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Identification of Fire Disaster Vulnerability in Karang Rejo Sub-District, Balikpapan Central District

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Keywords

Vulnerability ; fire ; Mitigation ; Disaster ; Balikpapan

Abstract

At least 617 cases of fire disasters were recorded in Balikpapan City from 2010 to 2020. In response, fire disaster mitigation is still a problem, especially in dense residential areas and unclean environments. One of the sub-districts with the characteristics of dense settlements and a history of fire incidents is Karang Rejo Village. This condition can be an obstacle in disaster mitigation. Therefore, it is necessary to identify appropriate mitigation efforts for this sub-district. Vulnerability assessment can be an essential first step to reducing the impact and losses of a fire disaster. The purpose of this study is to formulate fire disaster mitigation based on the level of vulnerability in Karang Rejo Village, Central Balikpapan District, using the spatial multi-criteria analysis method. The research results obtained are structural fire disaster mitigation at low, medium, and high vulnerability by mitigating aspects of building density, percentage of built-up areas, building materials, the width of access roads, availability of water reservoirs, availability of vacant land, the portion of households working in the informal sector, and the ratio of poor people.

1. INTRODUCTION

Settlement problems have become one of the problems always faced in big cities in Indonesia. As time goes by, the population will continue to increase, balanced by the growing need for housing. Burgess and Hoyt (in Yunus, 2000) stated that if there is an increase in population, there will indirectly be an increase in space requirements. An increase in population will impact the development and development of activities in a region (Arini, 2009). The growing population can increase an area's vulnerability to fire disasters (Priyono et al., 2006). Suprapto (2013) also gave the opinion that fire disasters can occur due to one of the factors, namely population density.

Fire is one of the natural disasters that frequently occur in urban areas in Indonesia. This incident is often caused by environmental factors, population density, and human factors such as negligence in using electrical equipment and fuel. The impact of fires is significant, both in terms of human casualties, material losses, and infrastructure damage (Supriadi & Oswari, 2020). Therefore, fire risk mitigation is necessary to prevent or minimize the impact of fires (Salazar, Romao, Pauperio, 2021). Fires often occur in urban areas and often cause material losses and human casualties. Fires can occur due to various factors, including natural factors such as dry weather and human factors such as errors in using electrical equipment or uncontrolled waste burning (Lu, et al, 2020). The development of urban areas also increases vulnerability to fires, especially in areas with high population density and semi-permanent buildings (Rush et al, 2020). Therefore, assessing the vulnerability to fire disasters in urban areas is essential to help plan and implement effective and efficient mitigation measures.

Several studies have been conducted to identify the factors that influence the vulnerability to fire disasters in urban areas. For example, a study by Granda and Ferreira (2019) showed that population density and building materials can affect the speed of fire spread. In addition, a study by Salazar, Romao, and Pauperio (2021) showed that socioeconomic characteristics such as income and education level can affect the vulnerability to fire.

Research on the assessment of vulnerability to fire disasters in urban areas is crucial to help the government, communities, and relevant institutions in planning and implementing effective and efficient mitigation measures to reduce vulnerability to fire disasters (Manzello et al, 2022; Forsyth et al, 2019). By conducting vulnerability assessments, areas with high vulnerability levels can be identified, enabling more specific and targeted mitigation actions (Faria et al, 2021; Log et al, 2020; Zani, et al, 2022). Vulnerability assessments can also help increase community preparedness in facing fire disasters, thus reducing the risk of greater human casualties and material losses.

The problem of fire prevention is still a problem experienced in various big cities, including Balikpapan City, where fires often occur in settlements, especially those that are not organised (Sardiyo, 2010). According to the Balikpapan City Disaster Management Agency (2021), there have been at least 617 cases of fire disasters in Balikpapan City from 2010-2020.

Based on the Balikpapan City Regional Disaster Management Agency (2021), Central Balikpapan District is one of the sub-districts where fires have also occurred; 19 fires have been recorded in Central Balikpapan District. Based on data from the Central Bureau of Statistics for the City of Balikpapan, Central Balikpapan District, in 2019 figures, Karang Rejo Village is the highest density level in Central Balikpapan District at 20,125 (people/km2). It is recorded that according to data from the Regional Disaster Management Agency (BPBD) of Balikpapan City, from 2019-2021, fire disasters occurred at least once every year in Karang Rejo Village.

Fire disasters will negatively impact material losses, physical conditions, casualties, social order, and others. Especially in densely populated areas, Xinjian Li & Runqi Qin. (2022) said that mitigating the risk of a fire disaster is how to control the spread of fire. Dense residential areas, especially in semi-permanent buildings, will increase the speed of fire spread. Proper fire mitigation in a high-density residential block can minimise the fire risk (Widyamadja, W & Purwanto, TH, 2014). The vulnerability level can be controlled to reduce the risk of a fire disaster (Januandari et al., 2017). Density can be a high factor that becomes a fire vulnerability because the fire will quickly spread to every house close together (Findia, 2019). Vulnerability assessment can be vital to minimising the impact and losses of fire disasters (Welle et al., 2014). Suppose the vulnerability to fire disasters continues to increase. In that case, it is feared that it will increase in more significant losses that damage the environment, physical buildings and public infrastructure and disrupt community economic and social activities (Latifah, RN, & Pamungkas, A., 2013). Turning Ayu Rachmawati (2018) argues that research on the vulnerability of fire disasters is a process to find out the impact caused by disasters to reduce disaster risk spatially. Wibowo (2015) says that a Geographic Information System (GIS) can be proper; for example, it functions to see the potential (vulnerability) index of an area, the size of the administrative area, and the distribution of population or settlements. Therefore, fire disaster mitigation efforts are needed based on the level of disaster vulnerability in Karang Rejo Village. Vulnerability assessment can be an essential first step to reducing the impact and losses of a fire disaster.

2. METHOD

2.1 Research sites

The research location is Karang Rejo Village, Central Balikpapan District. Karang Rejo Village has an area of 121.91 Ha and 87 RTs. Muara Rapak Village and Gunung Samarinda Village in the north border this village. To the south, it is bordered by Mekar Sari Village. Furthermore, the Village of Sumber Rejo and the Village of Karang Jati are each on the east and west.

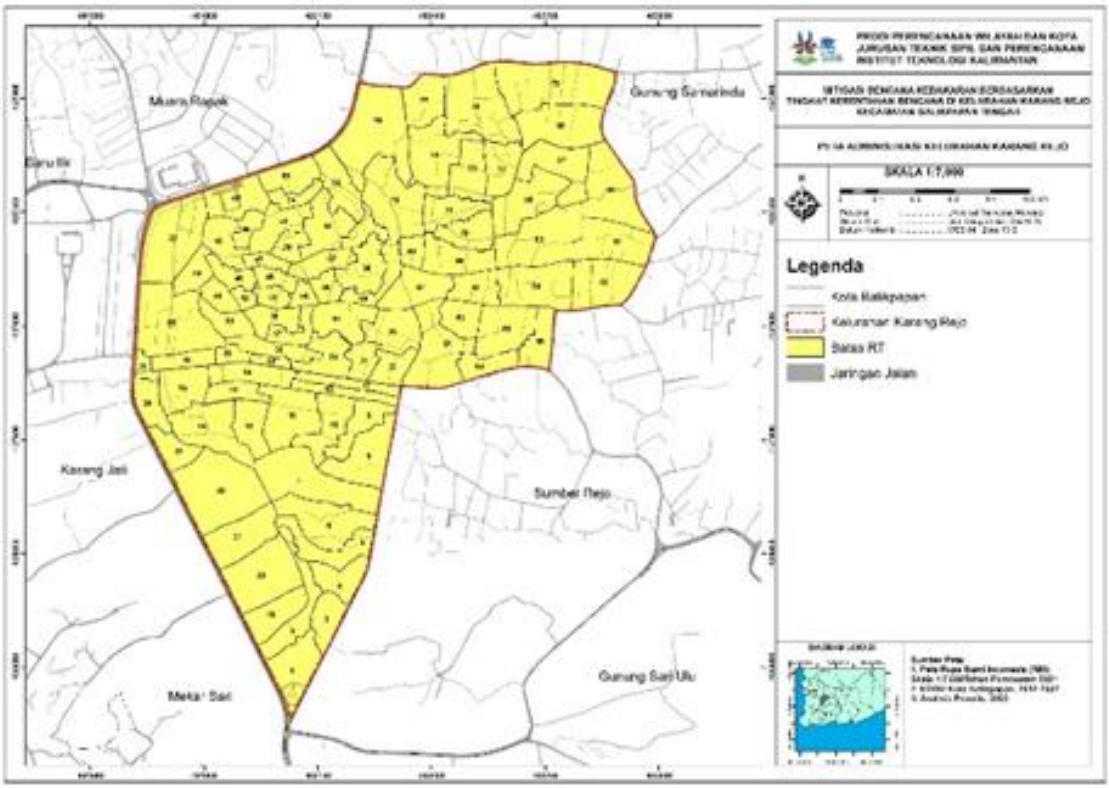


Figure 1. Research Sites

2.2 Research Variables

Variable means the value or behaviour of people, activities or objects with exclusive variations and units determined by the researcher to be studied and then a conclusion is obtained (Sugiyono, 2017). The following are the variables used in this study.

Table 1. Research Variables

Indicator	Variable
Social	Population density
Physique	Building Materials
	Percentage of Built-up Area
	Building Density
	Availability of Water Storage
	Entrance Width
Environment	Vacant Land Availability
Economy	Households Working in the Informal Sector
	Poor Population Ratio

Source: Luke with modifications, 2021

2.3 Data Retrieval Method

Collecting data in this study includes observation, interviews, questionnaires, and a literature study. The data requirements were obtained by observing the percentage of built-up areas, building materials, the width of access roads, building density, availability of water reservoirs, availability of vacant land, land use, and hydrants in Karang Rejo Village. Interviews are used for data needs by interviewing relevant agencies who better understand fire-prone areas. The agency survey aims to obtain population density data, the percentage of households working in the informal sector, and the percentage of low-income families in Karang Rejo Village.

2.4 Data Analysis Techniques

In this study, the analysis technique used was spatial multi-criteria analysis which included weighting or scoring and weighted overlay analysis.

2.4.1 Scoring Analysis

Weighting analysis or scoring is a measurement in determining the score for each variable of fire hazard vulnerability. The weighting method is used to determine the value of the level of fire disaster vulnerability according to (Widiantoro, 2016). Weighting variables are based on the relevant standard and are used to identify the actual condition. This analysis uses ArcGIS 10.5 software. The fire disaster vulnerability variable consists of 4 social, physical, environmental, and economic indicators. In determining the weighting, the next is the fire vulnerability category after the scoring is done. Vulnerability categories have a limit value or number determined based on an equal interval. Low vulnerability category if it has a total result of 9 – 15. Medium vulnerability category if it has a final result of 16 – 21, and the high class if it has a score between 22 – 27.

Table 2. Calculation of Fire Disaster Vulnerability Parameters

Indicator	Variable	Classification	Class	Weight
Social	Population density	Low	<150 People/Ha	1
		Currently	150 – Lives/Ha	2
		Tall	>200 People/Ha	3
Physique	Building Materials	Permanent Building	the construction of walls, reinforced concrete framework, and floor tiles	1
		Semi Permanent Building	the construction is made of half solid structure and half board, part of the boards or all of the walls of the panels, wooden frames, cement floors, and tiles	2
		Non Permanent Building	emergency construction with walls/frames made of bamboo, cement/soil floors, tiled roofs, and equipment for makeshift construction	3
	Percentage of Built Areas	Low	< 40 %	1
		Currently	40% - 75%	2
		Tall	>75%	3
	Building Density	Not solid	< 40 %	1
		Currently	40% - 75%	2
		Very solid	>75%	3
	Availability of Water Storage	Available	>1	1
		Less Available	1	2
		Not available	0	3
	Entrance Width	Wide	The width of the driveway is more than 6 m	1
		Somewhat Wide	Driveway width 3m - 6m	2
		Narrow	Driveway width < 3 m	3
Environment	Vacant Land Availability	Available	>1	1
		Simply Available	1	2
		Less Available	0	3
Economy	Households Working in the Informal Sector	Low	<20%	1
		Currently	20% - 40%	2
		Tall	>40%	3

Indicator	Variable	Classification	Class	Weight
	Poor Population Ratio	Low	<20 %	1
		Currently	20% - 40%	2
		Tall	>40 %	3

After calculating the fire disaster vulnerability parameters, the total weight value will be found, and the category classification will be carried out

Table 3. Fire Disaster Vulnerability Category

No	Vulnerability Level	Score
1	Low	9 -15
2	Currently	16 -21
3	Tall	22 - 27

2.4.2 Overlay Analysis of Fire Disaster Vulnerability Levels

After knowing the weights and scores of indicators and fire disaster vulnerability variables, an overlay analysis is performed. The map overlay is an analysis technique used to determine spatial analysis by overriding the map arrangement with the ArcGIS tool (Purnomo, 2019). This analysis uses ArcGIS 10.5 software. Fire disaster vulnerability is measured from four aspects: social, physical, environmental, and economic. Each element has parameters to be analyzed using the overlay method (Amalina et al., 2016) so that social vulnerability maps, physical vulnerability maps, environmental vulnerability maps, and economic vulnerability maps are produced. The four maps were then analyzed to obtain a map of fire disaster vulnerability in Karang Rejo Village based on the level of openness: low, medium, and high.

3. DISCUSSION AND DISCUSSION

In the process of analyzing the level of vulnerability, it is divided into four parts that refer to the index: physical, environmental, social, and economical. Research variables are used as input for the analysis process for each vulnerability using weighted overlay analysis in ArcGIS 10.5. It is necessary to score each variable referring to the criteria and scores set on the fire disaster vulnerability parameter before carrying out a weighted overlay analysis. When a weighted overlay analysis has been carried out, it will produce a level of social, economic, physical, and environmental vulnerability along with their distribution. After that, the level of vulnerability to fire disasters in Karang Rejo Village was generated from input data from ecological, economic, physical, and social vulnerability stations results that used the same analysis, namely weighted overlay using ArcGIS 10.5 software.

3.1 Analysis of Social Vulnerability Levels

Variables are used to measure social vulnerability levels, is population density. The Karang Rejo Village was dominated by a score of 3 with a total distribution of 51 RTs. The results of scoring one are spread over 23 RTs, and the middle-class RTs, which have achieved two, are spread over 13 RTs in Karang Rejo Village.

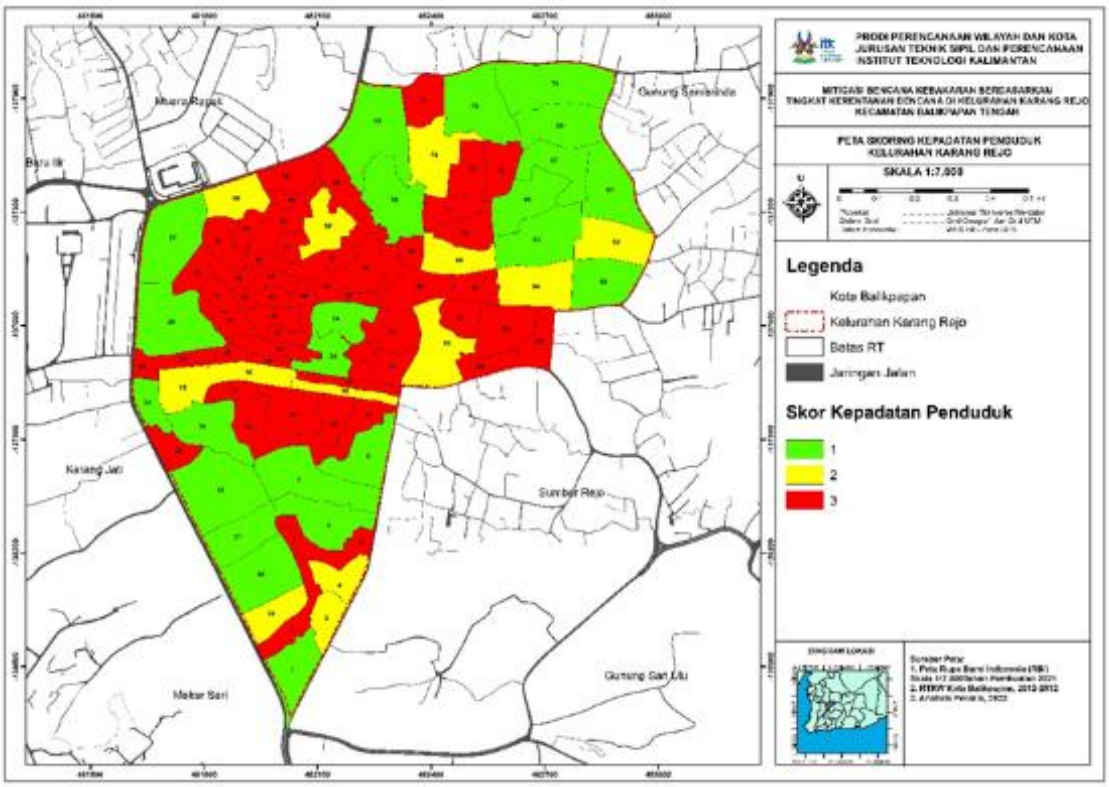


Figure 2. Population Density Scoring Map for Karang Rejo Village

After scoring the population density variable, the level of social vulnerability was analyzed using ArcGIS 10.5. Then it is classified into three classes using *the reclassify tool*. The weight of the population density variable corresponds to the fire disaster vulnerability category.

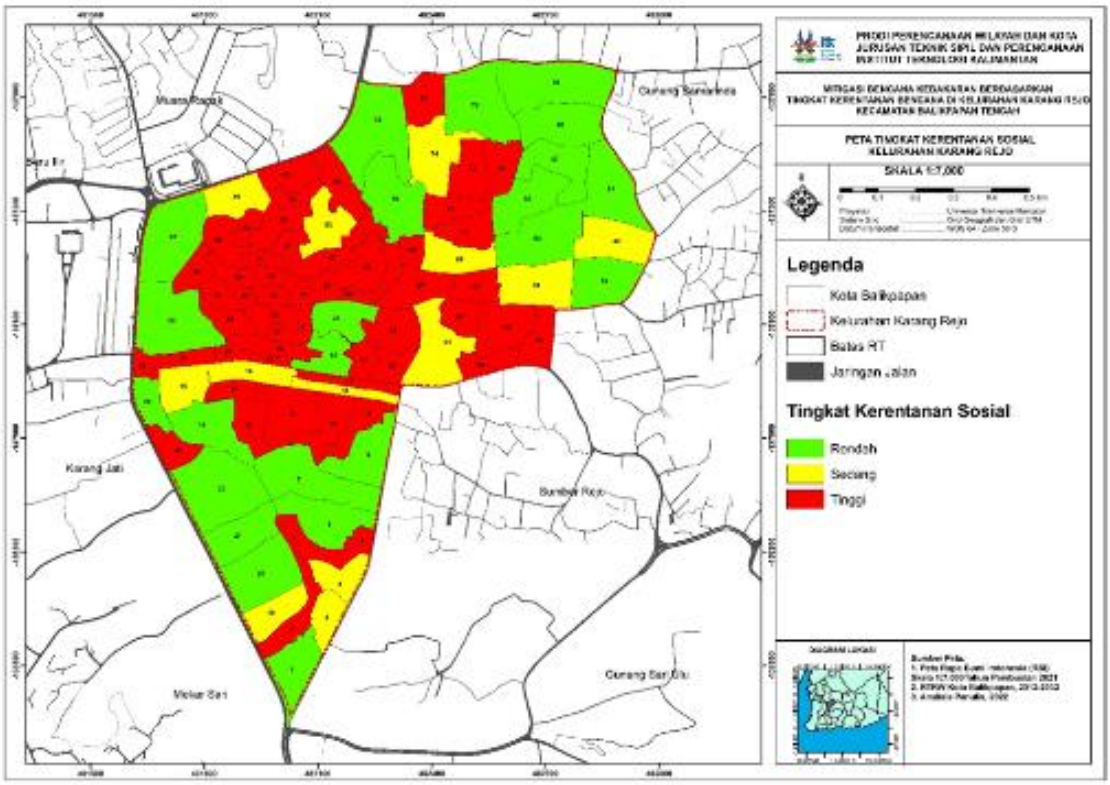


Figure 3. Map of Social Vulnerability Levels in Karang Rejo Village

It can be seen in the figure above that social vulnerability is dominated by a low score, around 55.29 Ha or 45%. Still, if you look at the number of RTs, the number of medium vulnerability levels is less than the high level of social vulnerability. This result can happen because the area in the RT with a low social exposure is, on average, quite large. The RT also has a low population density, so it has a low level of social vulnerability. Based on the distribution of RTs, the highest level of social vulnerability is found in the central part of Karang Rejo Village.

3.2 Analysis of Physical Vulnerability Levels

In the process of analyzing the level of physical vulnerability, various indicators, including the percentage of built-up areas, building density, building materials, width of access roads, electricity, and availability of water reservoirs, will be scored on each variable and calculation of the index value of the level of vulnerability physique. After scoring, it will produce the status and distribution of physical vulnerability in Karang Rejo Village using weighted overlay analysis.

The percentage of built-up areas in Karang Rejo Village is dominated by a score of 2 in 74 RTs and 1 in 13 RTs, or low to moderate built-up areas. Furthermore, score 1 means it has a built-up area of 0% - 40%, and a score of 2 is between 40% to 74% of the built-up area, as shown in the map below.

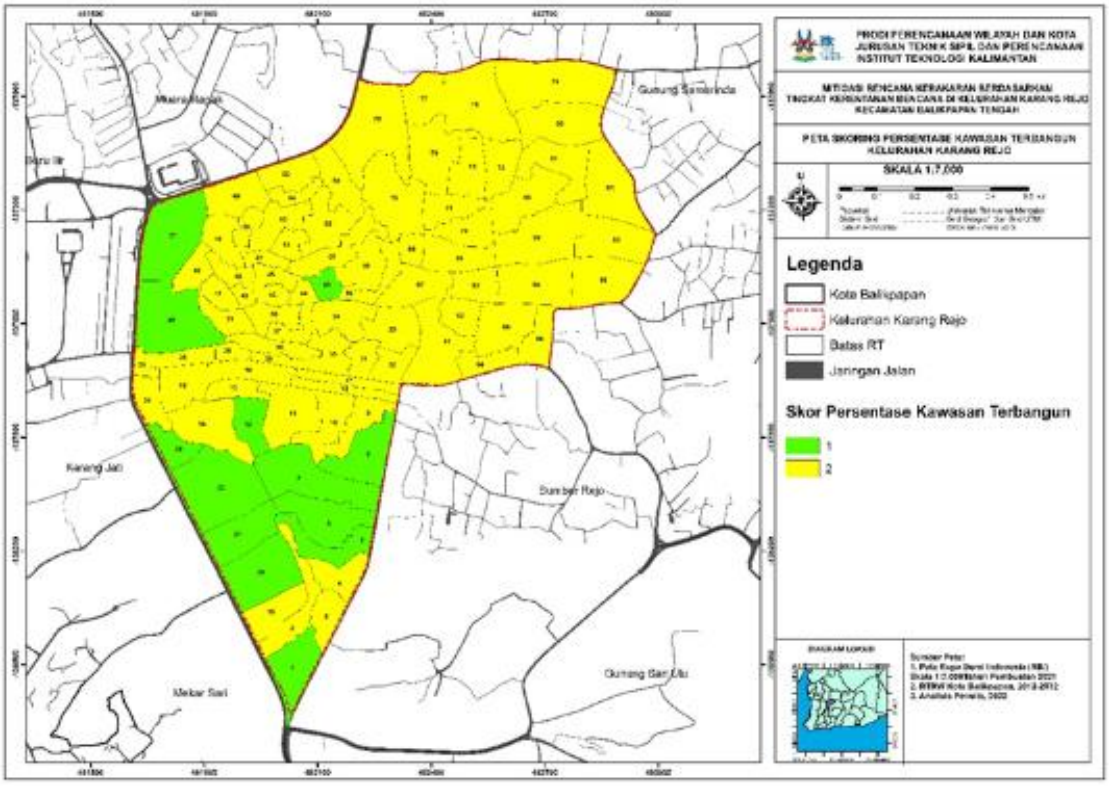


Figure 4. Scoring Map of the Percentage of Built-up Areas in Karang Rejo Village

The building density variable in Karang Rejo Village was dominated by a score of 2 in 74 RTs and 1 in 13 RTs. The density level has the same percentage range as the built area variable. The Building Density Weight Map can be seen below.

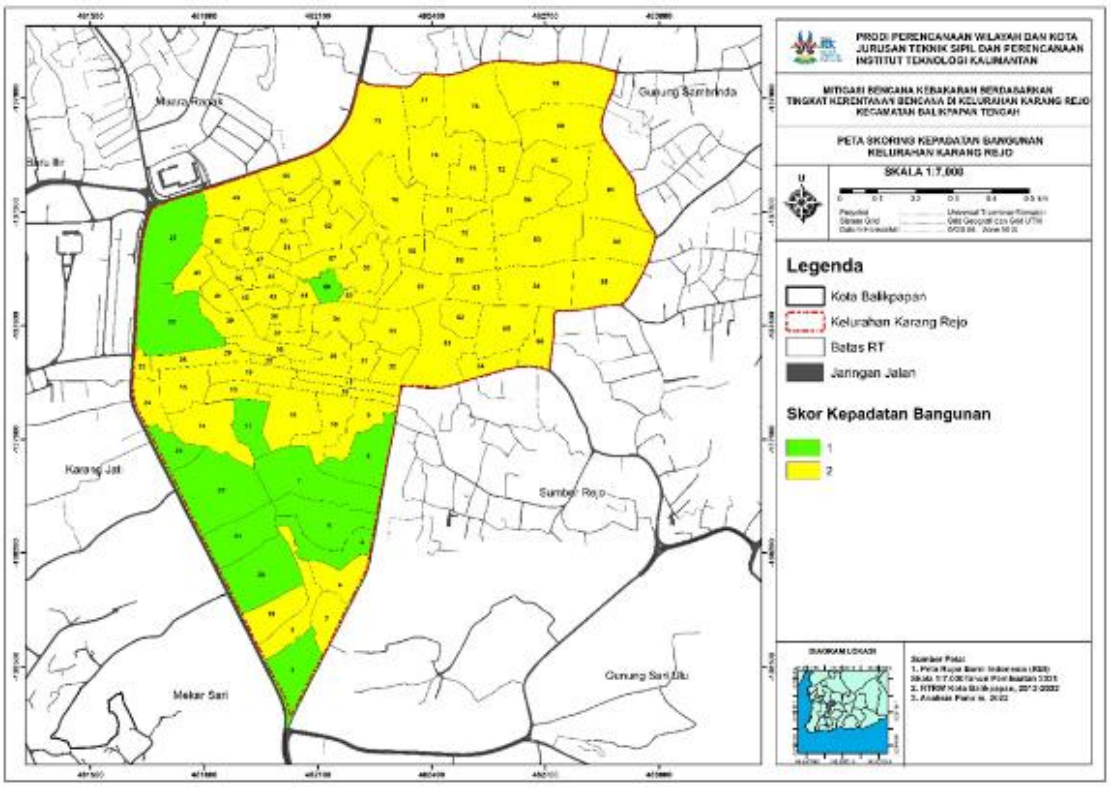


Figure 5. Building Density Scoring Map in Karang Rejo Village

Building materials with a score of 1 are spread across 56 RTs, with characteristics of more than 50% of the buildings in the RT being permanent structures. While score 2 is applied over 24 RTs, with a composition of more than 50% of the buildings being semi-permanent buildings, and score 3 is spread over 7 RTs, with the characteristics of more than 50% of the buildings being non-permanent buildings.

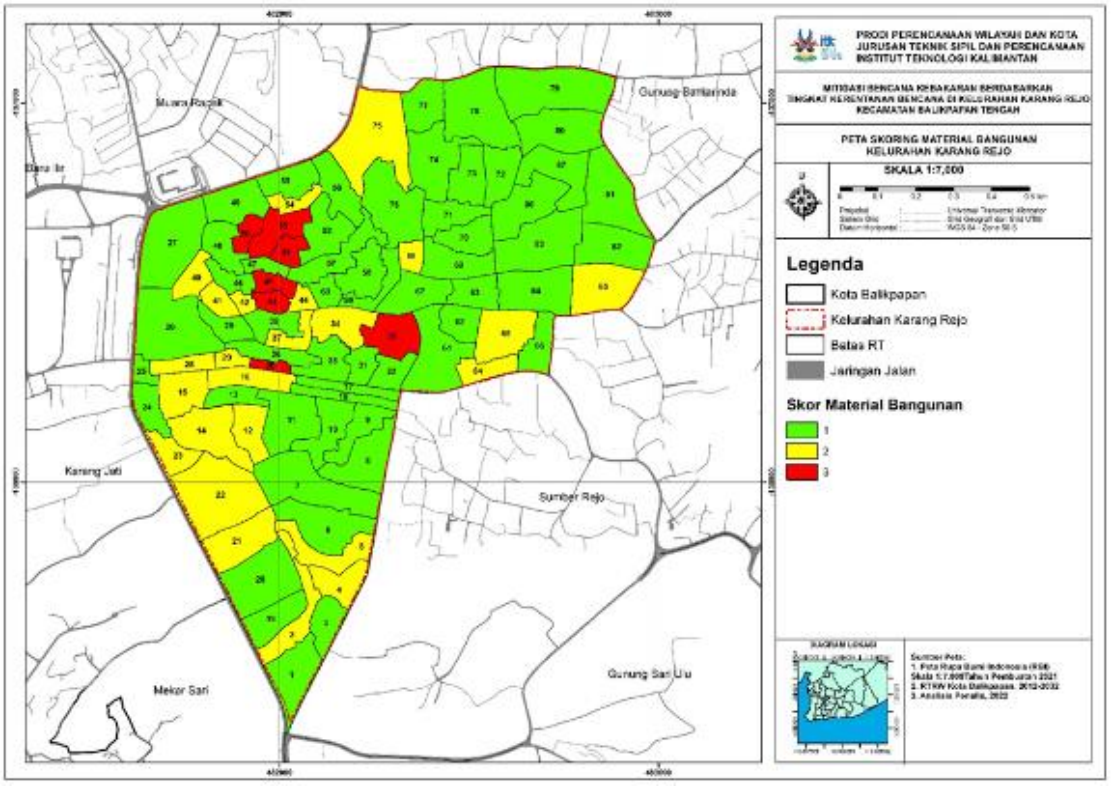


Figure 6. Scoring Map of Building Materials in Karang Rejo Village

Karang Rejo Village, for the variable availability of water reservoirs, is dominated by a score of 3 with a total of 82 RTs or does not have a water reservoir. For a score of 2, it is only found in 5 RTs, with the characteristics of having at least 1 water reservoir. There is only 1 RT in Karang Rejo Village with a score of 1, which means it has 2 water reservoirs.

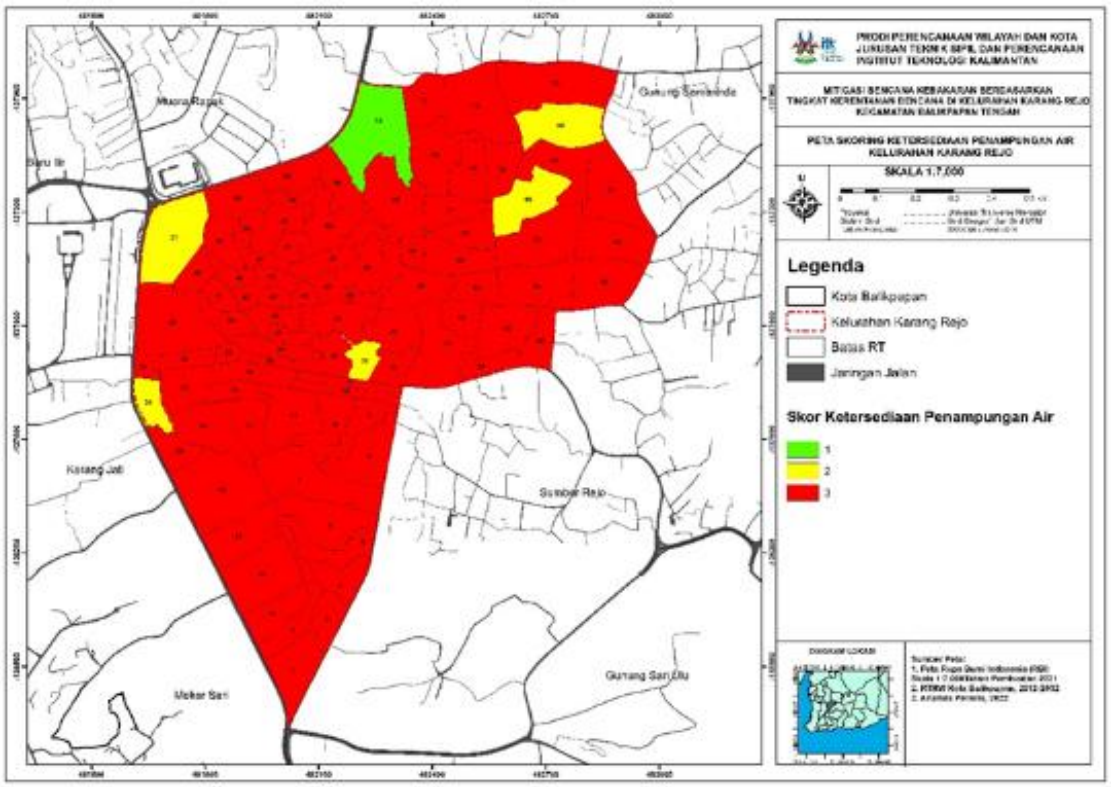


Figure 7. Scoring Map of Availability of Water Storage in Karang Rejo Village

The width of the entrance road to Karang Rejo Village is dominated by score 3, with 46 RTs, while score 2 has 41 RTs. In the Karang Rejo Village, there is no score of 1 which can be concluded that in the Karang Rejo Village, the access road variable is very vulnerable to fire disasters, namely in the road width range between 1 to 4 meters.

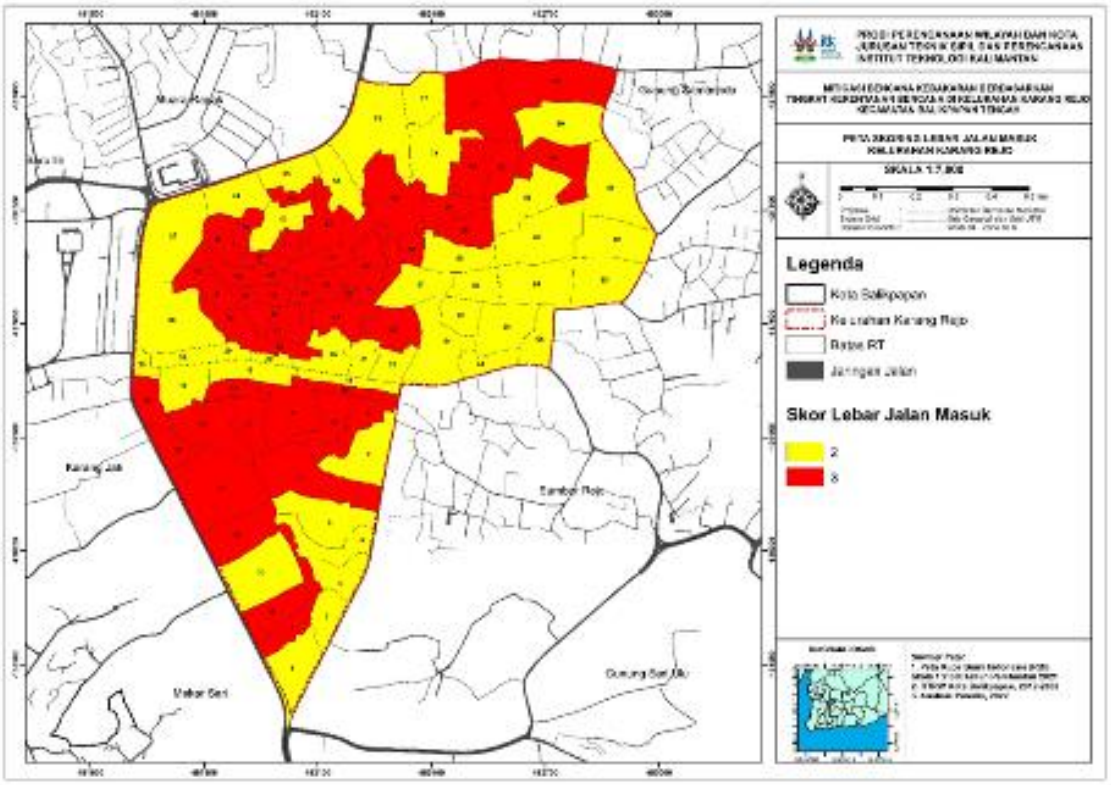


Figure 8. Scoring Map of Fire Car Entryway Width
Fire in Karang Rejo Village

After scoring each physical vulnerability variable, a weighted overlay analysis will be carried out, namely cutting maps of the percentage of built-up areas, building density, building materials, driveway width, and availability of water reservoirs into the ArcGIS 10.5 *software*. The five maps will be analyzed by weighted overlay using the *weighted sum tools*, which will then be classified into three classes using *the reclassify tool*.

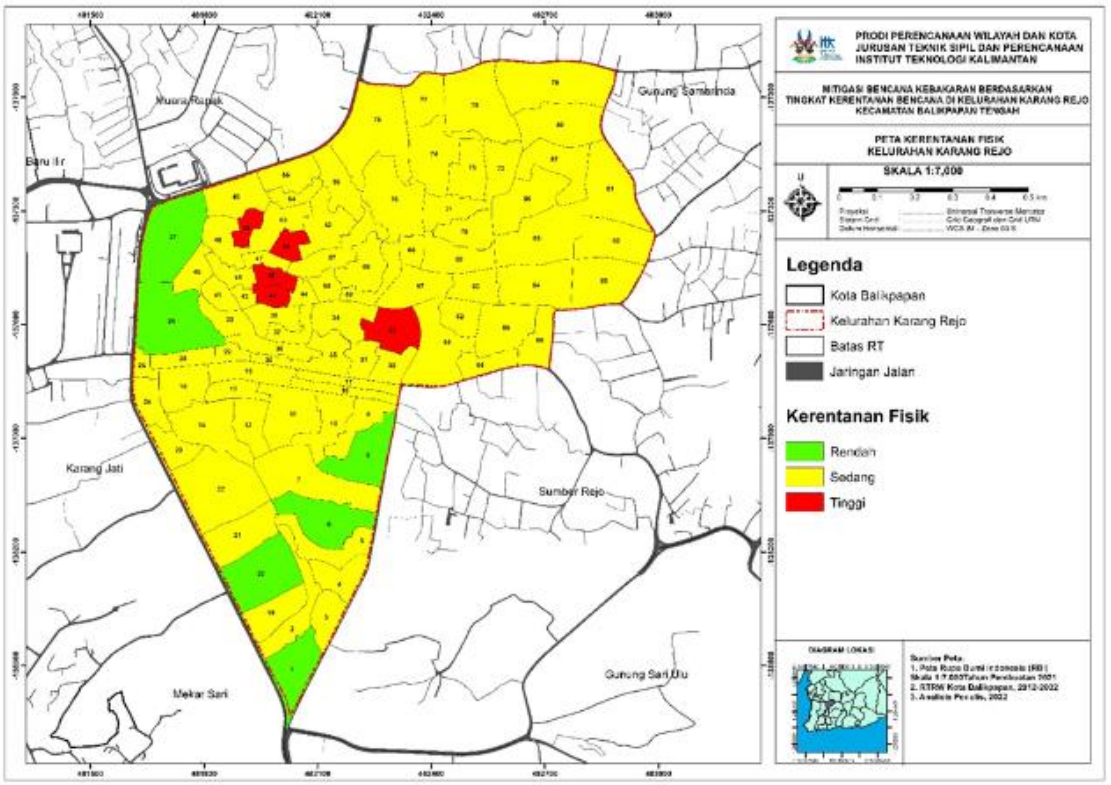


Figure 9. Map of Physical Vulnerability in Karang Rejo Village

Based on the map above, it can be seen that most of the Karang Rejo Village area is at a moderate level of physical vulnerability, and four RTs are at a high level of physical exposure.

3.3 Environmental Vulnerability Level Analysis

At the stage of environmental vulnerability analysis, there is an input variable on the availability of vacant land, which will be scored. In Karang Rejo Village, the variable availability of vacant land is dominated by a score of 3, namely a total of 48 RTs that do not have vacant land. Next is score 1, which is 26 RTs, each with an empty area between 0.5 Ha – 1 Ha. Finally, there are 13 RTs with a score of 2 with a range of vacant land between 0 Ha – 0.5 Ha.

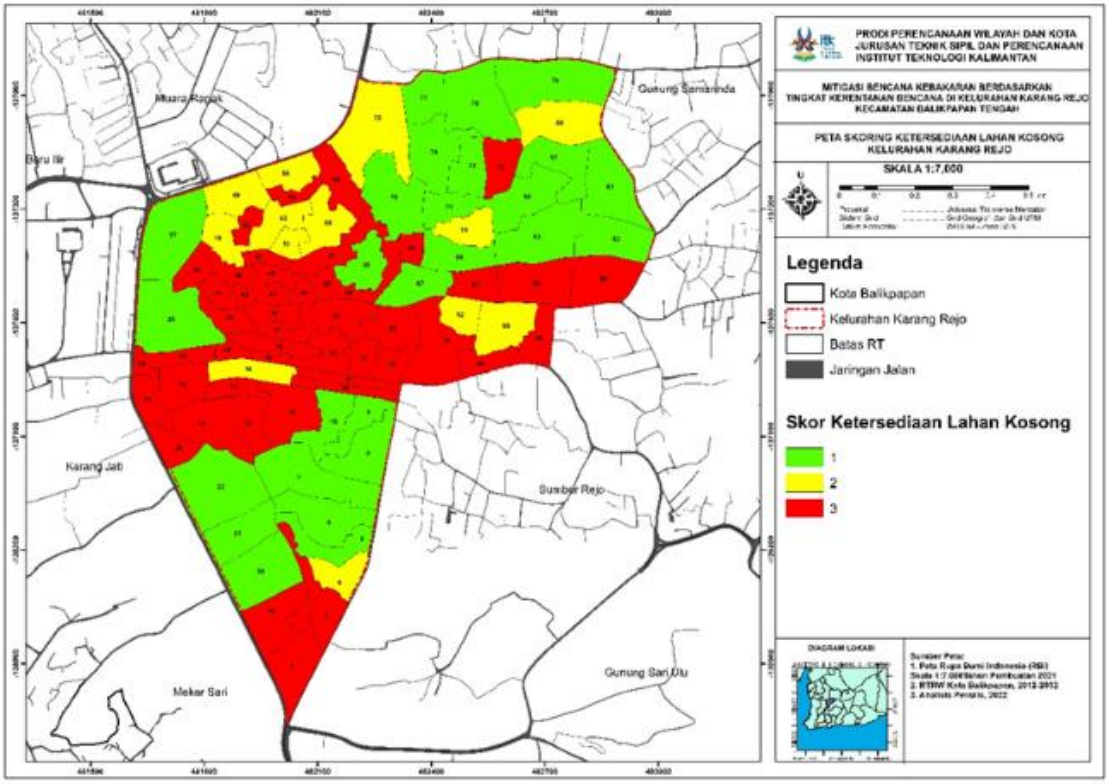
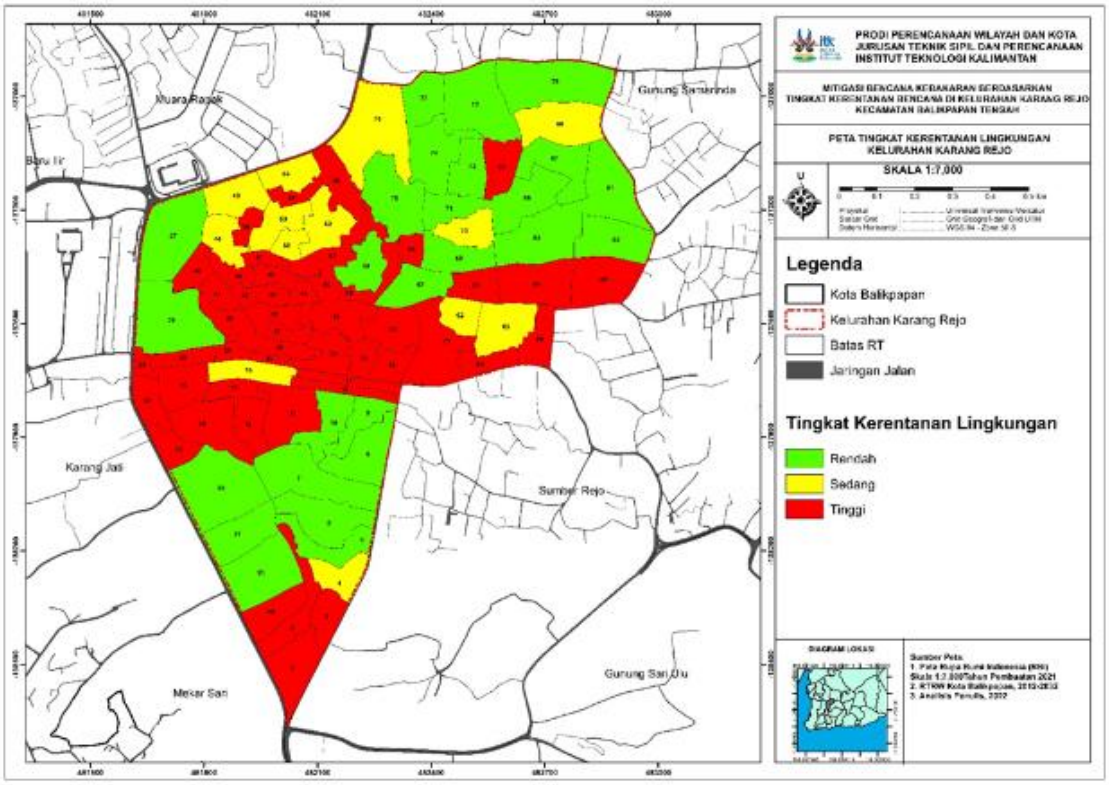


Figure 1. Map of Scoring Availability of Vacant Land in Karang Rejo Village

After scoring the vacant land availability variable for the level of environmental vulnerability, an analysis of the level of ecological vulnerability was carried out using ArcGIS 10.5.



Picture 11. Map of Environmental Vulnerability in Karang Rejo Village

The map above shows that low-class environmental vulnerability is the largest area in Karang Rejo Village, with a total area of 55.29 Ha. The high level of ecological vulnerability has a total area of 46.80 Ha and a moderate classification of 19.82 Ha.

3.4 Analysis of Economic Vulnerability Levels

In analyzing the economic vulnerability, variable input was carried out based on economic indicators, namely households working in the informal sector and the ratio of poor people, where each variable would be scored. The percentage of poor people in the medium class (score 2) spread over 48 RTs, ranging from 20% to 40% of the poor. On the other hand, 36 RTs have a score of 1 with a poor population of less than 20%. Lastly, there are 3 RTs with a score of 3 or a poor population above 40%.

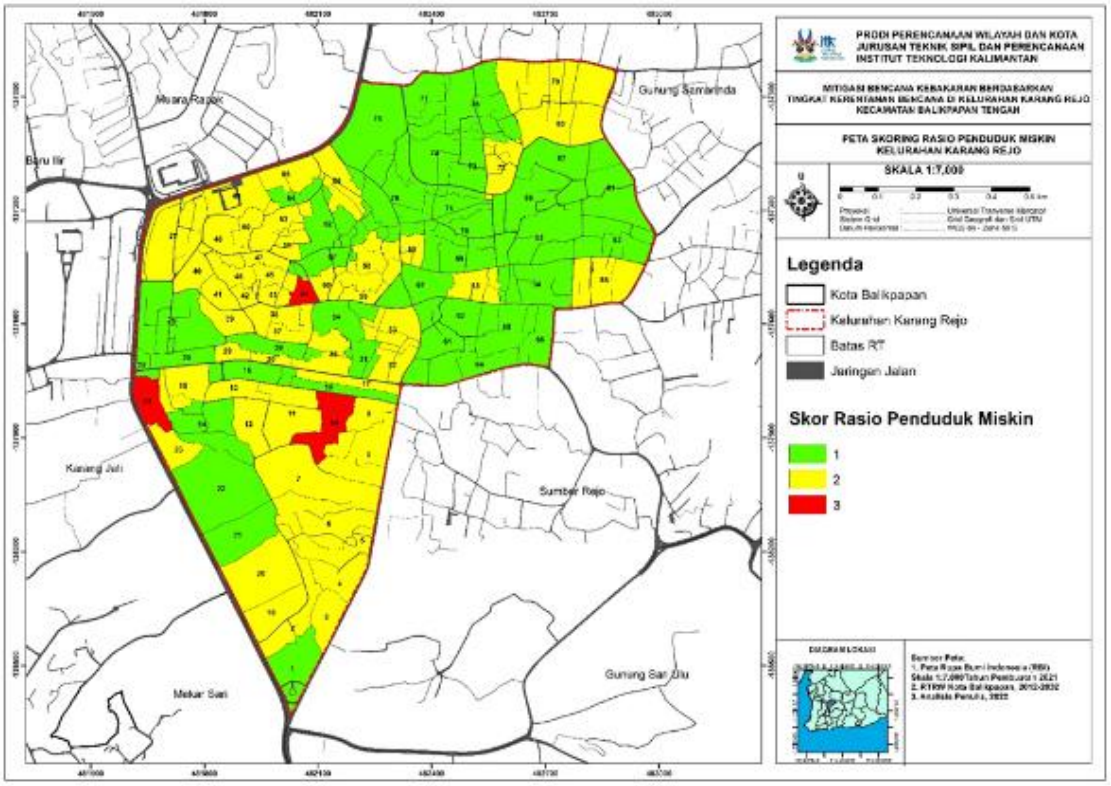


Figure 12. Poor Population Scoring Map in Karang Rejo Village

All RTs in Karang Rejo Village get a score of 1, or around 0% - 20% of households work in the informal sector.

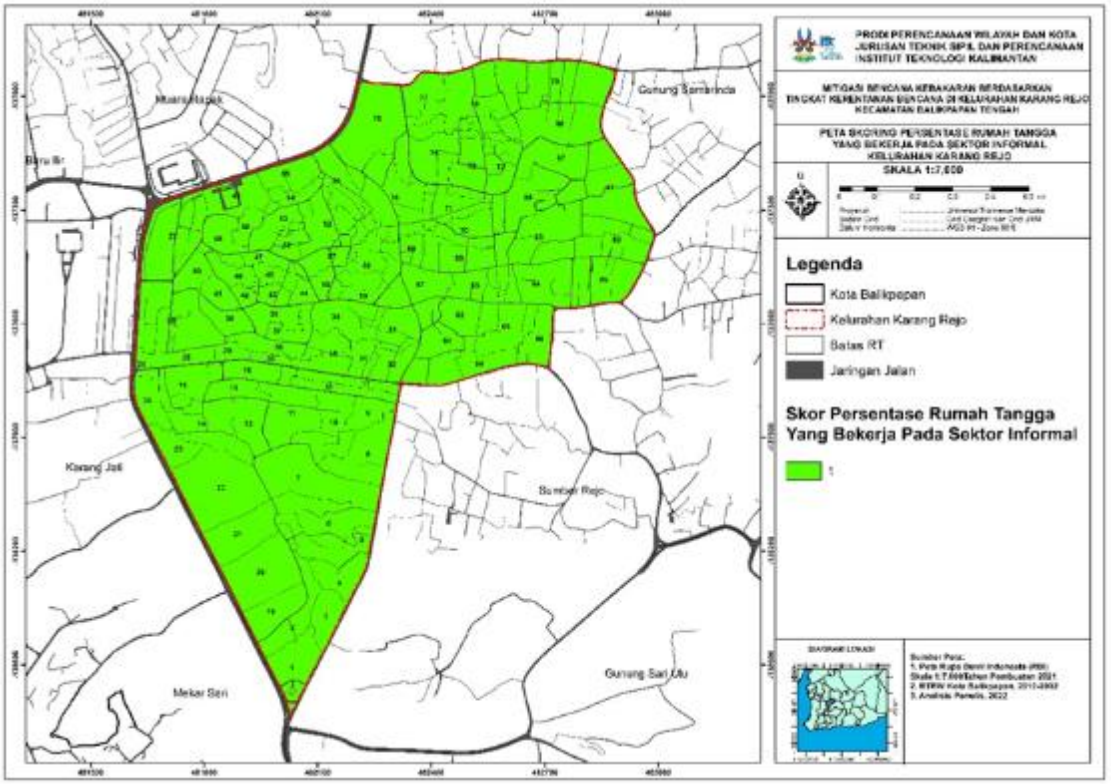


Figure 13. Scoring Map of the Percentage of Households Working in the Informal Sector in Karang Rejo Village

After scoring each variable in the economic indicators, a weighted overlay analysis will be carried out by inserting the scoring ratio maps of the poor and households working in the informal sector into ArcGIS 10.5.

Then a weighted overlay analysis was carried out using *the weighted sum tool*, which had previously been classified into three classes.

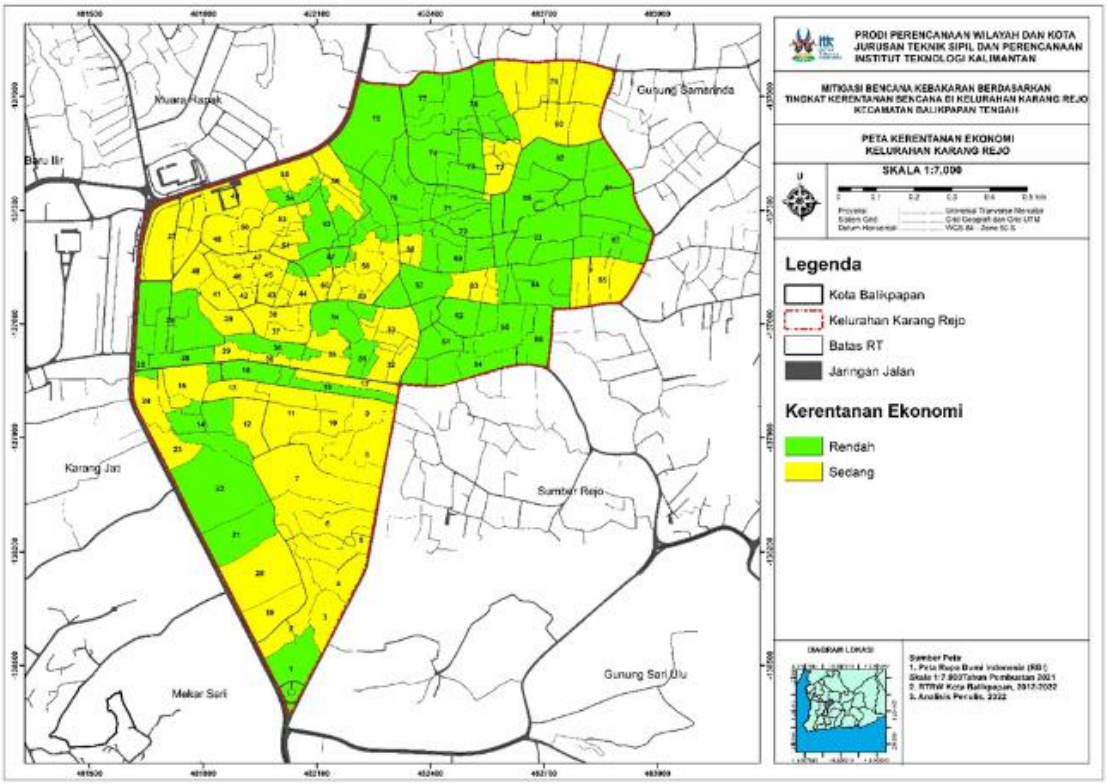


Figure 14. Map of Economic Vulnerability Levels in Karang Rejo Village

Based on the map above, it can be seen that the highest area of economic vulnerability is in a low category, with 61.54 Ha or 51%, the medium type, with 60.37 Ha or 49%, and there is no high category. However, when viewed from the distribution of RTs in Karang Rejo Sub-District, there were fewer low-level economic vulnerabilities than medium-level vulnerabilities, namely only 36 RTs. In comparison, there were 51 RTs with a moderate level of exposure. This result can happen because RTs in the intermediate category mostly have small RT areas. It can be concluded that the Karang Rejo Sub-District, an area with a moderate level of economic vulnerability, is quite capable of dealing with fire disasters. In areas with a low level of financial vulnerability, it can be said that they are not vulnerable when facing fire disasters.

3.6 Analysis of the Level of Vulnerability to Fire Disasters in Karang Rejo Village

After scoring each vulnerability index, a weighted overlay analysis can be performed using *the weighted sum tool*. After obtaining the results of the weighted overlay analysis, the class will be graded according to the reference in Table 3.3 and class classification into three levels, namely medium, high, and low, using the *reclassify tool*. A moderate level of vulnerability dominates Karang Rejo Sub-District to fire disasters with 62 RTs spread across Karang Rejo Sub-District, a low level of openness with a total of 20 RTs, and a high level of vulnerability with a total of 5 RTs.

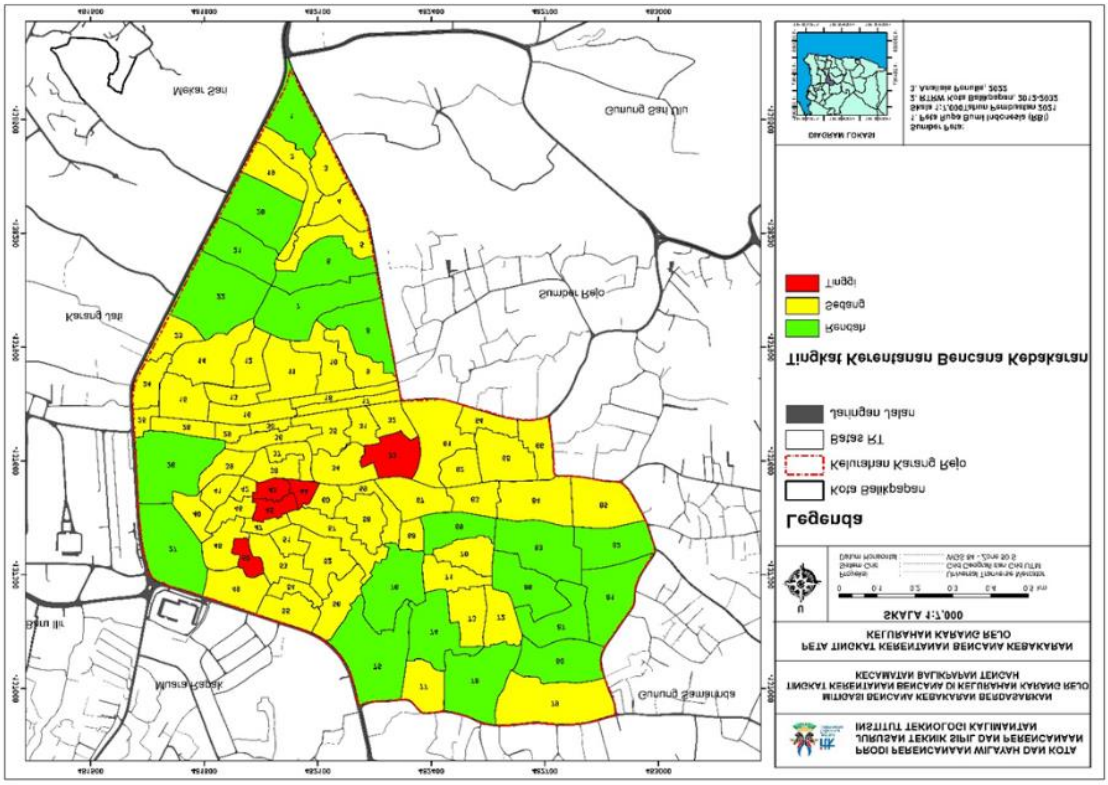


Figure 15. Map of Fire Disaster Vulnerability Levels in Karang Rejo Village

4. CONCLUSION

Based on the analysis results, it can be concluded that spatially, the predominant fire vulnerability in Karang Rejo Village is the moderate exposure spread throughout almost the entire central area of Karang Rejo Village. The site is categorized in the medium category because most have a high level of social vulnerability, a moderate level of physical vulnerability, a high level of environmental vulnerability, and an average level of economic vulnerability. Regions with a high level of fire disaster vulnerability will experience low capability and readiness in dealing with fire disasters. RT regions with a moderate level of fire disaster vulnerability will also experience reasonably low levels of preparedness and capacity but not as big as a high level of fire disaster vulnerability. The Karang Rejo Village in the northern part has a low level of fire disaster vulnerability because this area has a low level of social exposure, moderate level of physical vulnerability, low level of environmental vulnerability, and low level of economic vulnerability. Therefore, in areas with a low level of fire disaster vulnerability, it can be said that they are pretty capable of dealing with fire disasters.

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