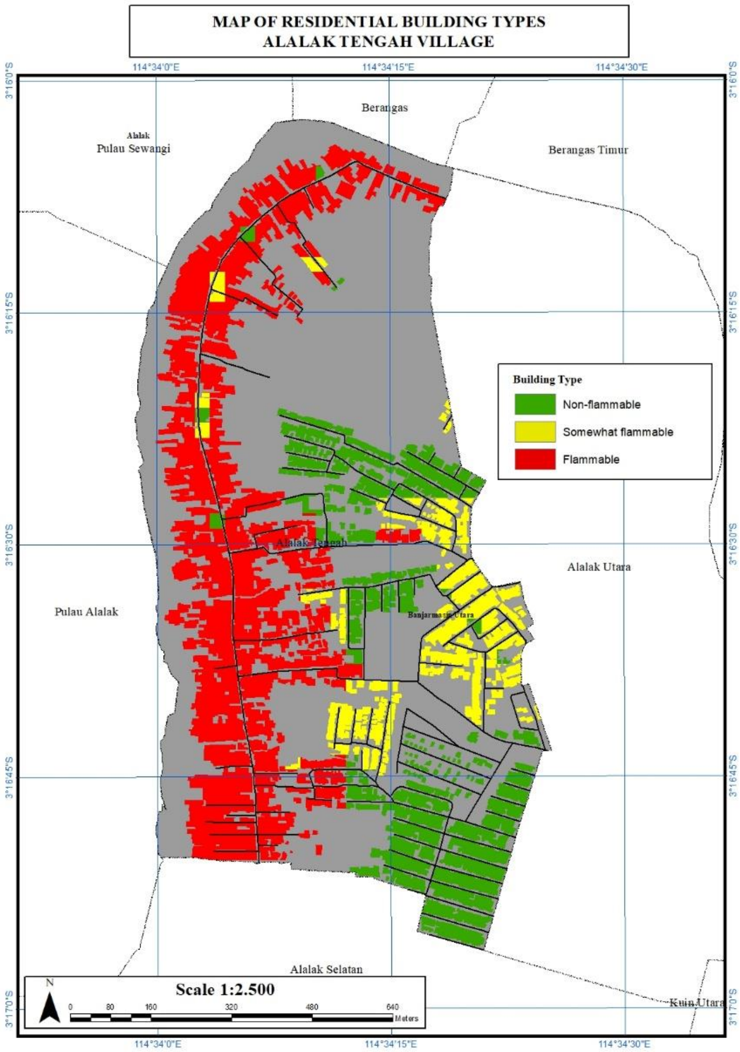

Figure 4. *Map Of Residential Building Types*
Source: Research Results 2025

The most unexpected and significant pattern is the very low accuracy of manufacturers (55.5%) in the moderately flammable class, as well as the relatively low accuracy of users in the non-flammable class (65.2%). This disparity indicates that there is considerable confusion in the classification model in distinguishing between “moderately flammable” materials and other classes. This could be due to the presence of buildings with mixed materials (e.g., partly wood, partly stone walls), or variations in material quality or age that were not captured by the initial data. For the non-combustible class, lower user accuracy means that some buildings classified as non-combustible may actually have undetected combustible components (Figure 4). This anomaly highlights the need for additional parameters or more advanced classification methods, such as deep learning from very high-resolution images, to accurately distinguish the nuances of building materials.

Geografi Vol.13 (2), 88-114
ISSN 2289-4470 /eISSN 2462-2400

Accurate mapping of building types has crucial implications for fire risk management in Southeast Asian cities, particularly in dense and informal settlements. In many of these areas, the use of combustible materials such as wood or semi-permanent materials is very common, increasing the risk of rapid fire spread. These findings underscore the importance of targeted mitigation programs, improved building codes and enforcement, fire response planning, and further research on composite materials. The overall accuracy for the settlement type parameter reached 80%, which is the minimum threshold value that indicates the classification has acceptable reliability in this study. With this accuracy, the map or classification results can be used, but in this study, the researcher improved the tentative map according to the field results, especially in classes with high omission or commission errors

Table 10.
Accuracy Test of Residential Building Type Map

	Class		Field Survey Results (Producer)			Total	Commission (%)	Producer Accuracy (%)
			Types of residential buildings					
			Flammable	Somewhat Flammable	Non-flammable			
Interpretation Result (Maker/Producer)	Types of residential buildings	Flammable	20	0	0	20	23	76,9
		Somewhat Flammable	2	5	0	7	44,4	55,5
		Non-flammable	4	4	15	23	0	100
Total			26	9	15	50	***Overall* Accuracy**	
Omissions (%)			0	28,6	34,7		**80%**	
Accuracy of Users (%)			100	71,4	65,2			

Source: Research Results 2025

4.14 *Accuracy Test Results of Settement Building Layout Pattern Map*

Validating the accuracy of residential building layout maps is an important aspect of assessing physical vulnerability to fire, as these patterns directly affect accessibility, air circulation, and the potential for fire spread. Our analysis revealed varying levels of accuracy among layout pattern classes, demonstrating the strength of the model in some areas but also highlighting the need for refinement in others. The overall accuracy for residential building layout pattern parameters reached 84%. This figure indicates that the classification results have a sufficiently high level of accuracy and the maps can be considered suitable for further analysis or decision-making, given that the overall accuracy value has exceeded the minimum threshold of ≥80% used in this study.

The overall accuracy of 84% for residential building layout pattern maps indicates an acceptable level of reliability and is consistent with the challenges often encountered in detailed urban mapping, especially in areas with varied settlement patterns (Figure 5).

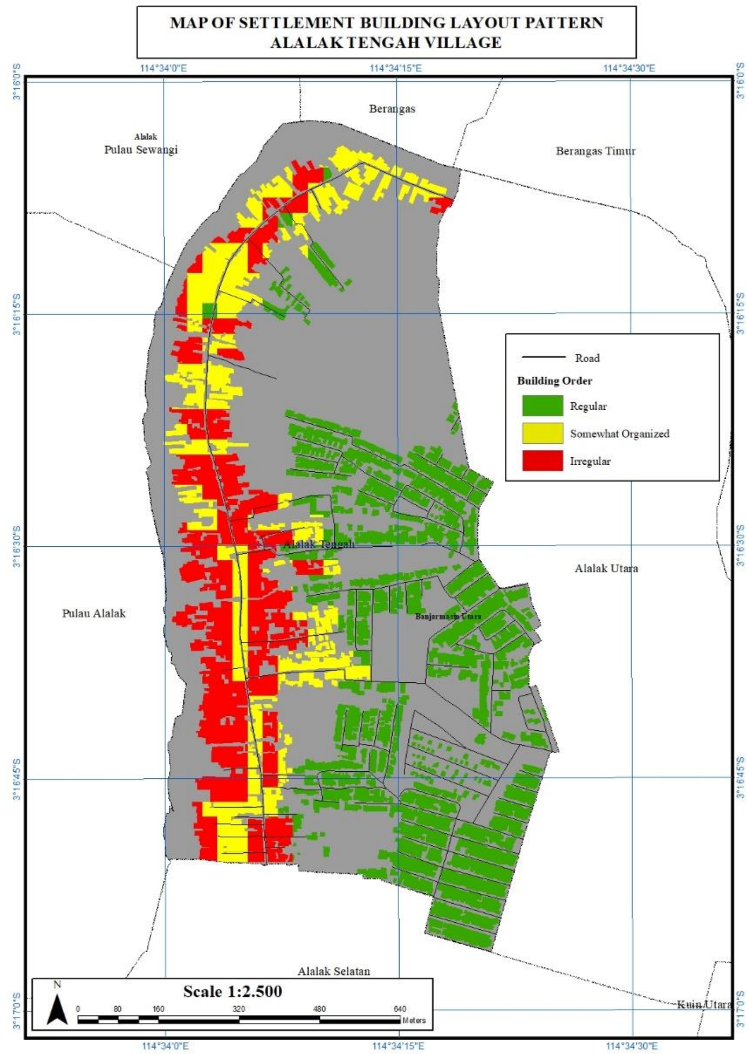

Figure 5. *Map Of Settlement Building Layout Pattern*
Source: Research Results 2025

The 100% accuracy in the regular class is in line with many studies that have successfully identified grid patterns or planned structures with high precision using satellite imagery or spatial data. However, the decrease in accuracy in the somewhat regular and irregular classes (both producer and user accuracy) reflects the complexity of categorizing less structured settlement patterns. This challenge is often encountered in research on informal or developing settlements, where the boundaries between "somewhat regular" and "irregular" can be highly ambiguous and require deeper interpretation, even with field verification. This contrasts with more easily quantifiable parameters such as road width or even extreme density.

Geografi Vol.13 (2), 88-114
ISSN 2289-4470 /eISSN 2462-2400

The most unexpected and interesting pattern is the contrast between producer and user accuracy in the irregular class. Although the producer's accuracy for this class is only 64.3%, the user's accuracy reaches 100%. This means that while the model struggles to identify all areas that are actually irregular (omission errors), every time the model classifies an area as "irregular," that classification is always correct from the user's perspective (no commission errors for this class). This may indicate that highly irregular patterns have very distinctive visual characteristics that are easily recognized by the model once identified, but the model may miss some other irregular areas that are less extreme or mixed with somewhat regular patterns. Conversely, the lower user accuracy for the somewhat regular class (60%) indicates that this is the most "confusing" class, both for the model and for the user, due to its characteristics being a transition between regular and irregular patterns. Accurate mapping of residential building layout patterns has significant implications for fire risk management in Southeast Asian cities, given the large number of densely populated and informal settlements with irregular patterns that complicate access and firefighting. The findings of this study underscore the importance of optimizing emergency response, risk mitigation planning, community awareness, and algorithm classification development.

Table 11.
Accuracy Test of Residential Building Layout Pattern Map

			Field Survey Results (Producer)			Total	Commission (%)	Producer Accuracy (%)
	Class		Residential Building Layout Pattern					
			Regular	Somewhat Organized	Irregular			
Interpretation Result (Maker/Producer)	Residential Building Layout	Regular	27	3	1	31	0	100
		Somewhat Organized	0	6	4	10	33,3	66,7
		Irregular	0	0	9	9	35,7	64,3
Total			27	9	14	50		
							Overall **Accuracy**	
Omissions (%)			12,9	40	0		**84%**	
Accuracy of Users (%)			87,1	60	100			

Source: Research Results 2025

Geografi Vol.13 (2), 88-114
ISSN 2289-4470 /eISSN 2462-2400

4.15 *Accuracy Test Results of Distance Fire Fighter Map*

The results of field checks according to the fire brigade collation in Alalak Tengah urban village, many fire brigades are absent and inactive. There are six fire departments in Alalak Tengah urban village, according to the Banjarmasin City Fire Service and Google *Maps*, but only one is still active. The results of the field check are presented in the following table:

Table 12.
Results of Field Checks of Fire Fighting Locations

No.	Fire Department Name	Longitude	Latitude	Description
1	PMK KOMPLEK WARGA INDAH IV	114.5701	-3.2733	None
2	TAMARA CPC	114.5683	-3.2779	Inactive
3	BPK/PMK HR RESCUE (HABAR REGIONAL)	114.5679	-3.2746	None
4	GASPAN CPC	114.5694	-3.2751	On
5	BPK BINTANG TIMUR	114.5674	-3.2725	Inactive
6	BPK NOOR AINI	114.5681	-3.2754	Inactive

Source: Research Results 2025

The results of the field check showed that most of the fire fighting units were inactive or not operating. Some units, such as PMK Komplek Warga Indah IV and BPK/PMK HR Rescue (Habar Regional), were not found in their registered locations, while BPK Tamara, BPK Bintang Timur, and BPK Noor Aini were recorded as inactive. Only BPK Gaspan was detected to be active and ready to operate. Research emphasizes the need for strategically locating fire stations in densely populated areas to enhance response times and coverage (KC et al., 2024). For instance, a study in Kuwait demonstrated that reallocating fire stations improved coverage and reduced response times significantly (Al-Omar, 2023). The results of the map analysis show that all areas in Alalak Tengah Village are within a radius of less than 1,500 meters from the fire station. This condition is a positive potential in fire mitigation efforts, as the close distance allows for a quick response by the fire-fighting team. In the context of residential fires, this distance is ideal because fire vehicles can reach the scene with a relatively short travel time, thus increasing the chances of minimizing the impact of losses (Figure 7).

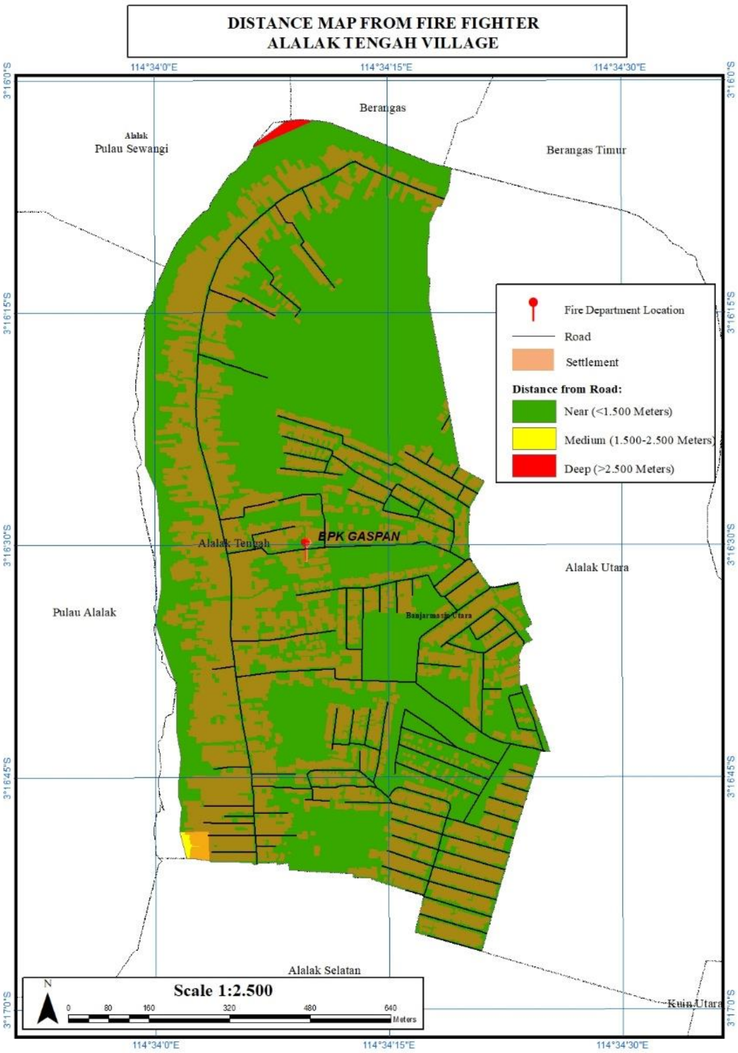

Figure 7. *Distance Map From Fire Fighter*
Source: Research Results 2025

4.16 *Accuracy Test Results of Distance From Water Resources Map*

The results of field checks of existing water sources in Kelurahan Alalak Tengah show that there are three additional small rivers in addition to the Barito River. Mapping the distance from water sources in Kelurahan Alalak Tengah shows that the area is dominated by areas less than 100 meters from water sources. This zone includes most residential areas, which are generally located around rivers. The close availability of water sources is a positive factor in fire management, as quick access to water can help minimize the risk of fire spreading. While a distance of <100 meters provides an advantage, environmental challenges such as tides can affect the effectiveness of such water sources.

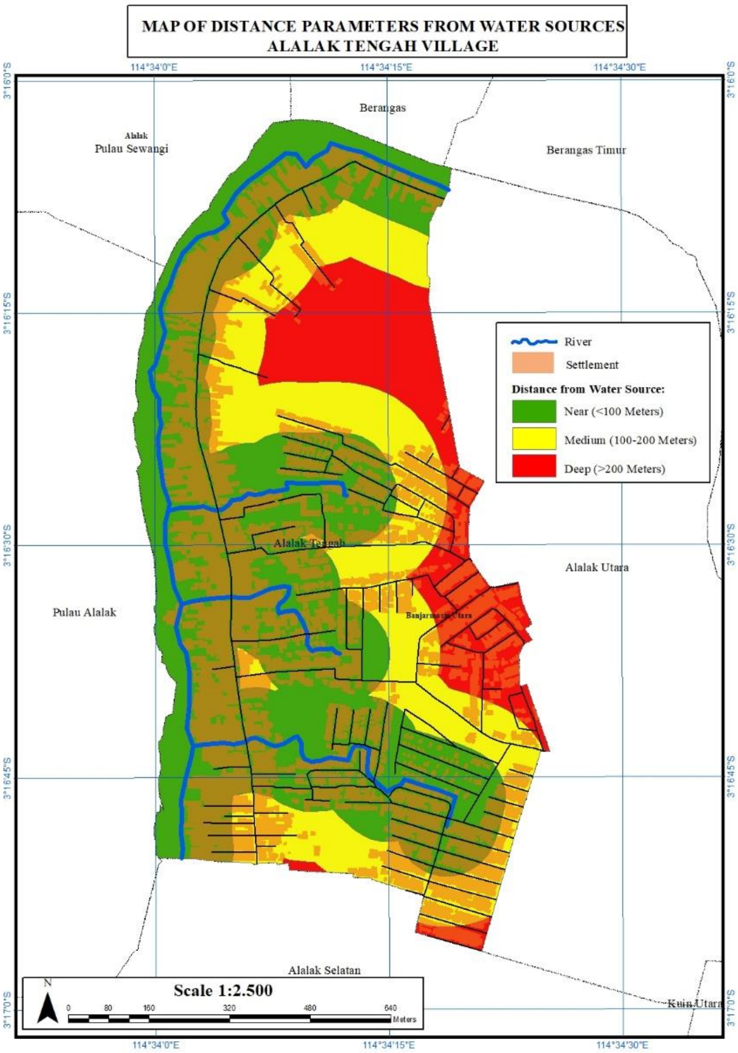

Figure 8. *Map Distance Parameter From Water Resources*
Source: Research Results 2025

4.17 *Accuracy Test Results of Distance Parameters From The Road*

The map analysis shows that the Alalak Tengah area is dominated by areas less than 50 meters from the main road. This condition reflects that most settlements have good accessibility to transportation routes. The close proximity to main roads provides a strategic advantage, especially in emergency situations such as fires, as it facilitates the mobility of firefighting vehicles to reach the scene. While this accessibility is advantageous, the presence of narrow and congested roads around residential areas can pose a challenge for fire response. Proximity to main roads is crucial for effective emergency response, as seen in the study of East Jakarta, where road network conditions significantly impact fire station service areas. The study emphasizes the need for strategic placement of fire stations and improved road infrastructure to enhance response times (Semedi et al., 2024).

Geografi Vol.13 (2), 88-114
ISSN 2289-4470 /eISSN 2462-2400

Zones within 50-100 meters from the main road include residential areas where accessibility is still quite good but relatively more challenging than zones <50 meters. Residents in this zone may take longer to access the main road, especially if there are no adequate connecting roads. In the context of fire mitigation, this location has a higher level of vulnerability as firefighting vehicles may face obstacles to reach the fire quickly.

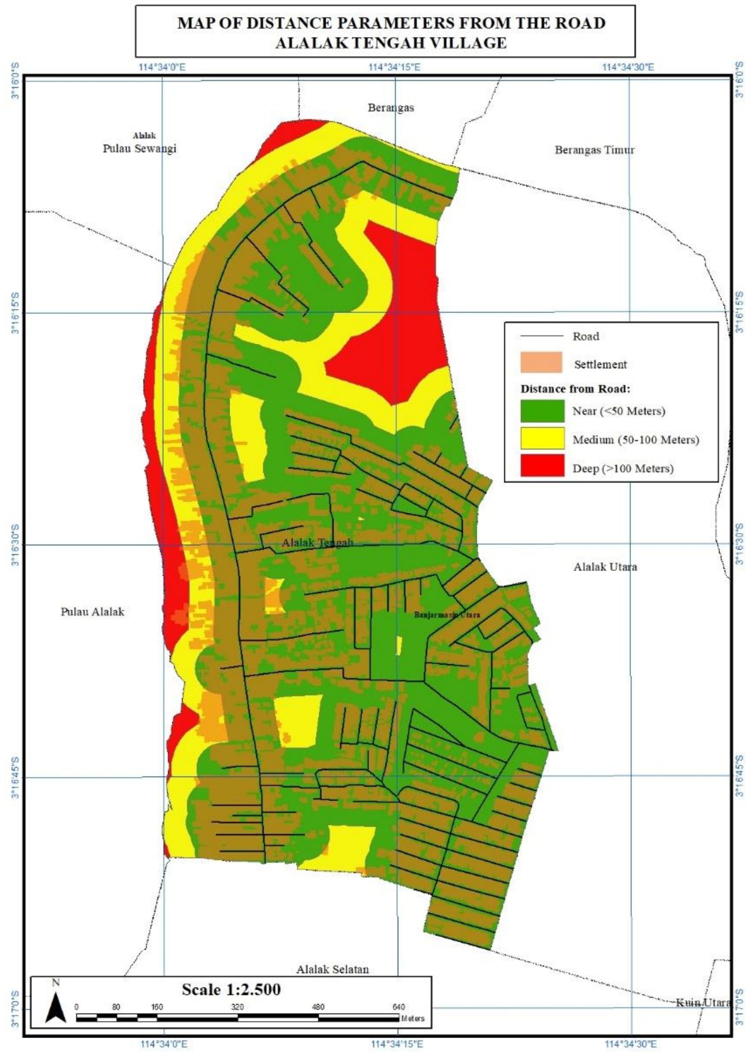

Figure 9. *Map Of Distance Parameters From The Road*
Source: Research Results 2025

Geografi Vol.13 (2), 88-114
ISSN 2289-4470 /eISSN 2462-2400

6.2 Settlement Fire Vulnerability Map Results

After calculating the value of each parameter, a total value of all parameters can be generated for classification in the level of fire and settlement vulnerability. After assigning a value to each parameter, the 7 parameters are overlaid. The overlay results in a total score or total value so that it can be classified into fire vulnerability classes using the formula and table below:

$$I = \frac{R}{K}$$
$$I = \frac{Max\,Value - Min\,Value}{3}$$
$$I = \frac{17 - 8}{3}$$
$$I = \frac{9}{3}$$
$$I = 3$$

This interval value becomes the range value for the division of 3 classes which will be classified in the following table:

Table 13.
Fire Vulnerability Class Results

No.	Value	Class
1	8-10	Low Vulnerability Level
2	11-13	Medium Vulnerability Level
3	14-17	High Vulnerability Level

Source: Research Results 2025

The results of data processing and analysis of the vulnerability level of residential fires show that the vulnerability level mapping can be classified into three categories, namely low, medium, and high vulnerability levels based on the range of values obtained from the marking of seven main parameters. These parameters include the density of residential buildings, type of residential buildings, settlement layout pattern, distance from water source, distance from fire location, distance from main road, and width of driveway. From the process of marking and overlaying, the resulting total value has a range of 8 to 17, which is then grouped into three classes using an interval of 3. Areas with values of 8-10 are categorized as low vulnerability, 11-13 as medium vulnerability, and 14-17 as high vulnerability.

Geografi Vol.13 (2), 88-114
ISSN 2289-4470 /eISSN 2462-2400

The map of the results of the physical vulnerability of residential fires in Alalak Tengah urban village is presented in the following figure 10:

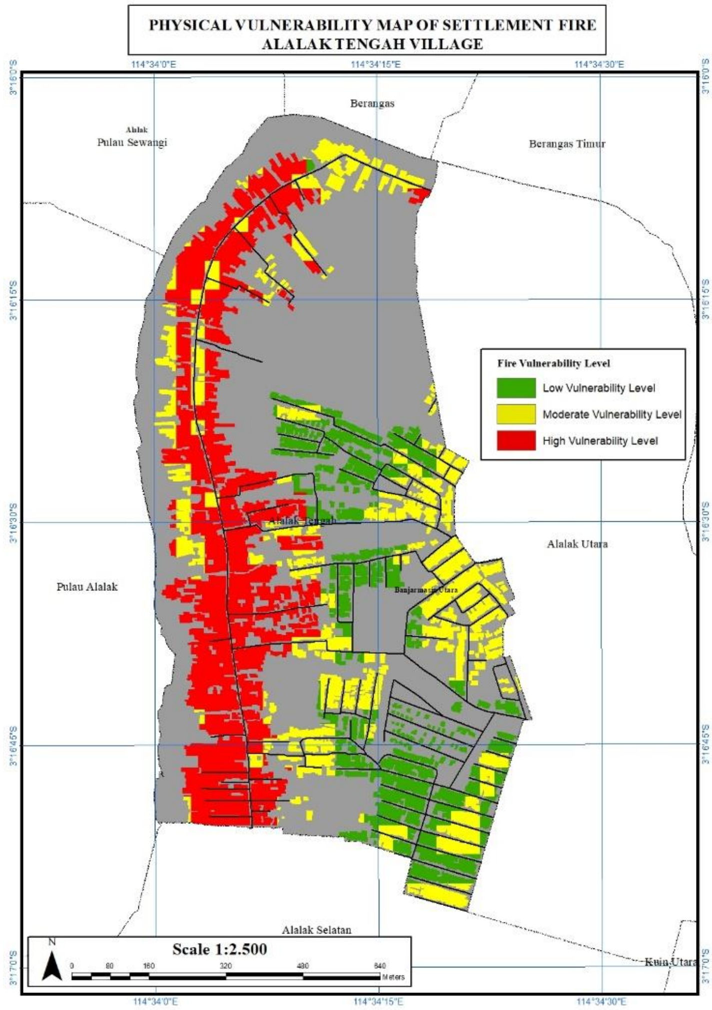

Figure 10. *Results of Physical Vulnerability Map of Settlement Fire in Alalak Tengah Village*
Source: Research Results 2025

Geografi Vol.13 (2), 88-114
ISSN 2289-4470 /eISSN 2462-2400

The process of marking and overlaying, the resulting total value has a range of 8 to 17, which is then grouped into three classes using an interval of 3. Areas with values of 8-10 are categorized as low vulnerability, 11-13 as medium vulnerability, and 14-17 as high vulnerability. These results suggest that Alalak Tengah has 3 levels of vulnerability totaling 36.3 Ha.The classification of physical fire vulnerability in Alalak Tengah shows that the area is divided into three levels of vulnerability: low, medium and high. Low vulnerability covers 8.2 Ha, most of which is located in areas with good accessibility, close proximity to main roads, non-combustible, less dense settlement types, and more regular settlement layout patterns. These areas have settlement characteristics that are more resistant to fire, such as non-combustible building materials. Areas with good accessibility and proximity to main roads are less vulnerable to fires. This is because emergency services can reach these areas quickly, reducing the risk of fire spreading (Gharaibeh, 2025). The moderate vulnerability level covers 11.7 ha, making it the second largest level in the study area. These areas typically have a combination of enabling and constraining factors for fire mitigation. These areas have access to water sources or main roads, but with limitations such as narrow roads. Other parameters such as irregular settlement layout patterns and the presence of flammable building materials can increase the risk of fire. The high amount of area in this category indicates that most areas require special attention to improve fire mitigation and response capacity. High vulnerability areas cover 16.4 Ha and tend to be located in areas with limited accessibility, long distances from main roads, and dense, flammable and irregular settlement layout patterns. These factors increase the risk of fire due to difficulties in controlling the spread of fire and slow response. In addition, the predominantly combustible building materials further exacerbate the level of vulnerability in this zone. Priority treatment needs to be given to these areas through infrastructure improvements such as the construction of hydrants or water tanks, road widening, and supervision of the use of building materials. The use of non-combustible building materials significantly reduces the risk of fire spreading. This is a key factor in low vulnerability areas, as such materials are more resistant to ignition and can withstand higher temperatures (Douglas, 2007).

7. Conclusion

The classification of physical fire vulnerability levels shows that the Alalak Tengah urban village is divided into three categories: low, medium and high. Low vulnerability covers 8.2 Ha, located in areas with good accessibility and regular settlement patterns. Medium vulnerability with 11.7 Ha is characterized by mixed conditions between supporting and inhibiting factors for fire mitigation. High vulnerability dominates with 16.4 Ha located in areas with limited access, dense settlement patterns, and flammable building materials.

Geografi Vol.13 (2), 88-114
ISSN 2289-4470 /eISSN 2462-2400

The accuracy test conducted provides confidence in the reliability of the spatial analysis results, so that the resulting vulnerability map can be used as a reference for fire risk mitigation planning. However, accuracy improvement through field data validation and periodic thematic data updates are necessary to ensure compliance with actual conditions. The conclusion of this study shows that Alalak Tengah has a variety of vulnerability levels from high vulnerability which dominates, then moderate vulnerability level, and low vulnerability which is the least compared to the previous 2 levels. To reduce the risk of fire, strategic measures are needed such as improving road infrastructure, providing water sources, and educating the community on fire prevention and management. Collaboration between the government, communities, and related parties is key to creating a safer and more resilient residential environment to fire risk.

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Conceptualisation, methodology, analysis, and writing original : Agus, Deasy & Muhaimin**:**
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Data Availability Statement: The authors confirm that the data supporting the findings of this study are available within the article

7. REFERENCES

Adyatma, S., Rahman, A. M., Saputri, S. G., Sari, N., & Riyanto, A. (2024). Pemahaman Potensi Kebakaran Permukiman Siswa SMAN 8 Kota Banjarmasin Melalui Pengembangan Buku Saku Kebakaran Permukiman. *SELAPARANG: Jurnal Pengabdian Masyarakat Berkemajuan*, *8*(1), 76–83. https://journal.ummat.ac.id/index.php/jpmb/article/view/20945

Afifah, A. A. N., Okyani, R., & Hasti, W. (2022). Mitigasi Kebakaran di Kawasan Permukiman Perkotaan. *Jurnal Manajemen Bencana (JMB)*, *8*(2), 143–152. https://doi.org/10.33172/jmb.v8i2.1121

Al-Omar, H. O. A. (2023). Firefighting Stations Allocation Model for the State of Kuwait. *International Journal of Operations Research and Information Systems*, *14*(1), 1–20. https://doi.org/10.4018/IJORIS.334126

Amin, N. F., Garancang, S., & Abunawas, K. (2023). Konsep umum populasi dan sampel dalam penelitian. *Pilar*, *14*(1), 15–31.

Asiri, L. (2020). Pelaksanaan Mitigasi Bencana Kebakaran Pada Dinas Pemadam Kebakaran Kabupaten Buton. *Kybernan: Jurnal Studi Kepemerintahan*, *3*(2), 28–40. https://doi.org/10.35326/kybernan.v3i2.843

At Taufan, S., Marleno, R., & Oetomo, W. (2025). Road Condition Analysis Using the Bina Marga Method on the Kaligunting-Bajulan Section, Madiun District. *Asian Journal of Engineering, Social and Health*, *4*(1), 83–92. https://doi.org/10.46799/ajesh.v4i1.506

BPS. (2023). *Provisi Kalimantan Selatan Dalam Angka 2023*.

Brezzi, M., Piacentini, M., Rosina, K., & Sanchez-Serra, D. (2012). Redefining urban areas in OECD countries. In *Redefining "Urban": A New Way to Measure Metropolitan Areas* (Vol. 9789264174). https://doi.org/10.1787/9789264174108-4-

Douglas, J. (2007). Physical vulnerability modelling in natural hazard risk assessment. *Natural Hazards and Earth System Sciences*, *7*(2), 283–288. https://doi.org/10.5194/nhess-7-283-2007

Fitria, L. M., Ni'mah, N. M., & Danu, L. K. (2019). Kerentanan Fisik Terhadap Bencana Banjir di Kawasan Perkotaan Yogyakarta. *Reka Ruang*, *2*(1), 1–9. https://doi.org/10.33579/rkr.v2i1.1048

Foody, G. M. (2024). Ground Truth in Classification Accuracy Assessment: Myth and Reality. *Geomatics*, *4*(1), 81–90. https://doi.org/10.3390/geomatics4010005

Forsythe, K. W. (2006). Field Methods in Remote Sensing edited by Roger M. McCoy. In *Canadian Geographer / Le Géographe canadien* (Vol. 50, Issue 4). http://doi.wiley.com/10.1111/j.1541-0064.2006.00161_2x

Gharaibeh, S. (2025). *Assessment of Urban Fire Risk Coverage and Accessibility through a Network and Spatial GIS Analysis of the Distribution of Fire Stations Case Study (Irbid City – Jordan)*. https://doi.org/10.21203/rs.3.rs-5820828/v1

Hafiz, M., & Candra, O. (2021). Perancangan Sistem Pendeteksi Kebakaran Berbasis Mikrokontroller dan Aplikasi Map dengan Menggunakan IoT. *JTEV (Jurnal Teknik Elektro Dan Vokasional)*, *7*(1), 53. https://doi.org/10.24036/jtev.v7i1.111420

Kartika, K., Yaslina, Y., & Diana, D. (2023). Pengaruh Pendidikan Kesehatan Terhadap Kesiapsiagaan Siswa/Siswi Dalam Menghadapi Bencana Gempa Bumi Di Sman Lubuk Basung. *Jurnal Kesehatan Tambusai*, *4*, 2509–2517. http://journal.universitaspahlawan.ac.id/index.php/jkt/article/view/15078%0A

KC, K., Ardianto, R., & Wang, S. (2024). Examining fire service coverage and potential sites for fire station locations in Kathmandu, Nepal. *Urban Informatics*, *3*(1), 20. https://doi.org/10.1007/s44212-024-00050-y

Kevin, V. (2023). *Perbandingan Hasil Tutupan Lahan Dengan Metode Klasifikasi Terbimbing Dan Obia Pada Area Jalan Tol Kecamatan Terbanggi Kabupaten Lampung Tengah*.

Kusuma, H. M., Sukmono, A., & Amarrohman, F. J. (2023). Analisis Perkembangan Kerapatan Hutan Mangrove di Kota Semarang dengan Metode Normalized Difference Vegetation Index Tahun 2017-2022. *Jurnal Geodesi Undip*, *12*(4), 388–395.

Muzani. (2020). *Bancana Kebakaran Pemukiman*. CV BUDI UTAMA.

Pemerintah Kota Banjarmasin. (2022). Keputusan Walikota Banjarmasin No 215 Tahun 2022 tentang Penetapan Lokasi Perumahan Kumuh dan Permukiman Kumuh di Kota Banjarmasin. In *Walikota Banjarmasin*.

Pratiwi, L. P. S., Hanief, S., & Suniantara, I. K. P. (2018). Pemodelan Menggunakan Metode Spasial Durbin Model untuk Data Angka Putus Sekolah Usia Pendidikan Dasar. *Jurnal VARIAN*, *2*(1), 8–18. https://doi.org/10.30812/varian.v2i1.314

Putri, E. A. W., Danoedoro, P., & Farda, N. M. (2024). Studi Komparasi Teknik Klasifikasi berbasis Objek terhadap Citra Resolusi Spasial Menengah dan Tinggi untuk Pemetaan Tutupan Lahan di Sebagian Kabupaten Kulonprogo. *Majalah Geografi Indonesia*, *38*(1). https://doi.org/10.22146/mgi.81374

Rahmaddani, A., & Sari, D. N. (2024). *Pemetaan Kerawanan Urban Fire di Kecamatan Kartasura Kabupaten Sukoharjo*. Universitas Muhammadiyah Surakarta.

Ramdhan, M. (2021). *Metode Kuantitatif*. Cipta Media Nusantara.

Rosyidiin, A. F., Lestari, F. P., Septia, W., & Tama, M. I. (2023). Perancangan Proteksi Kebakaran Sistem Hydrant Menurut Standar NFPA 14 Dan 20 Pada Gedung Cak Durasim UPT. Taman Budaya Jawa Timur. *INTECOMS: Journal of Information Technology and Computer Science*, *6*(2), 991–997. https://doi.org/10.31539/intecoms.v6i2.7026

Salampessy, J. S., Aryuni, V. T., & Safitri, Y. A. (2023). Pemetaan Tingkat Kerawanan Kebakaran Permukiman Dengan Pemanfaatan Sistem Informasi Geografis di Kecamatan Ternate Tengah. *Pangea : Wahana Informasi Pengembangan Profesi Dan Ilmu Geografi*, *4*(2), 337–346. https://doi.org/10.33387/pangea.v4i2.6612

Semedi, J. M., Pradana, M. R., Putera, D. A., & Rahatiningtyas, N. S. (2024). The Impedance of East Jakarta Road Network to Estimate Fire Station Service Areas. *Forum Geografi*, *38*(2), 280–290. https://doi.org/10.23917/forgeo.v38i2.4408

Sihombing, L. A., & Utami, C. F. (2023). Hirarki dan Distribusi Kota: Penyebaran, dan Kepadatan Penduduk serta Implikasinya terhadap Infrastruktur. *Equivalent: Jurnal Ilmiah Sosial Teknik*, *5*(2), 218–229. https://doi.org/10.59261/jequi.v5i2.159

Suvek, S. (2021). *Study Of Critical Fire Safety Parameters And Development Of An Evacuation Strategy For High Rise BUILDINGS (Doctoral dissertation, College of Engineering, UPES, Dehradun).*

Widodo, R. B. (2014). Pemodelan Spasial Resiko Kebakaran Hutan (Studi Kasus Provinsi Jambi, Sumatera). *Jurnal Pembangunan Wilayah & Kota*, *10*(2), 127. https://doi.org/10.14710/pwk.v10i2.7643

Wulansari Harvini. (2017). Uji Akurasi Klasifikasi Penggunaan Lahan Dengan Menggunakan Metode Defuzzifikasi Maximum Likelihood. *Bhumi*, *3*(1), 1–13.