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The Electronic Road Pricing System Planning: A Scenario of Curbing Congestion Issues on an Arterial Road in Makassar City, Indonesia

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Abstract

This study aims to analyze the traffic performance on arterial roads in Makassar City in the present and future with the implementation of Electronic Road Pricing, as well as how many tariffs can be applied when Electronic Road Pricing (ERP) is used. The data were collected from traffic surveys and questionnaires distributed to users of four-wheeled and two-wheeled vehicles. From the data, the existing traffic conditions on the road were analyzed, and the probability of moving road users was calculated during the implementation of ERP. Furthermore, the Willingness To Pay method determines the rates that can be applied. The research results show that when ERP is implemented on the Andi Pangeran Pettarani Road, there will be a 40% reduction in traffic flow due to the route changes and a 42% reduction in traffic flow due to the modal shifts. This affects improving traffic performance in the future, where the existing condition of this road segment which was initially at LoS D and E, can be increased to LoS B and C. The tariff that can be applied to the ERP system is Rp 8,838 for four-wheeled vehicles or more and Rp 4,343 for two-wheeled vehicles

1. INTRODUCTION

Makassar City is one of the metropolitan cities in Indonesia, which is also the capital of South Sulawesi Province. The rapid growth of government, trade, and industrial sectors in several cities caused the population to increase. Based on data from the Central Statistics Agency of South Sulawesi, it is predicted that the population number in Makassar city will be 1,571,814 in 2022 (Central Bureau of Statistics for South Sulawesi Province, 2022). The significant population growth of Makassar City causes the high ownership of private vehicles. Cities in developing countries with inadequate public transportation force their residents to use personal vehicles; therefore, the number of private vehicle owners is high (Hasim et al., 2019). The increase in the number of vehicles causes an increase in traffic flow, and this will affect the ability of the road to accommodate the flow of vehicles, resulting in a decrease in road performance (Anton, 2020). This is one of the causes of traffic congestion problems that are getting worse from year to year.

One of the traffic-heavy roads and part of Makassar's primary arterial road network is Jalan Andi Pangeran Pettarani (Makassar Regional Development Planning Agency, 2015). Andi Pangeran Pettarani Street is one of the main streets in Makassar city that links several streets to commercial districts, schools, universities, government offices, and social facilities. Based on a preliminary survey and information obtained from the Land Transportation Management Center of the Ministry of Transportation of Makassar City, the level of service of the A.P. Pettarani road segment is at level D during peak hours of congestion. The effective capacity of the A, P. Pettarani road section is lower than the design capacity due to roadside friction and the high growth rate of vehicles (Hasanuddin, 2018). Lolo et al. (2019) found that street vendors are spreading across several points on A.P. Pettarani street that occupies sidewalks and roadsides to form business facilities as their alternative creation on the conventional job and also a means of support for the urban poor (Anies & Kasim, 2022). This kind of roadside friction can influence road traffic performance and its level of service. In addition, Suruji (2018) also found that the congestion polemic that occurred in Makassar was caused by factors such as stubborn drivers, vehicles that parked on the shoulders and body of the road and seizing the rights of other

drivers. For this reason, a solution is needed to reduce the number of private vehicles user so that heavy traffic can be avoided. One solution that can be pursued is the application of Congestion Pricing. Congestion pricing is an additional fee or levy imposed on motorists when passing certain roads due to the driver's time of existence which causes congestion for other road users (Mohring, 1996). For decades, the standard method for reducing congestion was by forecasting traffic increase and then constructing enough road capacity to accommodate it. In the UK, this approach was abandoned in the 1990s due to evidence that new capacity soon fills up with additional traffic (Cervero, 2003). Other approaches to curb congestion have been tested around the world, including land-use planning, odd-even license plate limits on car use, and more, but these are expensive to implement and also blunt instruments for dealing with congestion because road-building makes driving more attractive and will encourage more driving (Lindsey, 2012).

In Indonesia, the basis for applying traffic control levies has been stated in several policies, such as in Government Regulation no. 97 of 2012 and Law no. 22 of 2009. Congestion pricing is the most effective way to overcome congestion (Agarwal et al., 2015). Electronic Road Pricing (ERP) is another name for congestion pricing. In the ERP system, every vehicle that passes through the road during peak hours requires electronic retribution to cross the street. Road pricing is described as the first best approach to Travel Demand Management (Saleh & Sammer, 2009). Travel demand management (TDM) is an effort to influence the travel behavior of road users in determining the choice of mode, length of trip, frequency of trips, and routes (Ison & Rye, 2008). TDM encourages road users to reduce relatively unnecessary trips, especially private vehicles and promotes using more effective modes of transportation, and one of them is the ERP approach. ERP systems have been implemented to cope with traffic in metropolitan cities and effectively reduce the number of vehicles entering a specific zone (Rizal et al., 2018). The congestion pricing concept has been widely applied to downtown roads in developed countries, such as Singapore, London, Stockholm, Milan, and Gothenburg (Lehe, 2019). In Indonesia, the ERP system has not been implemented at all in any city. ERP system has been planned to be implemented in Jakarta, state the capital of Indonesia, for the first time, and the Jabodetabek Transportation Management Agency (BPTJ) initially targeted this system to be implemented in 2020 (Anwar, 2020; Yuniartha, 2020). However, based on information from the Jakarta Transportation Agency's Electronic Paid Road System Management Unit, the ERP implementation has been postponed and will begin in 2023 (Simorangkir et al., 2021). ERP received a positive response from road users in Jakarta and can be immediately implemented to measure its effectiveness (Rifai et al., 2021). The positive response obtained for the ERP implementation plan in Jakarta and the effectiveness of the ERP system in overcoming traffic problems in metropolitan cities prompted a study to see the possibility of implementing ERP in Makassar City. ERP is expected to be a solution to overcome congestion polemics at several congestion-prone points in Makassar City. This study was conducted to know how if ERP was implemented in one segment of Makassar City. How it affects road traffic performance, and how much the rates can be applied if the policy is implemented. The ERP system implementation policy will be later expected to result in a win-win solution. Not only for service users who paid but also for the wider community and those who are willing to switch to public transportation. The road facilities are easier for those who can afford to pay to utilize. Meanwhile, those who wish to avoid using other own vehicles can take use of reliable, comfortable, punctual, and reasonably priced public transportation.

2. METHODS

Electronic Road Pricing was first introduced in Singapore in 1975, using a manually-paid scheme (Ng & Samuel, 1999, as cited in Rizal et al., 2018). Since then, the road pricing scheme has undergone many changes. Over the past 30 years, it has changed from being a manual scheme based on paper permits that were only relevant during the morning peak period to an electronic system that is now in use nearly all day (Chin, 2005). Establishing ERP is thought to be a successful strategy for implementing traffic limitation schemes, which have been done so in several major cities, including Singapore, Stockholm, and London (Selmoune et al., 2020). The application of costs for congestion drove a 53% reduction of fully chargeable traffic in 2007 at the cost of congestion of £ 8 in London and a 79.8% reduction in 2011 with a congestion fee of € 2 in Milan (Croci,

2016). Furthermore, positive impacts have also been in reducing emissions and road accidents in the area. In addition to having a good impact, ERP also has a negative one, such as in Singapore, retail real estate prices in the cordoned area could decrease by 19% as a result of the ERP toll charge increase of S\$1 per car (Agarwal et al., 2015). According to Menon & Guttikunda (2010), the ERP system could be successful in big cities if they provide a widely accessible public transportation system that can facilitate the transition to car-free transportation. ERP implementation in a city can be done when the condition of all road sections is by urban road design standards, and driver behavior follows the rules the driver follows the rules (Bandung City Department & of Transportation, 2016). Therefore, the implementation of ERP can be carried out in cities in Asia if these considerations have been fulfilled.

This research was conducted in one of the primary arterial road networks in Makassar, Jalan Andi Pangeran Pettarani, Makassar City, South Sulawesi Province. The boundary of the road to be studied is the road from the intersection of Boulevard street to the junction of Jalan Raya Pendidikan Makassar City. Based on a preliminary survey and information obtained from the Land Transportation Management Center of the Ministry of Transportation of Makassar City, the level of service of this road section is at level D during peak hours of congestion. This road section was chosen as the research location because, apart from the unstable traffic conditions at certain hours, there are alternative roads that can be considered for vehicle users to pass when the ERP is implemented.

Figure 1. Map and Traffic Condition of The Research Location.

This research was conducted in several stages. The first stage was through a preliminary study. The initial research began by conducting a site survey and checking the peak hour of the location under study. Furthermore, primary data was collected to obtain traffic flow and questionnaire data. Traffic data was obtained through surveys carried out for three days, on Monday, Wednesday, and Saturday, during peak hours, and questionnaire data were obtained by distributing questionnaires to respondents. Questionnaire distribution will be carried out after the traffic survey is completed due to the determination that the number of samples to be calculated is based on the number of vehicles passing A.P. Pettarani street. From the 3-day traffic survey, the highest number of vehicles was obtained in the survey conducted on Monday afternoon with a total of 8,421 veh/hour. This data was used as the basis for calculating the sample. Thus, the sample was determined to be 382 respondents. The data collected from the questionnaire included socio-demographic data and several questions related to the use of A.P. Pettarani street, response to the implementation of electronic road pricing in the future, and perceptions of modal and route shifts. Socio-demographic data, perception regarding the distribution of road pricing revenue, and other traffic management measures were also used by Rentziou et al.

(2011) as independent variables in their models. The secondary data consists of the layout of A.P. Pettarani street and the latest Makassar City GDP data. Data analysis was done after the information had been gathered. Several stages of analysis were carried out in this study. The first was to analyze the traffic performance of existing and future conditions. This analysis used the 1997 IHCM standard for counting the traffic performance of an existing condition. For traffic performance forecasting in the next five years, the analysis was calculated based on population growth data obtained through GRDP. Furthermore, an analysis of traffic conditions with the implementation of the ERP system was carried out. This analysis was conducted based on the results of the respondent's data calculated using binary logistic regression analysis. In a study conducted by Wang et al. (2017), the logit model was used to examine the influence of several socio-psychological characteristics on the likelihood that the policies relating to the electric vehicle would be adopted. Binary Logistics is an analytical method to analyze the discrete nature of receipts whose questions only have yes or no answers (Sunitiyoso et al., 2020). The result of this analysis would show the possibility of users switching routes and modes by users when ERP is implemented. After implementing the ERP system, a re-check of traffic performance on the road is carried out at A.P. Pettarani street to find out if the ERP system makes the Level of Service (LOS) better or not. Furthermore, the final analysis determines how much tariffs can be applied to four-wheeled and two-wheeled vehicles when the ERP is implemented based on the Willingness to Pay value. This analysis is calculated based on respondent data who chose the nominal listed in the distributed questionnaire.

3. RESULT AND DISCUSSION

Traffic performance analysis was carried out based on the Indonesia Highway Capacity Manual (Indonesian Directorate General of Highways of Indonesia, 1997). From the results of data analysis, the average volume of vehicles at peak hours in the morning is 3190 pcu/hour, and peak hours in the afternoon is 4060 pcu/hour. Analysis of traffic performance in 2022 on Andi Pangeran Pettarani is measured based on the parameter in the form of Volume Capacity Ratio (VCR). The calculation results of the degree of saturation can be seen in Table 1.

Table 1 shows that the level of service (LOS) for the existing condition on weekdays is at levels D in the morning and E in the afternoon. Meanwhile, on weekends, the service level is still at level C in the morning, but the service condition worsens at levels D to E in the afternoon. Traffic performance is adjusted to the level of service category that has been regulated, where level C is the level of service level for VCR 0.45 to 0.70, level D for VCR 0.70 to 0.85, and level E for VCR 0.85 to 1.00 (Ministry of Transportation of Indonesia, 2006). Existing condition data shows that on weekdays, the traffic flow conditions in the morning on this road are approaching unstable, and drivers begin to experience short-duration traffic jams in the afternoon. Meanwhile, on weekends, the flow conditions are still stable in the morning, although a higher traffic volume will control the speed and movement of vehicles. Leading to the afternoon, the traffic flow conditions are approaching unstable, and drivers also start to feel short-duration traffic jams.

Table 1. Analysis of Volume Capacity Ratio of Andi Pangeran Pettarani street

Day	Time	Sg	Vehicle Vol. PCU/Hour				Vol. PCU/hour	Capacity PCU/Hour	VCR
			LV	HV	MC	UM			
Week day	Morning	1	2102	36	5170	38	3510	4562	0,77
		2	2267	26	5267	22	3710	4752	0,78
	Afternoon	1	2789	52	5405	33	4224	4562	0,93
		2	2560	35	5661	26	4107	4752	0,86
Week end	Morning	1	1367	55	3280	22	2258	4562	0,49
		2	1546	28	4088	22	2606	4752	0,55
	Afternoon	1	2575	50	5441	41	4005	4562	0,88
		2	2479	46	5157	39	3833	4752	0,81

From the traffic data, the existing conditions were analyzed for traffic conditions in 5 years. The traffic volume prediction in the next five years is influenced by the GRDP of Makassar, so traffic predictions are analyzed using this data. Where to obtain a forecast of future traffic volume is used the formula:

$$P_n - P_o (1+r)^n \qquad (1)$$

Traffic performance for the next five years (2023-2027) can be seen in Table 2. Based on the existing condition data, the traffic volume on the A.P. Pettarani road is predicted to increase every year and reach the traffic saturation point because it reaches VCR > 1. It means the Level of Service is at level F, long and very high traffic density and low volume and congestion occur for quite a long duration (Ministry of Transportation of Indonesia, 2006). This condition makes traffic on A.P. Pettarani to be hampered. Therefore, ERP implementation is expected to reduce traffic volume in the future.

Table 2 Traffic Performance predictions for five years

| Day | Time | Sg | VCR | | | | |
			2023	2024	2025	2026	2027
Weekday	Morning	1	0.81	0.86	0.91	0.96	1.02
		2	0.83	0.87	0.92	0.98	1.03
	Afternoon	1	0.98	1.03	1.09	1.16	1.22
		2	0.91	0.97	1.02	1.08	1.14
Weekend	Morning	1	0.52	0.55	0.58	0.62	0.65
		2	0.58	0.61	0.65	0.69	0.72
	Afternoon	1	0.93	0.98	1.04	1.10	1.16
		2	0.85	0.90	0.95	1.01	1.07

Furthermore, traffic volume calculations are carried out when ERP is implemented. This analysis was carried out using logistic regression analysis, whose data were obtained through the results of respondents from the questionnaires that had been distributed. Wang et al. used the logit model to investigate the influence of several socio-psychological factors on the likelihood of acceptance of policies related to electric vehicles (Wang et al., 2017). Mehrolia et al. also studied perceptions of delivery services during the Covid-19 pandemic through binary logistics (Mehrolia et al., 2021). The logistic regression formula used is:

$$\text{Logit (p)} = \frac{e^{-(\alpha + \beta_1 X_1 + \beta_2 X_2 + \cdots)}}{1 + e^{-(\alpha + \beta_1 X_1 + \beta_2 X_2 + \cdots)}} \qquad (2)$$

The dependent variable in this logistic regression model consists of perceptions of route changes and mode shifts. In contrast, the independent variables consist of gender, age, occupation, income, transportation costs, travel destinations during weekdays and weekends, the mode used, ability to pay, and the type of mode used if changing. An overview of the results of the questionnaire data by respondent shows in Graph 1.
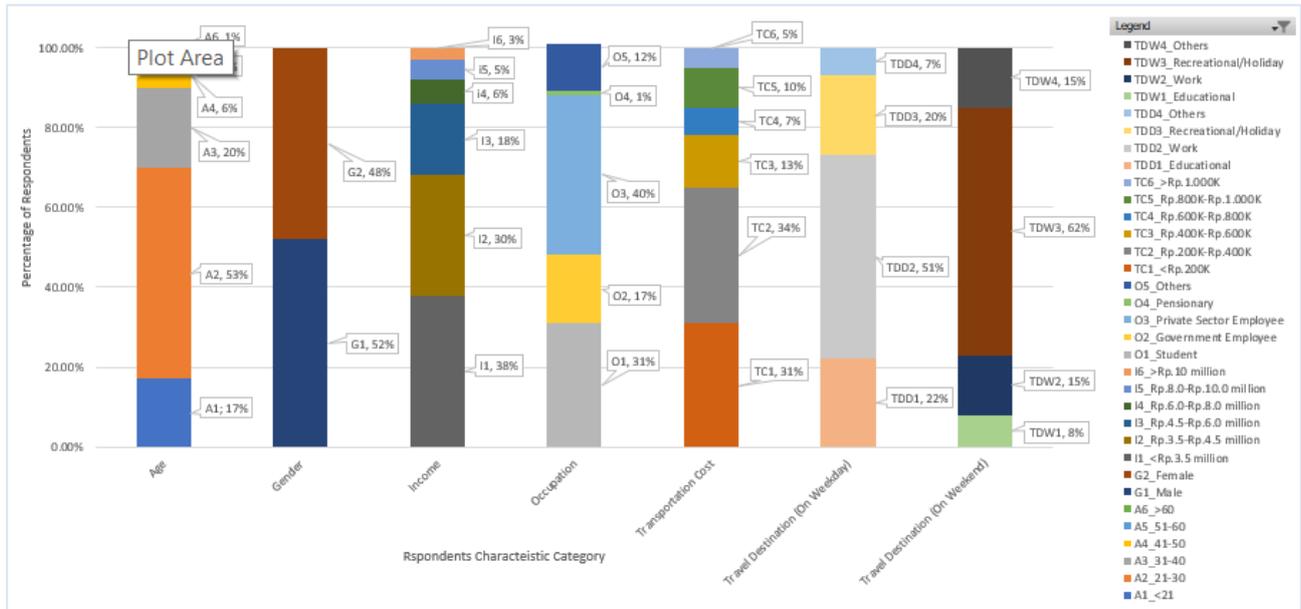
Graph 1. Characteristic of Respondents

Based on the results of the analysis of the binary logistic function, it was found that 204 users of A.P. Pettarani are not willing to pay for the ERP, of which 159 respondents were correctly predicted to change routes, and 45 respondents were incorrectly predicted/had the possibility of not moving. Meanwhile, road users willing to pay for the ERP on A.P. Pettarani street were 178 respondents, including 122 respondents precisely predicted to stay through the street, while 56 respondents wrongly predicted/could move. The analysis found that after ERP implementation, based on the perception of route change, there was a 42% reduction in traffic volume, so traffic performance in the next five years can be estimated to increase due to the volume capacity ratio decreased, as shown in Graph 2. While based on the perception of mode shift, there will be a 40% reduction in traffic volume when ERP implementation is implemented so that traffic performance in the next five years will increase, as shown in Graph 3.
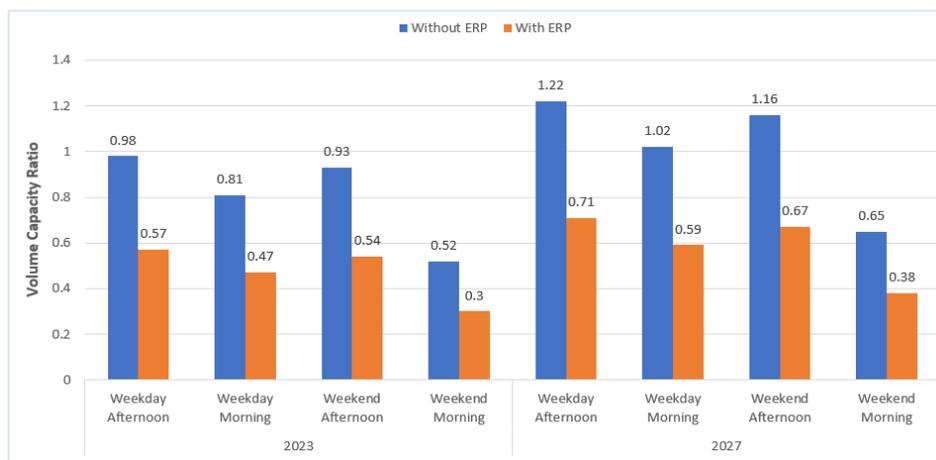
Graph 2. Comparison of traffic performance predictions in Segment 1 for the next five years in conditions without and with ERP intervention based on the perception of route shifts
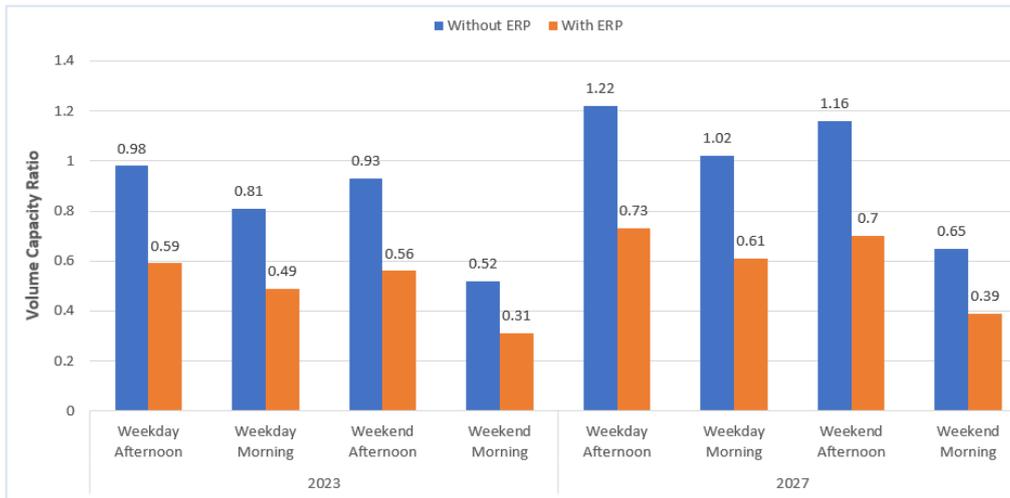
Graph 3. Comparison of traffic performance predictions in Segment 1 for the next five years in conditions without and with ERP intervention based on the perception of mode shifts

Based on the graph of the perception of route shifts and perceptions of mode shifts, it can be seen that ERP implementation effectively reduces traffic volume on A.P. Pettarani street. It reached the level of service (LOS) F in 2027 but can increase to level C with ERP implementation.

In implementing ERP, it is necessary to have the correct value for the application of costs for motorists who will pass A.P. Pettarani street. For this reason, the Willingness to Pay (WTP) method predicts what tariffs can be applied. WTP is the willingness of road users to spend a certain amount of money to be paid if they pass A.P. Pettarani street to implement ERP. Can be calculated using the formula:

$$WTP = \frac{\Sigma(\text{selected rate x number of respondents})}{Total\ Respondents} \quad (3)$$

The analysis of WTP was carried out based on data from 382 respondents who had chosen the nominal contained in the distributed questionnaire. Based on the results of the study, the WTP values for 4-wheeled and 2-wheeled vehicles are as follows:

Table 3 Distribution of WTP Value of 4-Wheeled Vehicles

Value of WTP	Total Respondents	Cumulative percent	Total
Rp 12.000	9	2%	Rp 0,283
Rp 10.000	142	37%	Rp 3,717
Rp 8.000	231	60%	Rp 4,838
	Total		Rp 8,838

Table 4 Distribution of WTP Value of 2-Wheeled Vehicles

Value of WTP	Total Respondents	Cumulative percent	Total
Rp 6,000	9	2%	Rp 0,141
Rp 5,000	113	30%	Rp 1,479
Rp 4,000	260	68%	Rp 2,723
	Total		Rp 4,343

Based on Tables 3 and 4, the average WTP value of respondents for 4-wheeled vehicles or more is Rp 8,838, and for 2-wheeled vehicles is Rp 4,343. The average value of the respondents' WTP obtained can determine the number of tariffs in the ERP policy on Jalan A.P. Pettarani.

Annual tariff adjustments to the Electronic Road Pricing policy on Jalan A.P. Pettarani Makassar City can be adjusted to the guidelines of the Toll Road Regulatory Agency (BPJT). BPJT evaluates and adjusts tariffs every two years based on the inflation rate and evaluates compliance with SPM (Minimum Service Standards) on toll roads or other paid roads (Republic of Indonesia, 2022).

4. CONCLUSIONS

The results of data analysis show that on the existing traffic conditions on A.P. Pettarani, the traffic flow was approaching unstable with Level of Service D on weekdays morning. It heads to level E in the afternoon, so drivers begin to experience short-duration traffic jams. Meanwhile, on weekends, traffic conditions remained stable in the morning with Level of Service C, although vehicle speed and movement were controlled by higher traffic volume. However, when it led to the afternoon, the traffic flow condition was approaching unstable, and there was short-duration congestion with Level of Service E. If this condition is not resolved immediately, the traffic conditions will worsen in 2027. The traffic performance forecasting results show that in 2027 the flow would reach traffic saturation because it reached VCR > 1 at Level of Service F.

The analysis result of a perception of route change and perception of mode shift shows that ERP implementation could solve this condition. It can be seen that by ERP implementation, traffic volume on the A.P. Pettarani was effectively reduced. The results show a decrease in traffic volume of 42% based on the perception of route changes after implementing the ERP. Meanwhile, based on the perception of modal shift, there will be a 40% reduction in traffic volume when the ERP implementation is implemented, which previously reached Level of Service F in 2027, and then increased to level C. Furthermore, If the ERP is implemented, then the tariff that is willing to be paid by vehicle users is in the average value of Rp 8,838 for four-wheeled vehicles or more and Rp 4,343 for two-wheeled vehicles. This value is obtained through a WTP survey that has been done, with a minimum initial value of willingness to pay adjusted to the value of toll road rates and parking rates in Makassar City. This value can be used to determine tariffs in ERP policies.

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Metoda GTAW Welding Joint Strength Study for AISI 1045 Application of Milling Tools

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Keywords:

GTAW Welding: AISI 1045 Steel: Mechanical Properties.

Abstract

Welding is a permanent connection process for metal materials using heat energy. The GTAW (Gas Tungsten Arc Welding) welding method is carried out on AISI 1045 steel material with a solid round shape, which has the characteristics and properties of the material slightly above low carbon steel. The welding process was carried out based on AWS A5.18 standard specifications in this study. by varying the welding amperage between ±70, ±90, and ±110 amperes as well as the ER70S-G series electrodes. To check the welding results with the amperage variation, perform tensile testing with standard ASTM A-370 testing, hardness testing using the Vickers method with standard ASTM E-92 testing, microstructure inspection, and grain size calculations as a control for the results of the hardness test. The focus of testing and inspection is carried out in three influential areas, namely, areas of weld metal, HAZ (Heat Affected Zone), and base metal. The results of this study show that for ±70 A welding amperage, the tensile test results in all samples breaking in the weld metal area. While welding amperage ±90A broke two samples in the weld metal area, welding amperage ±110A broke one sample in the weld metal area. For the hardness test results at ±110 A amperes, the hardness ratio in the weld metal area to the HAZ area shows that the difference in hardness is not too large compared to the two amperes used, so a welding amperage of ±110 A can be recommended. The microstructure test showed that most of the weld metal was pearlite and martensite, with a small amount of bainite. The hardness test showed that the weld metal was harder than the HAZ area and the base metal. Likewise, the results of grain size calculations using the Heyn method for regions with higher hardness make the grain sizes appear denser and smaller.

1. INTRODUCTION

One of the crucial production paths for most industrial businesses is welding as a fabrication technique. Welding is one of the primary manufacturing processes (Rudrapati, 2022). The selection of a welding technique depends on several parameters for a given application (Kumar & Singh, 2019). According to DIN (Deutsche Industrie Norman), welding is a metallurgical bond at a metal or alloy metal joint carried out in a melted or liquid state (Aditia et al., 2019). In other words, welding is a local, permanent connection of several metal rods using heat energy (Wiryosumarto in (Hardiyanto, 2020)). The GTAW welding method is a welding process that uses an arc between non-consumable tungsten electrodes at the welding point (Al Huda, 2019). The definition of welding, according to the American Welding Society (Pangaribowo & Putra, 2019), is a metal or non-metallic joining process that is carried out by heating the material to be joined to the melting temperature, which is carried out with or without using pressure or with or without using filler metal. According to Lawrence in (Anhar, 2019), welding is a metal joining process.

The welding process has many factors that affect the quality of the results, including the welding machine used, the materials used, the welding procedure, the welding method, the welding current, and the welder. This welding process is well-suited for fragile metals, making it possible to obtain high-quality welds (Dharma et al., 2022). This process uses argon shielding gas with or without applying pressure (Haikal et al., 2021). This process can be used with or without the addition of filler metal. The GTAW method is indispensable as a tool for many industries because it produces high-quality welding results with relatively low operating costs compared to other methods in its class (Li et al., 2021). In this study, the material used was AISI 1045 steel, namely carbon steel. Carbon steel has more substantial mechanical properties and is widely used as a machining tool because it has a relatively large carbon content of ±0.45%, a higher hardness level than low-

carbon steel (Purnomo et al., 2019). This research is intended for application to milling machine tools. Solid round samples with a diameter of 20 mm were chosen to approach the standard shape of milling tools. The results of this study can be used to join together two different materials or high-strength materials (Junaidi et al., 2022).

Gultom & Sabri's (2021) research showed that the average Brinell hardness test results for the mechanical properties of AISI 1045 steel for SMAW welding in the welding area with E-6013 electrodes at a current of 100 A was 160.04 BHN. For GTAW welding with TG-filer S50 at a current of 100 A, it was 172.53 BHN. The average value of SMAW welding voltage with an E-6013 electrode at 100 A current is 323.14 MPa, and that of GTAW welding with a TG-S50 filler at 100 A current is 411.57 MPa. The shape of the microstructure in the weld area with GTAW welding has a smaller microstructure than SMAW welding; this shows that the hardness value in the GTAW weld area is greater than the hardness value in the SMAW weld area. For fragile metals, we are making it possible to obtain high-quality welds.

Meanwhile, according to research conducted by Purnama (2022), SMAW welding has a greater tensile strength than GTAW welding. SMAW welding has the highest tensile strength of 52.43 Kgf/mm2 and the lowest tensile strength of 31.22 Kgf/mm2. At the same time, GTAW welding has the highest tensile strength of 31.88 Kgf/mm2 and the most insufficient tensile strength of 18.84 Kgf/mm2. Based on the findings of microstructural analysis by Banjarnahor (2019), microstructural analysis shows that specimens without welds have ferrite and pearlite microstructures, welded areas have cementite microstructures, and HAZ areas have bigger ferrite and pearlite microstructures. The Solidworks simulation's joint strength is 698 MPa with a tensile force of 36000 N.

Based on the background above, this study's formulation of the problem is to get the proper welding amperage for AISI 1045 steel using the GTAW method based on AWS A5.18 standard welding specifications. Mechanical properties are tested and inspected due to variations in the amperage of the welding performed (Kumar & Singh, 2019). The research aimed to find the proper welding amperage based on the AWS A5.18 standard for joining worn milling tools (Wardani et al., 2020). Scope of the problem the material used as the workpiece is AISI 1045 steel with a carbon content between (0.3 - 0.6%) with a solid sample form Ø=20 mm in diameter with AWS A5.18 standard welding specifications using amperage variations between (±70 - ±110) Amperes.

2. METHODS

The research method used experimental and observation techniques. The empirical research method is used to find the effect of specific treatments (Sugiyono, 2019). Exploratory research is one method that uses a quantitative approach (Sari et al., 2022). This research was carried out with the preparation of materials and equipment adapted to field conditions. The AISI 1045 material with a diameter of 20 mm as a sample was cut to a length of 220 mm based on the tensile test standard, ASTM A-370, as shown in Figure 1.

Furthermore, all the tensile samples were cut using a cutting machine into two parts. The next step is making a weld seam with a single V shape on both parts to be connected (see figure 3. Next, the welding process was carried out using the GTAW method with amperage variations of ±70, ±90, and ±110 based on the AWS A5.18 standard, after that the removing capping process was carried out using a lathe of result welding below figure 4.

Before the tensile test, the welding results are checked for NDT (Non-Destructive Tests) using the dye-penetrant method in figure 5. From the tensile test results, only samples that break off in the base metal area will be examined and tested. Three regions have an impact on the results of the welding, namely: the weld metal area, HAZ, and base metal area (Hammi et al., 2021). and then to be observed and analyzed as a recommendation for welding on materials with high strength or combining materials with different types.
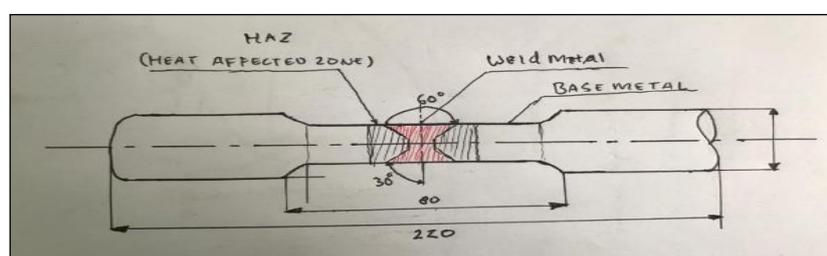
Figure 1 Research sample planning.

Tensile testing is one of the mechanical tests that aim to determine the mechanical properties of a metal, namely, among others, tensile strength, yield strength, and strain (Mahalle et al., 2019). The highest tensile strength refers to the quality of the weld (Bukhori, 2021). Then the test results are analyzed using a flowchart, as shown in Figure 2. This research is planned to facilitate the stages of the research process that will be carried out. The welding amperage is independent, while the fixed variable is the AWS A5.18 standard (Sayed et al., 2019).
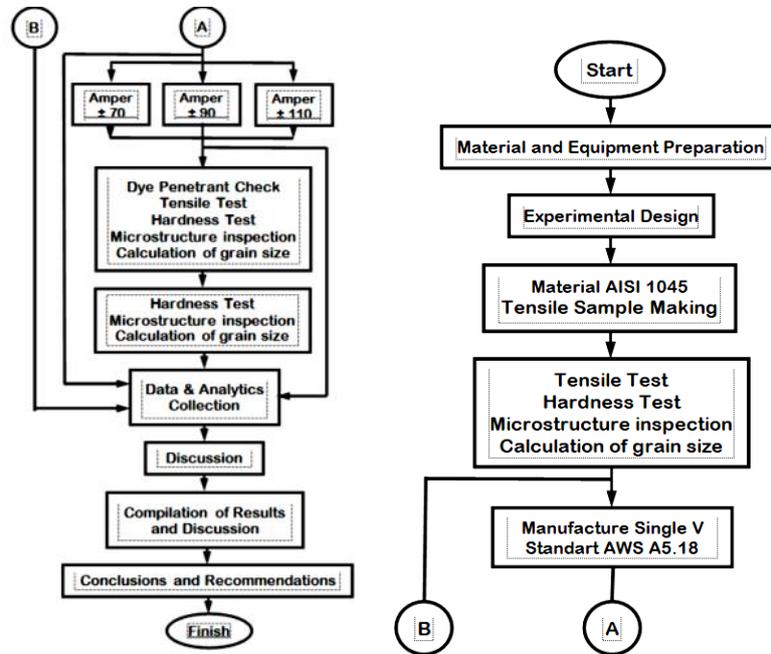
Figure 2 Research flow chart

3. RESULT AND DISCUSSION

After the cutting process is carried out according to the length and size required, the next step is to make welding seams by turning the seam angle to 60°, as shown in Figure 3 below.

Figure 3 The results of turning the sample from a single V

The welding process is carried out with a sample size of Ø:20 mm in diameter and 220 mm in length, according to the standard size of the tensile test, where the welding process is carried out in three layers. After the welding process is carried out, the next step is to remove the welding capping utilizing the turning process, as shown in Figure 4 below.

Figure 4 Results of welding and turning processes.

The next step is to carry out a non-destructive inspection (NDI) process, which is carried out using the dye-penetrant method. This inspection will provide information regarding the presence of cracks visually after the welding process and the removal of weld chips.

Figure 5 Results of dye-penetrant inspection

The dye-penetrant inspection of the welding process results showed that for the welding amperage of ±70 amperes, many red spots appeared on the three samples, as shown in Figure 5b. This indicates that the welding process using ±70 amperes resulted in many defects. Whereas for welding at ±90 amperes, there were several red spots visible in one sample, for welding at ±110 amperes, it showed very few red spots visible in all samples, so the defects that occurred for welding at ±110 amperes were quite good.

Table 1. Tensile test data from welding AISI 1045 materials

No	Sample	Ultimate Tensile Strength (Mpa)	Tensile Stress Yield (Ofseet 2%) (Kgf/mm2)	Maximum Load (KN)	Information
	Raw Material	707,20	680,27	68,64	
	Amper ±70				
1	Sample 1.1	316,22	288,52	39,869	Break up in welded metal
2	Sample 1.2	365,90	311,91	46,351	Break up in welded metal
3	Sample 1.3	248,16	297,11	45,292	Break up in welded metal
	Rata-rata	310,09	229,18	43,837	
	Standart Deviasi	48,25	70,64	2,84	

	Amper ±90				
1	Sample 2.1	596,76	458,38	80,187	Break up in welded metal
2	Sample 2.2	607,74	489,15	76,502	Break up in base metal
3	Sample 2.3	354,72	263,70	45,218	Break up in welded metal
	Rata-rata	519,74	405,74	67,300	
	Standart Deviasi	202,25	299,90	15,69	
	Amper ±110				
1	Sample 3.1	576,00	494,07	78,824	Break up in base metal
2	Sample 3.2	600,51	518,73	74,166	Break up in welded metal
3	Sample 3.3	615,42	555,15	82,821	Break up in base metal
	Rata-rata	797,31	522,65	78,600	
	Standart Deviasi	159,91	25,09	3,54	

At ±70 A amperage, an average tensile stress of 229.18 N/mm^2 was obtained, and all samples broke in the weld metal area. While welding at a current of ±90 A, it got a moderate tensile stress of 405.07 N/mm^2. In sample 2.2, it broke in the base metal area, and the average tensile stress in welding amperes of ±110 A was 522.65 N/mm^2. Two samples broke in the base metal area, namely samples 3.1 and 3.3, where the average tensile stress with amperage ±110 A is the greatest compared to the other two types of amperage.

Figure 6 Sample evidence of tensile test results

Figure 6 above shows the sample results from the tensile test that has been carried out. For a welding amperage of ±110A, two samples break off in the base metal region. This welding amperage can be a reference for the welding.
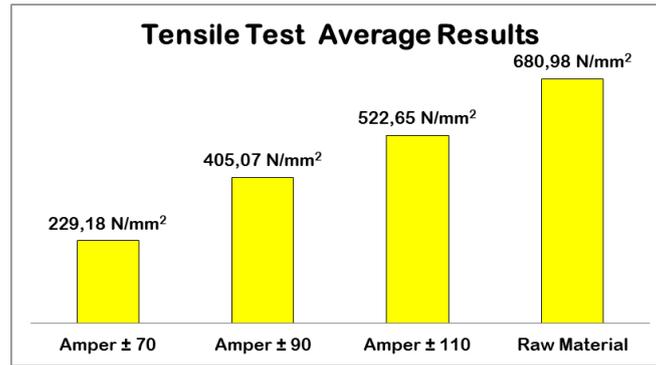
Figure 7 Comparison graph of tensile test results

The hardness graph below shows that the highest average hardness value in the weld metal area is ampere ±110A, with a hardness value of 268.13 HV. The most important thing from this hardness result is the hardness comparison between the weld metal area of 226.13 HV, the HAZ of 227.22 HV, and the base metal of 225.45 HV, and this ratio is not too big. So that the two samples broke up in the base metal region. Meanwhile, at ±90A welding amperage, the difference in hardness between the weld metal area and the HAZ is significant enough that one sample breaks off in the base metal area (Sugestian, 2019). The weld was not tested for hardness while welding at ±70A ampere because three samples broke in the weld metal area.
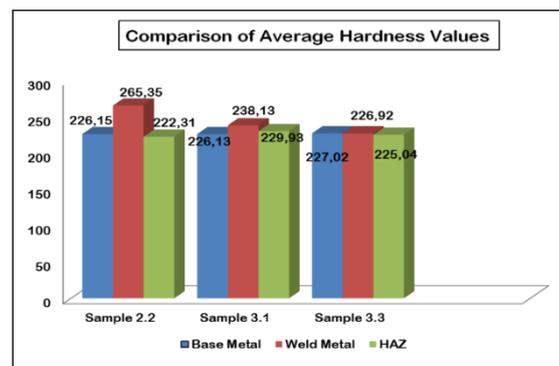
Figure 8 Graph of hardness test comparison

There is no significant difference in hardness in the base metal area for all samples. This is because the AISI 1045 material consists of a ferrite structure, which is white or light in color, while the pearlite structure, which looks dark, is grey. This is because there are no significant microstructural changes in this area. After all, it is not affected by the effects of heat caused by welding. The influence of the heat effect is concentrated in the weld metal area and the HAZ area for materials with a carbon content of around 0.46%, so this material is quite complicated. As shown in Figure 9, the obtained microstructure shows a boundary between the base metal and the weld metal, which have different surface shapes.

From the microstructure data obtained, the grain size can be calculated. By using the Hyne method equation, as in the formula below,

$$Dm = \frac{L.p.10^3}{Z.V} (\mu m) \qquad (1)$$

Note: The length of the line is 60mm

P: Number of lines 6

Z: The number of truncated grains

V: Enlargement of microstructure

This grain size is calculated as a comparison control for the hardness value in each welding area, with the welding amperage variation as the independent variable. Meanwhile, the microstructure obtained was only in samples that broke off in the base metal area, namely when welding at amperes of ±90 and ±110A.
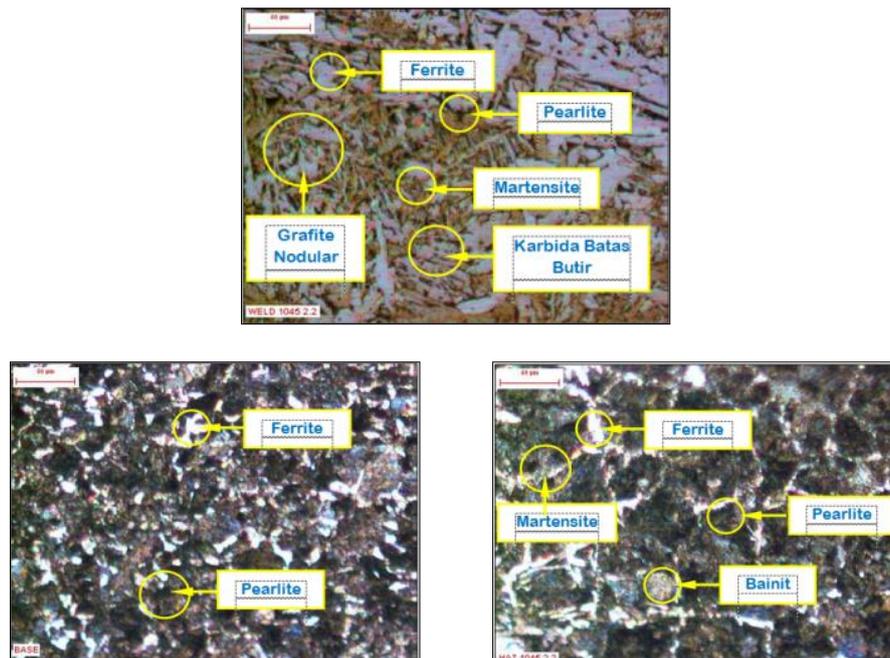
Figure 9 Microstructure of ±90 ampere welding results

The phases that appear in the base metal area at ±90 A welding amperage with 500x magnification are the white ferrite phase, which merges with the dark black pearlite phase, which collects with a large enough area to combine with the ratio of ferrite seen to be less than pearlite, which is more numerous around 60% for steel with a carbon content of around 0.46%. Whereas in the HAZ area, the white ferrite phase looks much reduced, while the dark black pearlite also begins to decrease and gather to enlarge. This is due to the influence of heat. There is a slight martensite phase that appears due to the effect of heat caused by the welding process, and this phase is sharp and rough in shape, and there is a tiny bit of bainite phase, which is in the form of a soft round shape. A slight pearlite phase remains visible for the weld metal area, while the ferrite phase changes to a nodular graphite phase. While the martensite phase is present in sufficient quantities and a small carbide phase is current, this area is more complex than the base metal and HAZ regions.

Figure 10 Microstructure of ±110 ampere welding results

In the base metal area for ±110 A welding amperage with 500x magnification, a white ferrite phase is still seen much less with increasing welding current. Meanwhile, the dark black pearlite phase blends quite nicely with ferrite, which appears less and less than pearlite, which has a higher concentration. In the HAZ region, the white fe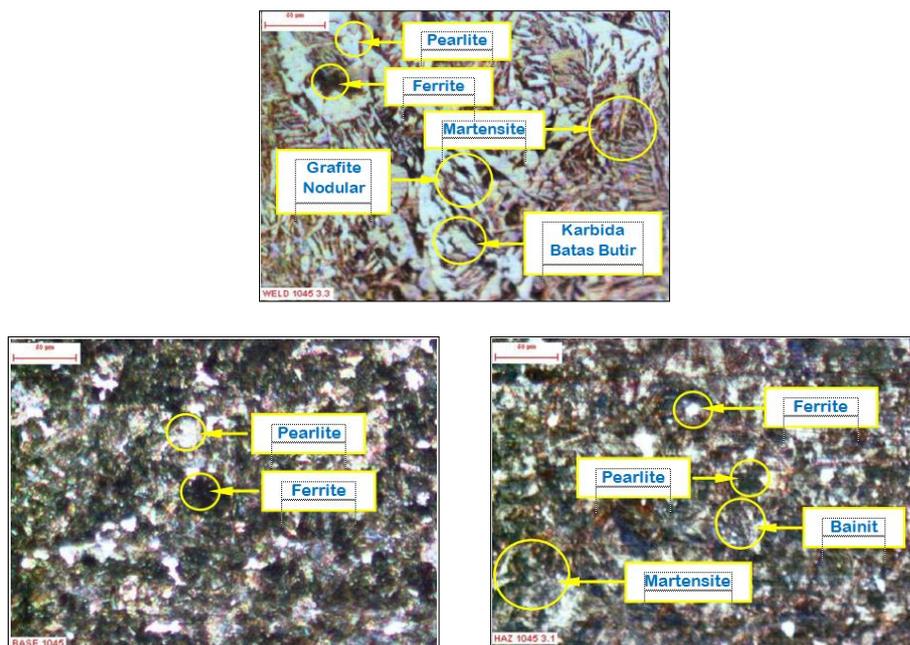rrite phase seems much reduced compared to the base metal area, while the dark black pearlite phase in this area is much reduced. While the martensite phase occurs as a result of the effect of heat caused by the increase in the amperage of the welding process being carried out, this phase has a sharp shape, and there is much less of the bainite phase, which has a soft round shape with increasing welding current. There is still less pearlite phase in the weld metal area, while the ferrite phase has changed to a nodular graphite phase. Meanwhile, the martensite phase is much more abundant with increasing welding current, and there is less grain boundary carbide phase, so this area is more complex than the base metal and HAZ areas (Moghaddam & Kolahan, 2021). The hardness value results from the hardening process, transforming the soft ferrite or austenite microstructure into a complex martensite structure (Saputra, 2020).

Table 2 Calculation of grain size

No	Sample	Zone	Z value	Item size value
1		*Base metal*	3300	109,1 µm
2	±70 A	HAZ	2500	144 µm
3		*Weld metal*	5600	64,2 µm
1		*Base metal*	3700	97,3 µm
2	±90 A	HAZ	3300	110 µm
3		*Weld metal*	5200	70 µm
1		*Base metal*	3400	105 µm
2	±110 A	HAZ	2700	133,3 µm
3		*Weld metal*	5200	69 µm

The results of the grain size calculation shown in Table 2 above show that the smaller the grain size, the more complex the rock in that area. This explains that the hardness test results are correct because an error in attaching the hardness testing penetrator to the workpiece will result in inaccurate hardness calculation results.

4. CONCLUSIONS

Based on the examination of the chemical composition of AISI 1045 steel, medium carbon steel has a carbon content of around 0.46%, while the standard carbon content is in the range (of 0.25% - 0.60%). From the welding amperage tensile test results of ±110A, the average tensile strength was around 55.265 N/mm^2, one sample broke in the weld metal area, and two samples broke in the base metal area. This explains that large welding amperes can be recommended for welding with high-strength steel materials for welding AISI 1045 steel with the GTAW method based on the AWS A5.18 standard. While the average tensile strength for welding using high welding amperes approaches the raw material tensile strength of 68,098 N/mm^2.

The Vickers method was used to test the hardness from the results of welding AISI 1045 material in three welding areas, including; the area of weld metal, HAZ, and base metal. Amperage ±70A is not carried out for welding because all samples break in the weld metal area, so this amperage is not recommended. The welding amperage of ±90A in sample 2.2 breaks in the base metal so that this sample can be tested for hardness. For the weld metal area, the hardness is 265.35 HV, while for the HAZ area, the hardness is 222.32 HV for the base metal area, 226.15 HV. Meanwhile, the difference in hardness between the weld metal area and the HAZ area is around 43 HV. For the welding amperage of ±110A for sample 3.1, the hardness value of the weld metal is 238.13 HV, while in the HAZ area, the hardness value is 229.93 HV and the base metal is 226.13 HV so that the hardness difference between the weld metal area and the HAZ area is 8.2 HV. Whereas in sample 3.3, the hardness value of the weld metal was 226.67 HV, while in the HAZ area, the hardness was around 225.04 HV, this difference was not significant, around 1.6 HV, while in the base metal area, it was 227.02 HV.

The difference in hardness between the weld metal area and the HAZ area should be more negligible, the slightest difference is better, and it is possible to break in the base metal area.

With a magnification of 500x, it can be seen that the white ferrite phase and the dense black pearlite phase gather with a large enough area to blend with a smaller ferrite ratio compared to thicker pearlite, which is around 60% in the base metal region. The ferrite and pearlite phases are reduced for the HAZ region, and the aggregate is enlarged. This area contains a small amount of martensite due to the heat from the welding process, and this phase has a rough, sharp shape and a small amount of soft, rounded bainite. A slight pearlite phase remains visible for the weld metal area, while the ferrite phase changes to a nodular graphite phase. While the martensitic phase is appreciable and a small carbide phase is present, this region is more complex than the base metal region. In this study, based on the results of the tests carried out, current variations affect the welding process's tensile strength, hardness, and microstructure. The use of high amperage in this welding can be recommended, especially for welding the combination of different materials, such as welding between HSS (High-Speed Steel) and AISI 1045, for further research. Grain size calculations were carried out using the Heyn method from the microstructure taken from the welding results as a control for hardness testing. The grain size calculations show that the hardness results are significant, especially in the area of weld metal, where the grain size is getting smaller. The hardness data and grain size calculations are appropriate.

5. ACKNOWLEDGMENTS

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Comparative Performance Results of Classification Algorithm in Data Mining to Identify Types of Glass Based on Refractive Index and Its Elements

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Abstract

Keywords:

Performance evaluation; Classification algorithm; Data mining; Glass

Data science is becoming familiar to the public and companies in the era of the Industrial Revolution 4.0. One part of data science is data mining. Data mining is the process of collecting information to see patterns from very large datasets and data discovery which is processed in such a way as to become knowledge based on the interpretation of the information obtained. This paper aims to compare the performance evaluation results of several classification algorithms in data mining (such as DT C-45, Neural Network, KNN, LDA, Naïve Bayes, SVM, and Rule Induction) for identifying types of glass based on its elements and the refractive index. The dataset used is a glass identification dataset from the *UCI Machine Learning Repository*. The results of the evaluation can be seen from the criteria like Accuracy and Kappa using *10-fold-cross validation*. As a result, the K-Nearest Neighbors (KNN) algorithm has the best Accuracy and Kappa values, namely 72.90% for Accuracy and 0.632 for Kappa values. To determine the significance of the accuracy value, the T-Test method is used.

1. INTRODUCTION

One of the most frequently used data mining functions is classification. The Classification method is *supervised learning* where the main objective is to find a model or characteristic of a class from a dataset and can predict or identify test data into a particular label or class (Larose, D. T., & Larose, C. D.2014). The classification algorithm that is often used in the classification process is a Decision Tree, Support Vector Machine (SVM),Neural Network (NN), K-Nearest Neighbor (KNN), Naïve Bayes (NB), Linear Discriminant Analysis (LDA), Rule Induction (RI), and so on.

Each classification algorithm must have its advantages and disadvantages. Therefore, one algorithm cannot be certain that it is better than another. It may be that an algorithm is very suitable for a particular dataset but very bad for another dataset. For that, it is necessary to evaluate the performance of each algorithm in a dataset so that it can be concluded that the algorithm is best applied to the dataset.

In this article, the dataset used is the glass identification dataset taken from the *UCI Machine Learning Repository*. The importance of developing a classification method that can assist in identifying glass types effectively and efficiently. This dataset contains seven *types of glass* whose formation process is influenced by the *refractive index* and the composition of the elements, namely *Sodium (NA), Magnesium (MG), Aluminum (Al), Silicon (Si), Potassium (K), Calcium (Ca), Barium (Ba), and Iron (FE)*. For the *types of glass* variable, there are seven, namely *(1) vehicle windows non float processed, (2) vehicle windows float processed, (3) Building windows float processed, (4 building windows non float processed), (5) headlamps, (6)) tableware, (7) containers*. Therefore, seen from the existing attributes, it is very suitable to carry out the classification process for this dataset where the variable type of glass is used as the label/class while the refractive index variable and the composition of the elements are used as attributes.

There have been many classification algorithms developed, but it is still unclear which algorithm is the most effective and efficient in classifying glass types. Therefore, this study was conducted to compare the performance of several classification algorithms on glass identification datasets. By knowing which

classification algorithm is the most optimal, it is hoped that it can help improve the accuracy and efficiency of identifying glass types better. In addition, this study also aims to increase understanding of the use of classification algorithms in data processing and provide information about the performance of the classification model used in this study. Thus, it is hoped that the results of this research can be useful for the development of better classification methods in the future (Awopetu, O. A., & Olugbara, O. A. 2016).

The significances of this research are:

1. Improving the quality of glass products: With a more accurate and efficient classification algorithm, it is hoped that it can assist glass manufacturers in better-identifying types of glass to improve the quality of glass products.
2. Prevent accidents: Using the wrong type of glass can cause accidents, therefore a better classification algorithm is expected to prevent accidents caused by using the wrong type of glass.
3. Development of classification methods: This research can contribute to the development of classification methods in the field of data processing.
4. Development of technology: The results of this research can also be applied to other fields of technology such as the development of object recognition systems, facial recognition, and others that require classification methods.
5. Adding insight: The results of this study can also increase understanding and knowledge of the classification algorithm on the glass identification dataset and the performance evaluation technique of the classification algorithm.

A previous study using a *glass identification dataset* conducted by Mus Mulyadi Baharuddin et all, only used the KNN algorithm to identify the type of glass and the results reached 64% accuracy, 63% precision, 71% recall, and 67% F-Measure where the K value the best is at K = 3 (Baharuddin, M. M., Azis, H., and Hasanuddin, T.2019). Research conducted by 1. E. Karlik and O. Baykan (2009) resulted that SVM can classify glass types properly. And for research conducted by A. Kumar and A. Kumar (2014), it was found that the KNN algorithm can identify the type of glass based on its constituent elements well, it's just that it is often wrong to identify the type of float glass by reading window glass. Research conducted by S. Sultana and S. Islam (2014) shows that the decision tree can be used to classify the type of glass from the Glass Identification dataset well.

For research on the comparison of classification algorithms that was carried out by Pandito Dewa Putra (Putra, P. D., & Rini, D. P.2020) in predicting heart disease, the best algorithm in the dataset used was the Naïve Bayes algorithm with an accuracy of 84.07%(Putra, P. D., & Rini, D. P. 2020). In addition, Kawsar Ahmed et al. (Ahmed, K., & Jesmin, T.2014)compared the performance of algorithms to predict diabetes, it was found that the best classification algorithm was the Bagging algorithm with an accuracy value of 85.2308%.

Based on the background above, this research aims is to compare the performance of several classification algorithms in identifying types of glass based on their refractive index and elemental composition.

2. METHODS

The application used in this study is Ms. Excel 2016 for collecting data and preprocessing data and RapidMiner Studio Version 7.6 (update 2022) for data processing such as modeling, validation, and significance test.

The flow chart in this study is
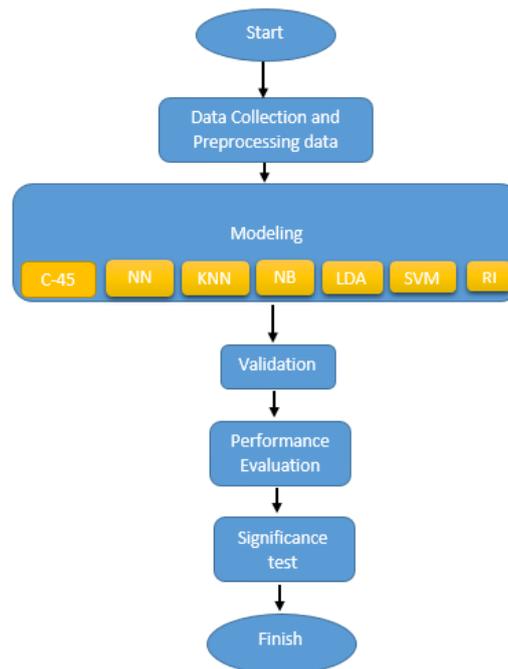
Figure 1. Flowchart

2.1 Data Collection and Preprocessing Data

The dataset used in this study was obtained from the *UCI Machine Learning Repository*, namely the glass identification dataset. The UCI Machine Learning Repository is an online repository that provides various sets of data that can be used for machine learning purposes. This repository is maintained by the University of California, Irvine (UCI) and provides a variety of data types, including numeric, textual, and image data. These data have been processed and organized so that they can be used for various purposes, such as developing prediction and classification models, data analysis, and developing artificial intelligence applications. Data sets in the UCI Machine Learning Repository are frequently used in academic and industrial research and machine learning competitions. (Kelleher, J. D., Tierney, B., & Tierney, B.2018)

All processes in this study started from data input to significance testing using the Rapidminer Studio 7.6 software. In this dataset, there are 10 variables, namely *type of glass*, *refractive index,* and composition of its elements, *Sodium (NA), Magnesium (MG), Aluminum (Al), Silicon (Si), Potassium (K), Calcium (Ca), Barium (Ba), and Iron (FE)*. For the *types of glass* variable, there are seven, namely *(1) vehicle windows non float processed, (2) vehicle windows float processed, (3) Building windows float processed, (4 building windows non float processed), (5) headlamps, (6)) tableware, (7) containers.*

For the type of data, only the *type of glass* variable is polynomial, while the other is real (numeric). Therefore, if we look at the data contained in this dataset, it is very suitable for a classification process, where the *type of glass* is the *label/class*, while the refractive index and elemental composition are *attributes*.

Name		Type	Missing	Filter (10 / 10 attributes):		
∨	Label **Tipe**	Polynominal	0	Least 6 (9)	Most 2 (76)	Values 2 (76), 1 (70), ...[4 more]
∨	**RI**	Real	0	Min 1.511	Max 1.534	Average 1.518
∨	**Na**	Real	0	Min 10.730	Max 17.380	Average 13.408
∨	**Mg**	Real	0	Min 0	Max 4.490	Average 2.685
∨	**Al**	Real	0	Min 0.290	Max 3.500	Average 1.445
∨	**Si**	Real	0	Min 69.810	Max 75.410	Average 72.651
∨	**K**	Real	0	Min 0	Max 6.210	Average 0.497
∨	**Ca**	Real	0	Min 5.430	Max 16.190	Average 8.957
∨	**Ba**	Real	0	Min 0	Max 3.150	Average 0.175
∨	**Fe**	Real	0	Min 0	Max 0.510	Average 0.057

Figure 2 Statistics from the *glass identification* dataset

By looking at Figure 2, it is very clear that there is no missing data and all data looks normal so that it can be continued to the next process, namely modeling.

2.2 Modeling

There are seven classification algorithms chosen for the modeling process in this study, namely: Decision Tree, Support Vector Machine (SVM),Neural Network (NN), K-Nearest Neighbor (KNN), Naïve Bayes (NB), Linear Discriminant Analysis (LDA), Rule Induction (RI),. The seven algorithms were chosen because they are the most known algorithms so far for the classification process.

Each classification algorithm must have its advantages and disadvantages. Therefore, one algorithm cannot be certain that it is better than another. It may be that an algorithm is very suitable for a particular dataset but very bad for another dataset. For that, it is necessary to evaluate the performance of each algorithm in a dataset so that it can be concluded that the algorithm is best applied to the dataset.

2.2.1 Decision Tree C-45

Decision Tree C4.5 is the development version of Decision Tree ID3 initiated by Quinlan (Quinlan, J.R. 1996). The strong point is the Decision Tree Algorithm. C-4.5 is capable of dealing with features with numeric types, performing decision tree *pruning*, and obtaining rule sets. However, Algorithm C-4.5 also still relies on the Gain criteria, namely the Gain Ratio to determine the features that break up the nodes in the induced tree (Witten, I.H., Frank, E., Hall, M.A., Pal, C.J., and DATA, M.2005)

The process of the Decision Tree C4.5 induction is as follows (Gorunescu, F.2011):
1. The initial process, namely determining Entropy (E) for the root node on the class/label composition

$$E(s) = -\sum_{i=1}^{m} p(w_1|s) \, log_2 p(w_1|s) \qquad (1)$$

Where $p(w_1|s)$ is the proportion of the ith class in all processed data at node s. $p(w_1|s)$ is obtained from the sum of all rows of data labeled class I divided by the number of rows of all data, while m is the number of different values in the data.
2. Furthermore, for numeric attributes, the best 'v' value must be determined to be used as a solver value by calculating its *Gain value*. The value with the highest Gain will be used as the Solver value for each attribute of the numeric type

$$G(s,j) = E(s) - \sum_{i=1}^{n} p(v_1|s) \times E(s_i) \tag{2}$$

Where $p(v_1|s)$ is the proportion of values of v that appear in the class in the node. $E(s_i)$ is the entropy of composition of the value v from the *j-th* class in the *i-th* data node and n is the number of different values in that node.

3. Then calculate the *Entropy* of each attribute against the class/label, then calculate the *Gain* for each attribute. The attribute that has the highest Gain value will be used as the root node.
4. Next, the split position is a count for the attribute that has become the root node by counting the *gain ratio*. To count the *gain ratio*, first, count the *split info*.

$$Splitinfo(s,j) = -\sum_{i=1}^{k} p(v_1|s)\, log_2 p(v_1|s) \tag{3}$$

$$GainRasio(s,j) = \frac{G(s,j)}{Splitinfo(s,j)} \tag{4}$$

Where *k* represents the number of fractions, in the same way in Eq. 4, we get the *gain ratio* for the other options. The highest *gain ratio* will be the next branch node under the *root node*.

5. For the next node, repeat steps 1-4 by calculating the *Entropy, Gain,* and *Gain ratio* using the remaining data from the node process above.

Continue recursively on each of the next branch nodes by repeating steps 1-5 until all data in each node provides only one *label class*. The nodes that cannot be broken down are called the *leaf nodes* containing the decisions (*label classes*).

Excess of Decision Tree C-45:

1. Easy to understand and interpret by humans because the resulting model is in the form of a decision tree that can be easily explained.
2. Able to handle numeric and categorical data.
3. C-45 can handle incomplete data by deleting data or using the average value of the missing attribute.
4. C-45 can be used to build more complex models by combining multiple decision trees.

Lack of Decision Tree C-45:

1. Overfitting: The C-45 can produce very large and complex decision trees, which have the potential to overfit the training data.
2. Sensitive to noise: The C-45 is sensitive to noise in data, which may affect model performance.
3. Limitations in dealing with continuous problems: C-45 cannot deal with continuous problems effectively without preprocessing first.
4. Difficulty in handling minority classes: C-45 tends to produce decision trees that ignore minority classes, which can reduce the model's performance in classifying unequal data.
5. Limitations in handling linear relationships between features: C-45 cannot handle linear relationships between features well and requires more complex algorithms to solve them.

2.2.2 Neural Network (NN)

The Neural Network (NN) algorithm is a type of machine learning algorithm that is used to classify data. NN works by adopting the workings of the human brain which processes information in a parallel and distributed way. (E. Prasetyo, 2014).
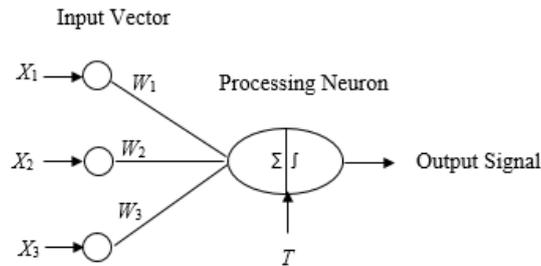
Figure 3. NN design in general

From Figure 3, The NN algorithm for classification consists of several layers consisting of neurons (x). The neurons are connected by a weight that can be adjusted during the model training process. The Activation Function (T) is a mathematical function that is used for each neuron to produce output based on the input received and the weights set. There are three types of layers used in NN, namely:

1. Input Layer: The first layer on the NN functions to receive input from the input data.
2. Hidden Layer: The middle layer in the NN which functions to carry out the transformation process on the input received from the previous layer.
3. Output Layer: The last layer in the NN which produces output in the form of class predictions from the data provided.

The advantages of the Neural Network (NN) algorithm for classification (Brownlee, J.2021):

1. Ability to process complex and unstructured data: NN can handle unstructured data such as images, text or sound well, making it very suitable for classification tasks on complex data.
2. Ability to classify large data: Compared to traditional classification methods, NN can process larger data more quickly and accurately.
3. Ability to learn independently: NNs can learn on their own from the data provided and improve the performance of their models automatically.
4. Ability to solve multicollinearity problems: NN can solve multicollinearity problems in data which means the independent variables have a correlate with each other.

Disadvantages of the Neural Network (NN) algorithm for classification (Li, M., Deng, X., Du, X., Hu, J., & Yang, J. 2020):

1. Algorithm complexity: The NN algorithm is complex algorithm and requires considerable time and resources to learn, implement and execute.
2. Reliance on training data: NNs require large and representative training data in order to learn and improve their models properly. If the data is unrepresentative and incomplete, the performance of the Neural Network model may decrease.
3. Overfitting: NNs can overfit if there are too many trainers with training data, affecting model performance on data that has never been seen before.
4. Difficulty in the interpretation of results: The results of the NN algorithm can be difficult to interpret and explain due to the complexity of the algorithm. It becomes a challenge for the user to explain the results produced by the NN model to others.

2.2.3 K-Nearest Neighbor (KNN)

The K-Nearest Neighbors (KNN) algorithm is one of the machine learning algorithms used for classification or regression. In classification, the goal is to predict the class of data based on the classes in the training data. (Gorunescu, F.2011).

The KNN algorithm works by calculating the distance between test data and existing training data. The training data that has the closest distance to the test data will be used to predict the class of the test data.

KNN assumes that data that are closer together tend to have similar characteristics. Therefore, KNN is often referred to as the "nearest neighbor" method. (Kelleher, J. D., Tierney, B., & Tierney, B. 2018)

The KNN algorithm process for classification can be explained as follows:

1. Determines the value of K (number of nearest neighbors) be used.
2. Calculate the distance between the test data and all training data using distance metrics such as Euclidean distance, Manhattan distance, or Minkowski distance.
3. Take the K training data that has the closest distance to the test data.
4. Voting to determine the class of test data. If K = 1, then the class of the test data is taken from the training data class that has the shortest distance. If K > 1, then the class of the test data is determined based on the majority of the classes from the closest K training data.
5. Returns the class predicted from the test data.

The advantages of the K-NN for classification are:

1. KNN can be used for multiclass classification.
2. KNN can be used on unstructured data, such as image data or text.
3. KNN can be used on small datasets or with a small number of features.
4. KNN is easy to understand and implement.

However, there are several drawbacks to the KNN algorithm, including:

1. KNN requires a long computational time to calculate the distance between data during training, especially on large datasets.
2. KNN requires optimal K parameter settings to produce accurate results. Incorrect setting of the K parameter may result in underfitting or overfitting.
3. KNN is susceptible to data that contains noise or outliers, which can affect classification significantly.
4. KNN cannot generalize to data that has never been seen before. This means that KNN cannot be used to make accurate predictions on data that has never been seen before. (Yadav, S. K., Kumar, P., & Singh, V. K.2021)

2.2.4 Naïve Bayes (NB)

The Naive Bayes algorithm is a probabilistic classification method based on Bayes' theorem. This algorithm is often used in text processing and data classification, especially in email spam classification and sentiment analysis.

Basically, the Naive Bayes algorithm works by calculating the probability that input data belongs to a certain class based on the frequency of occurrence of certain features in the data. (Zhang, H., & Liu, Y. 2021).

Mathematically, to carry out a classification using the Naive Bayes algorithm, it is first necessary to calculate the posterior probability, namely the class probability (y) for the given features (x). Then, the class with the highest probability will be selected as the output class.

The Naive Bayes algorithm is considered "naive" because it assumes that the features in the input data are independent of one another. Although this assumption is often not met in real data, the Naive Bayes algorithm can still provide good classification results in many cases.

The Naive Bayes algorithm can be used in various applications, such as text classification, image classification, and numeric data classification. The advantages of the Naive Bayes algorithm are that it is simple, fast, and can be used for large datasets. However, the downside is the assumed independence between attributes, which can result in lower accuracy in some cases. (Raschka, S., & Mirjalili, V.2021)

2.2.5 Linear Discriminant Analysis (LDA)

The Linear Discriminant Analysis (LDA) algorithm is a data analysis technique used to project multi-dimensional data into a lower-dimensional space for classification purposes. LDA tries to find a line or linear plane that can distinguish between different classes of data. (Zhang, Z., Chen, J., Wang, J., & Li, C. 2022)

The general steps in LDA are as follows:

1. Compute the mean and covariance matrices of each class.
2. Calculate the scatter matrix between classes and the scatter matrix within classes.
3. Calculate the Fisher matrix which is the inverse of the within-class scatter matrix multiplied by the inter-class scatter matrix.
4. Calculate the eigenvalues and eigenvectors of the Fisher matrix.
5. Sort the eigenvectors based on their associated eigenvalues and take the top few eigenvectors to form a transformation matrix.
6. Use a transformation matrix to project data into a lower-dimensional space.
7. Classify the projected data using simple classification algorithms such as k-nearest neighbor (KNN) or logistic regression.

Overall, LDA is a powerful algorithm for data classification with well-defined features and a sizeable amount of data. However, LDA can become less effective when there is a lot of noise or when there are too few data samples in the training set. (Liu, B., Zhu, Y., & Zhang, L.2021)

2.2.6 Support Vector Machine (SVM)

The SVM (Support Vector Machine) algorithm is a machine learning method used for classification and regression. SVM works by building a model that can separate two different data classes with a hyperplane (hyper field) that has the largest margin (distance) between these classes.. (Javed, K., Gani, A., & Khan, S.U.2021)

Following are the general steps of the SVM algorithm for classification:

1. Entering data and labels into the SVM model.
2. SVM will find the best hyperplane to separate the two classes. This hyperplane will be selected based on the largest margin between the two classes, thereby minimizing misclassification.
3. Then, SVM will take into account several support vectors, namely data that is closest to the hyperplane. This support-vector will affect the location of the hyperplane and the resulting margins.
4. Once the hyperplane and margins are found, SVM will classify the new data by entering it into the model and seeing where it is relative to the hyperplane. The new data will be classified into the appropriate class according to its position relative to the hyperplane. (Figueiredo, M.A., & Gama, J.2021)

The advantages of SVM in the classification of data mining are as follows:

1. Able to solve classification problems on complex data with high dimensions.
2. Very effective in overfitting the training data.
3. Able to handle cases of unbalanced data (imbalanced data) well.
4. SVM has strength in separating contiguous or contiguous classes.
5. Can use different types of kernels to project data to different feature spaces.

Disadvantages of SVM in the classification of data mining, namely:

1. Not effective in dealing with non-linear data without using the right kernel.
2. It takes a long time to train models on large data.
3. Very sensitive to parameter settings, such as kernel parameters and C parameters.
4. SVM tends to require more memory and computation compared to other classification algorithms. (Deng, Y., Qian, Y., Chen, Y., & Xie, C.2021)

2.2.7 Rule Induction(RI)

The Rule Induction Algorithm is one of the methods used in machine learning to classify data. This algorithm focuses on creating rules that can be used to distinguish between different classes or categories in the dataset.

The main process of the Rule Induction algorithm is to look for significant patterns in the dataset and create rules based on these patterns. In this stage, the algorithm will group data based on relevant features and find recurring patterns. . (Tan, M., & Li, J. 2021)

After the patterns are found, the algorithm will generate rules that can be used to classify data that have not been seen before. These rules can be in the form of a conclusion-condition set (IF-THEN) or a set of rule sets. The rules generated by the Rule Induction algorithm will continue to be refined and evaluated using techniques such as pruning and cross-validation to improve classification accuracy. This algorithm can be used in various types of data, such as numeric, categorical, and incomplete data. (Guo, H., Huang, X., & Sun, X.2021)

The advantages and disadvantages of the RI algorithm are:

Advantages:

1. Easy to interpret and understand. The resulting rules can be used to explain the relationship between the attributes in the data and the classes contained in the data.
2. Efficient in data processing with a small number of attributes and a relatively small amount of data.
3. Able to capture complex patterns in data and create rules based on these patterns.
4. It can be used in various types of classification problems in Data Mining (such as binary and multiclass classification).

And Disadvantages:

1. Less effective in dealing with data that has a very large number of attributes or too much data.
2. The resulting rules tend to be rigid and inflexible in dealing with data variations that may occur in the future.
3. The ability to find patterns and make rules depends on the quality of the training data used.
4. Dependence on the algorithm used to find patterns in the training data. The algorithm used can have weaknesses and affect the quality of the generated rules.

2.3 Validation

In evaluating the performance of a data mining method, a systematic way must be needed (Gorunescu, F.2011). For this reason, data validation is needed to determine the best type of learning scheme to be used, based on training data to train learning schemes to maximize data usage (Witten, I. H., Frank, E., Hall, M. A., Pal, C. J., and DATA, M.2005). In this study, the technique used to validate is 10-cross-fold validation. This means that the test is carried out 10 times because the existing data is divided into 10 parts. Of the 10 sections, each section will make 9% training data and 1% for test data. The measurement result is the average value of the 10 times the test.

2.4 Performance Evaluation

Evaluation of the performance of the classification model is based on testing true and false objects (Wu, X., & Kumar, V.2009). In this study, the results of performance evaluation can be seen from the accuracy and Kappa value. Accuracy is the percentage of accuracy in predicting or identifying test data, while Kappa is the consistency of the assessment by considering all aspects in the matrix.

2.5 Significance Test

The significance test aims to test how far the performance evaluation results differ from each classification algorithm. If it is not significant, it means that the performance evaluation of these algorithms is practically the same. In this study, the significance test method applied was the T-Test. (Sawyer, T. L., & Kotrlik, J. W.2021).

3. RESULT AND DISCUSSION

This section discusses analysis results that can be displayed in a diagram, figure, table, or other illustration which is easy to understand and communicate.

The purpose of this research is to compare performance evaluations in the form of accuracy and Kappa of each classification algorithm model used to identify types of glass based on the refractive index and composition of the elements contained in the glass identification dataset. The results can be read in Table 1 below

Table 1. Accuracy and Kappa Values

	Accuracy	**Kappa**
C45	67,29 %	0,544
KNN	72,90 %	0,632
NN	69,16 %	0,576
LDA	59,35 %	0,425
NB	45,79 %	0,291
SVM	46,26 %	0,207
RI	69,16 %	0,576

When viewed from table 1, it is very clear, the algorithm that has the best Accuracy and Kappa values is the KNN algorithm with an Accuracy value of 72.90% and Kappa of 0.632. Meanwhile, the algorithm with the lowest performance evaluation is the NB algorithm with an accuracy of 45.79% and Kappa of 0.291. However, to ascertain whether an algorithm model can be said to be better than other algorithm models in a dataset, a significance test is needed. If the results are significant, then it can be said that the algorithm is better or worse than other algorithms, if the results are not significant, then it can be said that there is no difference between one algorithm and another algorithm in its use (Shrestha, R., et al. 2019). The results of the significance test with the T-Test method in this study can be read in the following table

Table 2. The results of the significance test using the T-Test

	C-45	**KNN**	**NN**	**LDA**	**NB**	**SVM**	**RI**
C-45		0,068	0,662	0,023	0	0	0,696
KNN			0,393	0	0	0	0,417
NN				0,037	0	0	0,988
LDA					0,002	0	0,052
NB						0,862	0
SVM							0
RI							

According to statistics, if the T-Test value is more than 0.05, it can be concluded that there is no significance between the two algorithms compared. In table 2, for yellow cells, the value is less than 0.05 and for white ones, the value is greater than 0.05. This describes to us that between the C-45, KNN, NN, and RI algorithms, the performance evaluation can be said to be no different because the results are not significant. As for the Naive Bayes and SVM algorithms, it can also be seen that the performance between these two algorithms is the worst used in this dataset.

4. CONCLUSIONS

Based on the discussion above, it can be concluded:

1. The results of the performance evaluation to identify the type of glass based on the refractive index and the composition of its elements on the *glass identification dataset*, the largest of which is the KNN algorithm with an accuracy of 72.90% and a Kappa of 0.632, and the smallest is owned by NB algorithm with an accuracy of 45.79 % and Kappa 0.291

2. Based on the significance test, the C-45, KNN, NN, and RI algorithms are best used, while the NB and SVM algorithms are the worst to be applied as classification models on the *glass identification dataset*.

3. It is necessary to develop or improve existing algorithms to improve performance in classifying glass types.

4. With a more accurate and efficient classification algorithm, it is hoped that it can assist glass manufacturers in better-identifying types of glass to improve the quality of glass products.

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Expansive Soil Swelling Test of Small Scale Laboratory Model on Sambungmacan Soil, Central Jawa

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Keywords

Expansive Soil; Pressure; Swelling

Abstract

Soil is one of the most important elements in any civil engineering work, almost all construction activities are related to soil. One of the most common soil problems is expansive soil. This type of soil has a high potential to expand when compared to other types of soil. This research aims to find out how expansive the tested soil is and how it reacts when wetting. The test in this research is experimental, where the expansive soil test is modeled in a rectangular test box with a soil volume of 0.08 m3. The swelling and expansion pressures were measured using proving rings and dials, each totaling five units. The expansive soil used came from Sambungmacan Subdistrict, Sragen Regency, Central Java. The results of the property index test of Sambungmacan soil have a plasticity index percent value of 49.33% and a liquid limit (LL) of 90.16%. The test results showed that the maximum swelling reached 28.3% of the initial soil height of 200 mm and the maximum soil swelling pressure reached 103.23 kPa with a moisture content of 22.62%. The maximum pressure that occurs in each proving ring is at an average moisture content of 31.81%. The results of this study also show the effect of every 1% moisture content will produce a percent soil swelling of 0.40% to 1.08% and the average percentage of swelling pressure that occurs is in the range of 4.65 kPa to 10.26 kPa at every 1% swelling.

1. INTRODUCTION

The term used for soils that have a high potential for expansion and shrinkage due to changes in moisture content is called expansive soil, (Sudjianto, 2015) this type of soil has a behavior that will expand when soil conditions are wet and will shrink when soil conditions are dry, so these soils are often called shrinkage or mobile soils. Expansive soils are dominated by fine-grained clay and silt. Expansive soil according to (Hardiyatmo, 2017) is very sensitive to water due to the presence of montmorillonite mineral content, this mineral will cause the soil to expand when it comes into contact with water. Clays or silts that do not contain the mineral montmorillonite will not swell as much as those that do.

In the country, the problem of expansive soils exists in almost all regions from Sabang to Merauke, there are no reports of losses that are detailed, based on the results of surveys and research conducted by the Bina Marga dan Departemen Pekerjaaan Umum, the majority of the damage that occurs on several roads in Java is caused by expansive soil problems (Mochtar, 2000). One example of road damage is in East Java, particularly in the Soko area of Ngawi Regency, which is the main road connecting Central and East Java, the most dominant damage according to (Sudjianto, 2007) on the road section occurred due to expansive soil problems on the basic soil with very high swelling potential. An example of road body damage that also occurred was mentioned in research (Marcel, 2022), namely on Jl. Raya Timur, Sambungmacan District, Sragen Regency. Road damage in the Sragen area has been well-known since the Dutch colonial era, It was noted that the newspaper during the Dutch colonial period that had highlighted the damage to the road was De Locomotief in a report on December 4, 1935, calling Solo-Sragen the worst road in Vorstenlanden (Duhri, 2021).

One way to minimize the negative impact of expansive soil is to check the soil type first before building on it. To prevent post-construction failure of civil engineering structures due to increasing urbanization and

industrialization associated with expansive soils, It is very important to evaluate the parameters and characteristics of soil strength before the construction process is carried out. (Das et al., 2011; Bell, 2014l; Puppala dan Pedarla, 2017; Christopher dan Chimobi, 2019). (Chen, 1975) stated that to understand the development of expansive soils, there are two parameters used to measure the quality of expansive soil development, namely swelling potential and swelling pressure, in line with this statement (Diana et al., 2020) stated that one of the ways to check the soil that can be done is to calculate how much the ground surface rises and the pressure caused by expansive soil. Research related to expansive soils is still being conducted because there is no appropriate method to solve this problem, Based on the current literature, most researchers research mixing expansive soil with certain materials so that the expansiveness of the soil is reduced, such as research conducted (Alazigha, 2018; Pooni, 2019; Jalal, 2020; Blayi, 2020). The calculation of expansive soil swelling potential is mostly done using an oedometer, Research that uses an oedometer in measuring expansive soil swelling includes (Ferdiansyah et al., 2012) which examines the effect of adding water content on vertical direction pressure, (Al, 2017) in research on the effect of field moisture content and air-fly ash ratio on the strength and swelling of expansive soil, (Arbianto, 2020) researched the prediction of soil swelling with clay content.

This research uses a test box to see the pressure reaction and swelling of expansive soil, the soil used in this research is the soil from the Sambungmacan area of Sragen district, Central Java province (7°21'43,874" ; E 111°7'15,627"), the soil of this area was chosen because based on the results of the property index test in the laboratory showed a liquid limit value (LL) of 90.16% and a plasticity index (PI) of 49.33, based on previous literature on expansive soil classification, that expansive soils are characterized by high liquid limit values (LL) and (PI) (Hardiyatmo, 2017). The purpose of this research is to see the development reaction and swelling pressure that occurs when expansive soil is wetting with a method that is still rarely used, namely using a proving ring to determine the value of the development pressure that occurs.

1.1 Expansive Soil Identification

Identification of expansive soils is usually done in the laboratory by conducting swelling tests, mineralogy tests, and chemical analyses and their correlation with classification and soil index properties. According to (Thomas, 1998) there are two ways to identify the expansion-shrinkage of expansive clay soils, namely direct identification, and indirect identification. (Noormalasari, 2000) also mentioned that there are three methods to identify the shrinkage of expansive clay soil, firstly direct measurement method, secondly indirect and lastly mineral identification. The direct measurement method is carried out by actual testing of the swelling including mineralogical identification, while the indirect measurement method involves physical properties and soil classification to predict shrinkage swell, both methods according to (Snethen, 1975) can be combined into one.

1.2 Correlation of Swelling with Atterberg Limits

The potential of soil to release and withdraw water depends on the initial moisture content of the soil and the moisture content relative to the moisture content of the consistency boundaries, such as the plastic limit, liquid limit, and shrinkage limit (Hardiyatmo, 2017). Through the Atterberg limit test, the plasticity index (PI) and liquid limit (LL) values can be determined. The classification of the degree of Swelling based on the Atterberg boundaries of several researchers is shown in table 1.

Table 1. Classification of Atterberg boundaries concerning the degree of swelling *(Hardiyatomo, 2017)*

Degree of Swelling	Plasticity Index (PI) (Raman; V. Dakshanamurthy, 1973)	Shrinkage Index	Shrinkage Indeks (Ranganathan, 1984)	Liquid Limit (LL) Ladd dan Lambe (1961)
Low	<12	<15	<20	20 – 35
Medium	12 – 23	15 – 30	20 – 30	35 – 50

High	23 – 32	30 – 60	30 – 60	50 – 70
Very high	>32	>60	>60	70 - 90
Extra high				>90

2. RESEARCH METHODS

The test was conducted at the Soil Mechanics Laboratory of Sebelas Maret University Surakarta using the experimental method. This research was carried out in three stages, namely preparatory work, testing (wetting and reading of proving ring values), and analysis of test results. The testing standards used are ASTM (American Society for Testing and Materials) and SNI (Indonesian National Standard) standards. Experimental methods using proving rings to measure the swelling pressure of expansive soils like this are still rare, Expansive soil testing is generally carried out using an oedometer, even (Diana et al., 2020) in their research summarized more than fifty literature from all over the world related to measuring soil expansiveness using an oedometer. So far there is no standardized procedure or test method for calculating soil expansiveness so there are often different results because it is done in various ways (Hardiyatmo, 2002).

The soil used in this study was taken in a disturbed state (disturbed sample) on the soil surface to a depth of 50 cm, the soil sample was then dried by drying in the sun. The soil was then pounded and sieved with sieves number 4, 10, and 40 respectively, the soil that passed sieve number 4 was used for swelling testing in the test box. The volume of dry soil used in this test is 0.08 m3 with a weight of 104.46 kg.

Before wetting the soil, the property index, initial moisture content, dry weight content, and initial CBR value of the soil in the test box were tested. The proving ring used was first calibrated to determine the value of the Load Ring Constanta (LRC) on each proving ring used. Wetting is carried out only on one side of the box, the wetting process in this test lasts for 53 days until all pressure and development values at each proving ring point have not increased in value anymore and tend to decrease.

2.1 Tools and Materials

The tools and materials used during the research were as follows:

Table 2. Tools and materials

No.	Alat		Materials
	Properties index test	Test Box Set	
1	Soil moisture content tester ASTM D2216-71	Test box	Soil
2	Soil-specific gravity tester ASTM D854-00	Anchoring Portal	Water, distilled water
3	Liquid limit and plastic limit tester ASTM D4318	Set of proving ring	Sand
4	Shrinkage limit tester SNI 4144:2012		Stone
5	Oven, scales, thermometer, and desiccator		

2.2 Test Box Display

The test box used is made of iron, rectangular with dimensions as shown in Figure 1. The front and back sides of the box are 2 cm thick acrylic membrane, and both sides of the box are held by iron strip plates transversely and longitudinally. The dimensions of the test box used in this test are 120 cm long, 50 cm wide, and 98 cm high.
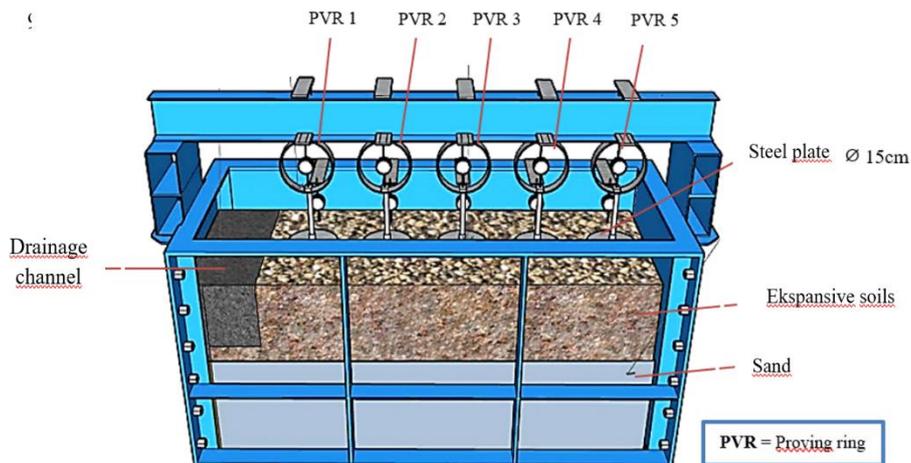
Figure 1. Assembled test box circuit

The configuration of the proving ring and dial placement points is set with the same distance between the first point and the next point, the configuration view is illustrated in Figure 2.
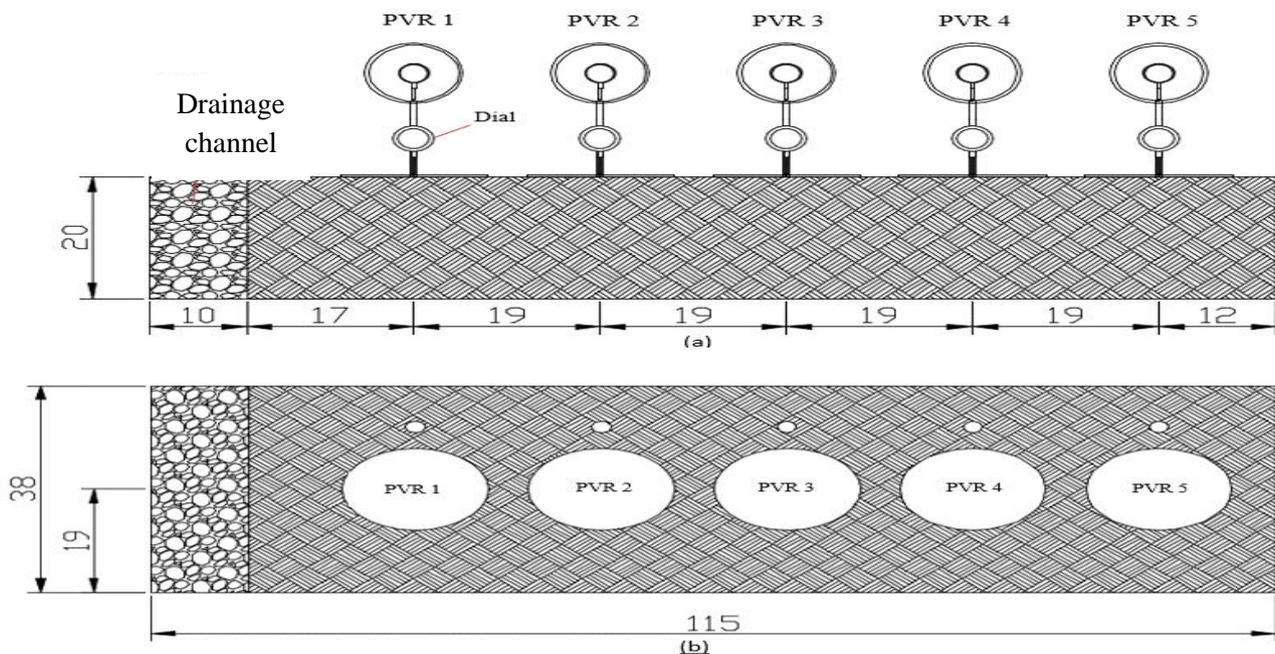
Figure 2. Configuration of proving ring and dial placement, (a) front view (b) top view

2.3 Measurement of Soil Swelling Pressure Value

Measurement of swelling pressure is carried out to determine the value of soil pressure that occurs. This pressure value is calculated using equation (1), by multiplying the reading value of the load dial reading (LDR) by the load ring constant (LRC) of each proving ring and then dividing by the area of the plate used, so that the swelling pressure value is obtained,

$$k = \frac{q}{A} \qquad (1)$$

exolanation:

q = LRC * LDR *proving ring (kN)*

A = Penetration Plate Surface Area (mm^2)

k = Swelling Pressure

3. RESULTS AND DISCUSSION

3.1. Soil Property Index Test Results

The results of the property index test on Sambungmacan soil are shown in Table 3 below,

Table 3. Soil property index test results

Properties	Value	Units
Initial moisture content, w	3,3	%
Specific gravity, Gs	2,273	-
Liquid limit, LL	90,16	%
Plastic limit, PL	40,83	%
Plasticity index, PI	49,33	%
Shrinkage limit, SL	22,70	%
Percent of soil grains passing the No.200 sieve	78,44	%
Percent of soil grains retained on sieve No.4	4,28	%
Percent clay fraction 0.002 mm, C%	4,91	%
Optimum moisture content, w_{opt}	27,8	%
Maximum dry volume weight, γd max	1,28	gr/cm^3
Unified system soil classification	(MH)	
Development (oedometer)	14,02	%
Pressure Development (oedometer)	89,5	kPa

Based on the results of this test, the value of PI 49.33% and LL 90.16% is obtained, which means that Sambungmacan soil falls into the category of very high swelling degree.

3.2 Graph of swelling value and swelling pressure during the test

Based on the results of testing for 53 days, the pattern of soil swelling that occurs as shown in Figure 3, it can be seen that the reaction of soil swelling, when filled with water, has different swelling values in each proving ring area.
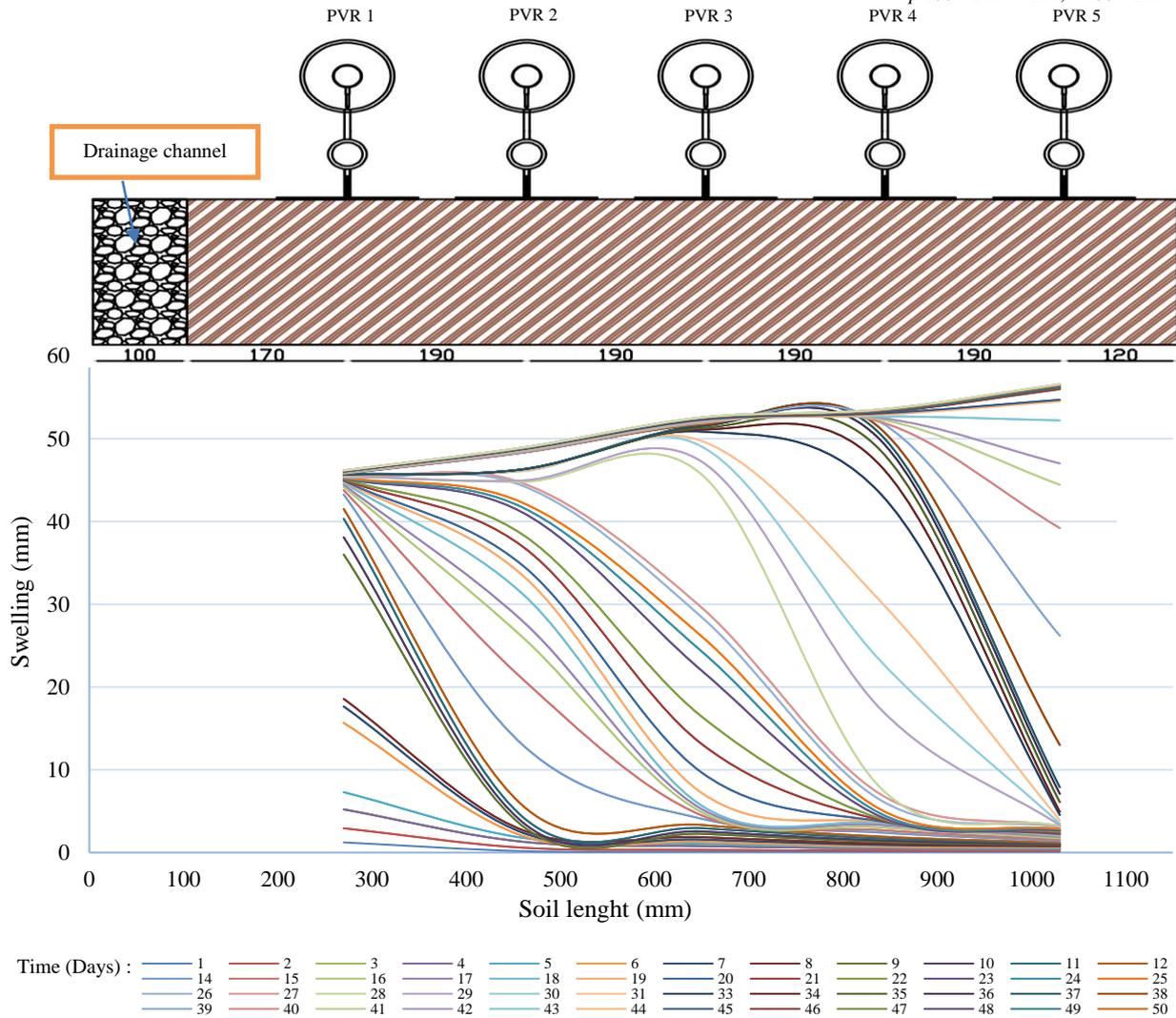
Figure 3. Swelling soil pattern

Figure 3 shows that the highest swelling is at the furthest point from the wetting area, the maximum swelling value in each proving ring is shown in Table 4.

Table 4. Maximum swelling value on each proving ring

Proving ring	Initial soil height	Swelling (mm)	Percent swelling (%)	Water content (%)
1	200	46,16	23,08	62,58
2	200	48,92	24,46	59,96
3	200	52,55	26,28	58,06
4	200	53,53	26,77	56,04
5	200	56,6	28,3	55,23
Average		51,55	25,78	58,37

Furthermore, Figure 4 shows the pattern of swelling pressure that occurs during soil wetting. The pressure value in each proving ring area is different, the highest pressure occurs in proving ring area 2 and the lowest in proving ring area 1.
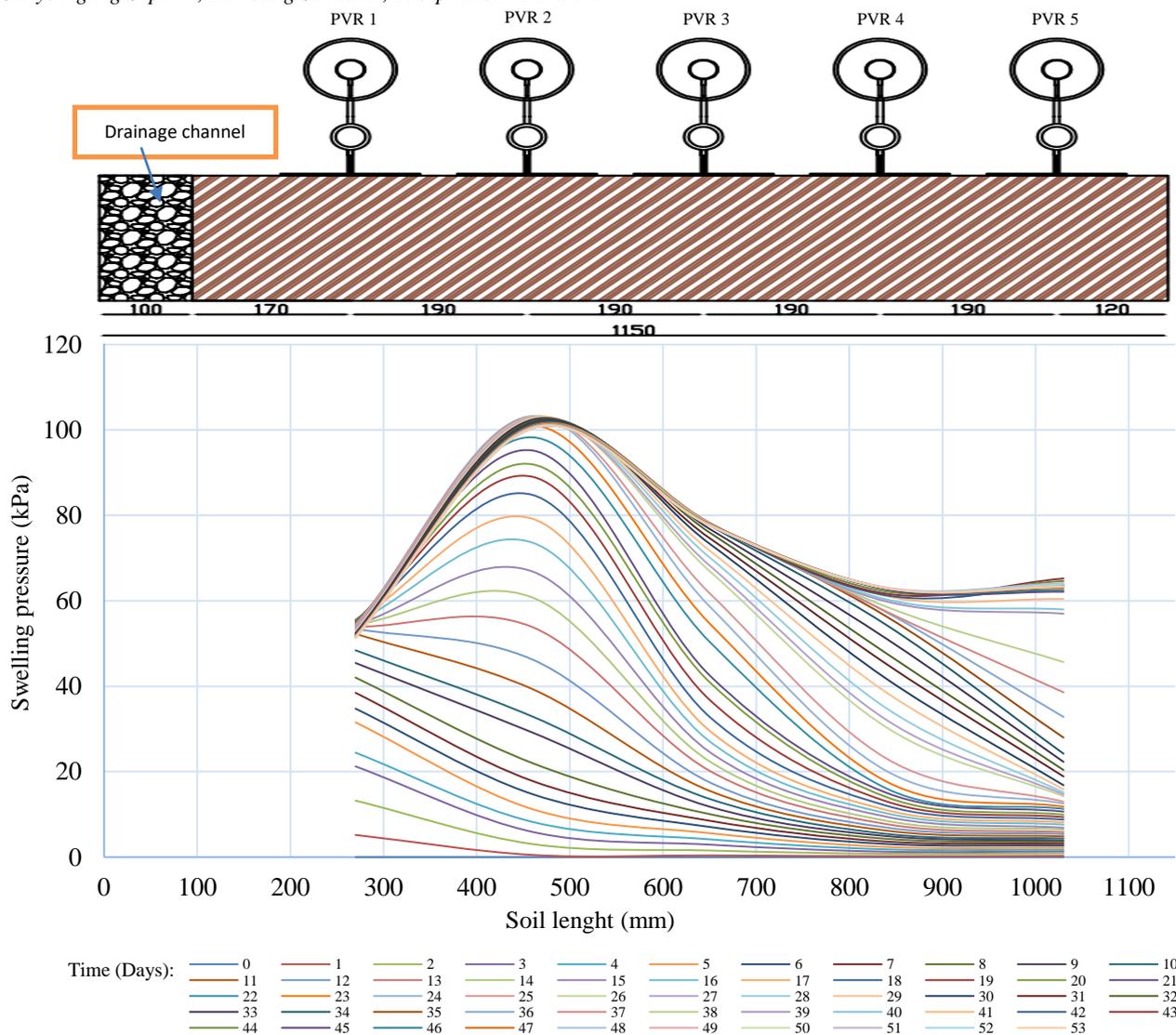
Figure 4. The Pattern of soil swelling pressure

The values of maximum swelling pressure, moisture content, and the time that occurs when the maximum pressure is due to the wetting process are shown in Table 5.

Table 5. The maximum swelling pressure value

Proving ring	Max swelling pressure (kPa)	Water content (%)	Time of day-
1	55,51	21,9	18
2	103,23	22,62	24
3	78,23	33,42	35
4	62,93	47,53	48
5	65,22	33,59	43
Average	73,02		

3.2 Relation of percent swelling to water content

The relationship of how much percent swelling occurs when the water content increases every percent, relation is drawn based on the situation when the proving ring area starts to be touched by water flow until it reaches the maximum swelling pressure in each proving ring,

Proving ring 1   Proving ring 2

Proving ring 3

Proving ring 4
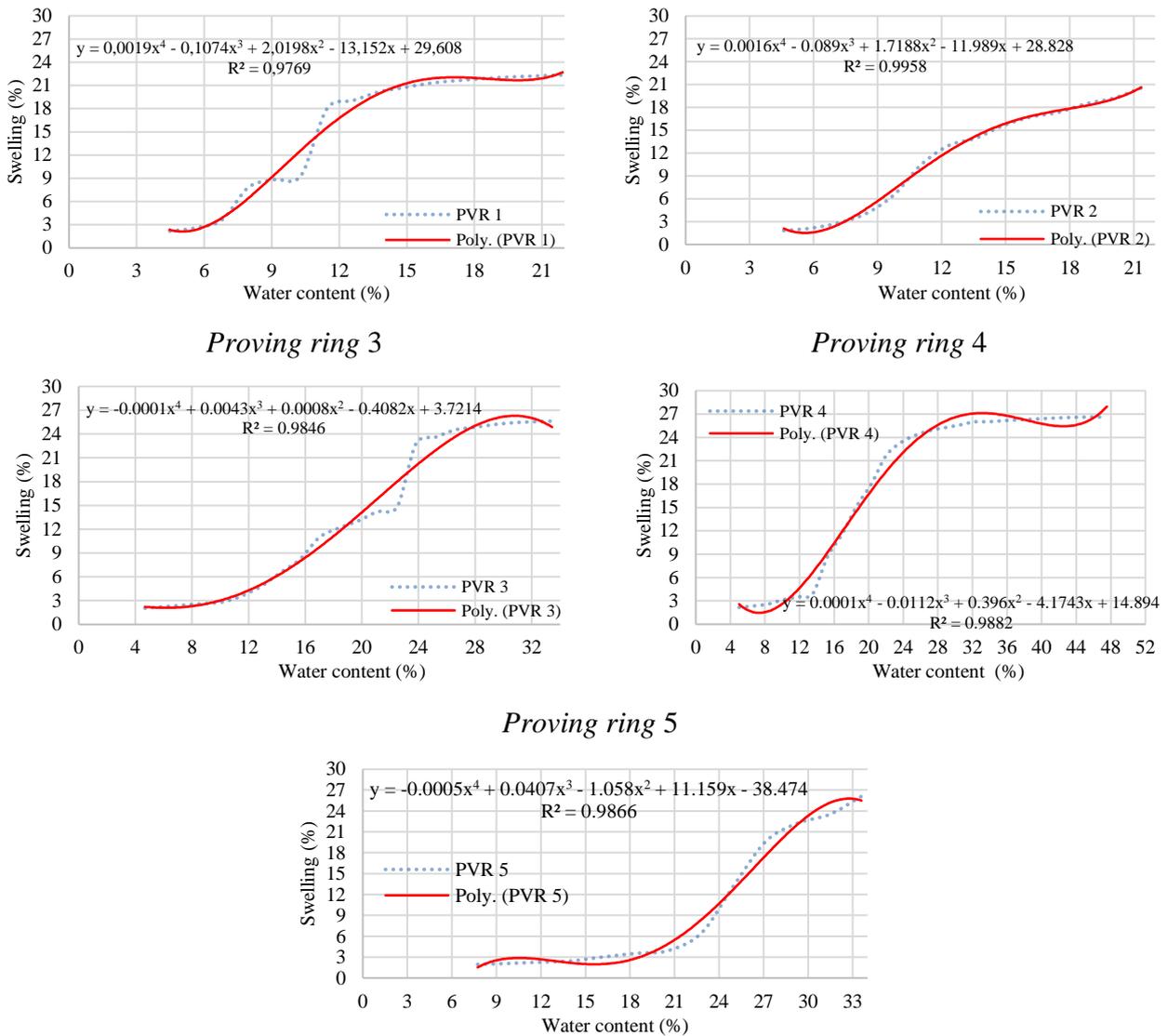
Proving ring 5

Figure 5. Relation of percent swelling to water content

Figure 5 is a graph of the relationship between the percent swelling value and water content in each proving ring, from this relation graph it can be seen that the average value of the coefficient of determination R2 from the results of the 4th-degree polynomial (quartic) regression analysis of each proving ring is close to 1, meaning that moisture content simultaneously affects the soil swelling that occurs. Based on this regression analysis, the equation of the relationship between water content and the percent of soil swelling that occurs is obtained, this equation is used to predict the percent swelling that occurs due to the effect of additional moisture content at each proving ring distance. Every 1% moisture content will cause the percentage of swelling with a value range of 0.40% to 1.08%, this result answers that the potential swelling of expansive soil is strongly influenced by changes in moisture content by the opinion (Hardiyatmo, 2017). These results can also be a reference for further research and input for previous research in predicting the effect of 1% moisture content on expansive soil swelling that occurs, most previous studies only show the effect of moisture content until maximum swelling occurs, such as research conducted (Ferdiansyah et al.,2012) and (Arbianto, 2020).

3.3 Relation of percent swelling to swelling pressure

The relation of how much swelling pressure occurs when the percent swelling increases, the relation is drawn based on the situation when the proving ring area starts to read the pressure value until it experiences the maximum swelling pressure in each proving ring, the following results, and explanations:
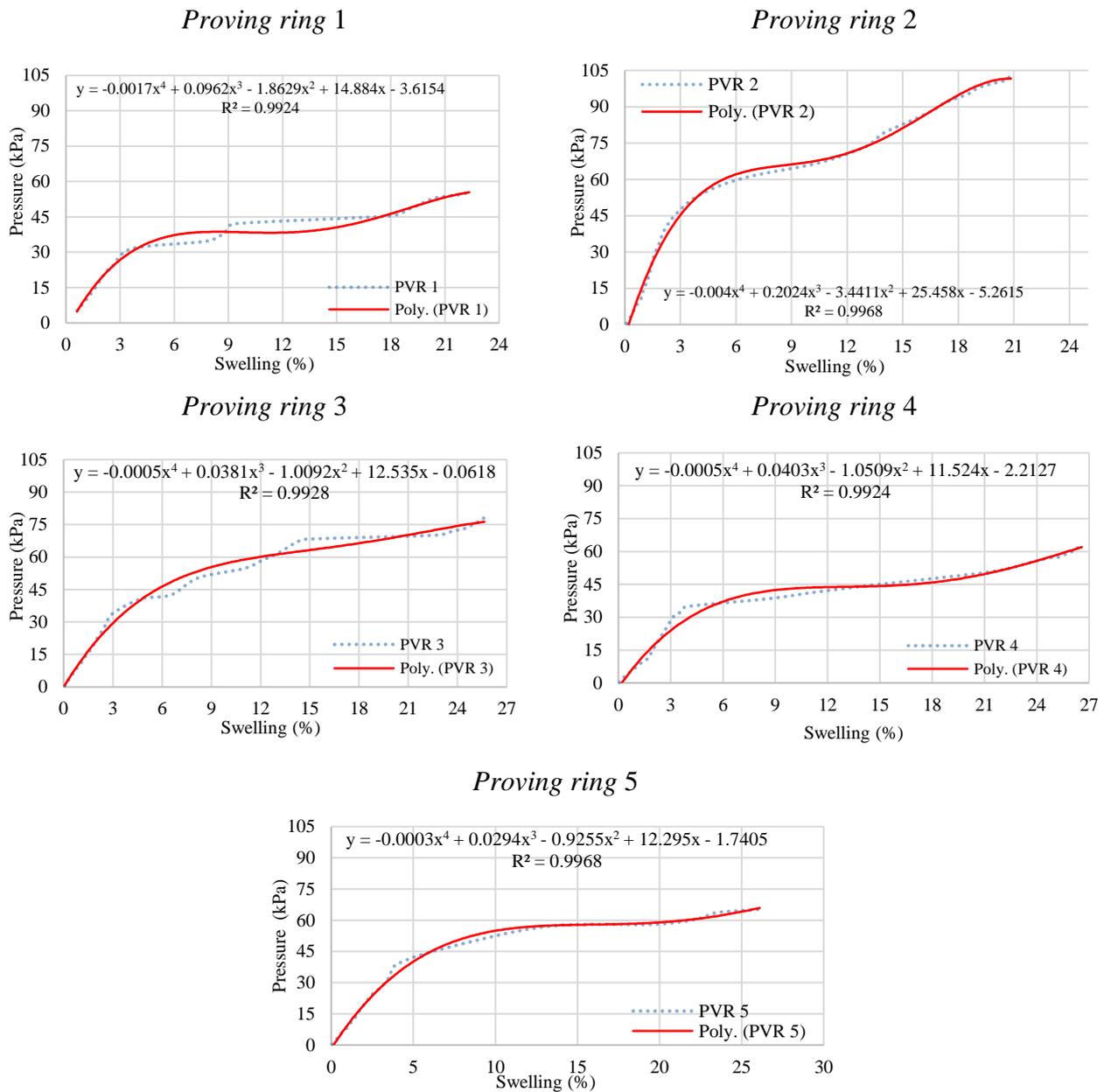
Figure 6. Relation of pressure to percent swelling

Figure 6 is a graph of the relation between the value of swelling pressure and percent swelling in each proving ring, from this relation graph it can be seen that the average value of the coefficient of determination R^2 from the results of the regression analysis of polynomial degree 4 (quartic) in each proving ring is close to 1, meaning that the water content simultaneously affects the soil swelling that occurs. Based on this regression analysis, the equation of the relation between swelling pressure and the percent of soil swelling that occurs is obtained, this equation is used to predict how much swelling pressure occurs due to the influence of the percent of soil swelling at each proving ring distance. Every 1% swelling will cause swelling pressure of 4.65 kPa to 10.26 kPa in Sambungmacan soil. Similar to the relation of moisture content to swelling, the relationship of swelling to swelling pressure can also be a reference for further research and input for previous research in predicting the effect of 1% swelling on the swelling pressure that will occur.

4. CONCLUSIONS

Expansive soils will react when in contact with water. Soil exposed to water will expand and the swelling that occurs will exert pressure. Based on the classification results concerning the liquid limit (LL) and plasticity index (PI) values, it is concluded that the Sambungmacan soil is included in the expansive soil

classification with a very high degree of swelling. The average swelling percentage value of this soil is 25.77%, while the mining pressure value obtained in this test is 103.23 kPa for the maximum swelling pressure value, 55.51 kPa for the lowest swelling pressure value, and the average swelling pressure is 73.02 kPa.

Based on the results of this study, it is also known that every 1% water content will cause a swelling percentage with a value range of 0.40% to 1.08% and every 1% swelling will cause a swelling pressure of 4.65 kPa to 10.26 kPa in Sambungmacan soil.

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Adaptation Strategies to Climate Change Impacts in The Area of Sidenreng Lake, Sidenreng Rappang Regency

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Vulnerability;
Sidenreng Lake

Abstract

The research site is one of the high-risk flood district zones along with Panca Lautang, Tellu Limpoe, and Wattang Sidenreng District since it is adjacent to Sidenreng Lake. The issue allied to climate change at the research site is a real phenomenon in which high rainfall occurs, leading the lake water to overflow and the weather, which previously could be calculated by the community in various ways, is currently unpredictable. The clime vulnerability analysis was utilized at the outset of this study to figure out the level of climate vulnerability. Secondly, Spatial Analysis using ArcGIS Software with Overlay Method towards each flood parameter to address the level of high-risk flood at the sitete of the research. The third analysis used in this research was AHP-SWOT to formulate some alternative strategies to overcome flood disasters brought about by climate change in the area of Lake Sidenreng. The results of the study showed that the level of flood vulnerability was Very Vulnerable, with 130.94 km^2, Vulnerable at 134.98 km^2, Quite Vulnerable at 88.93 km^2, Less Vulnerable at 22.97 km^2, and Not Vulnerable at 3.03 km^2 with the total amount of 380.85 km^2. Subsequently, the analysis results of the climate vulnerability from 27 villages, 14 of which are at a very low level (Class I), 2 villages are at a low level (Class II), 4 villages are at a Medium level (Class III), and 1 village which is Wette Village is at a very high level (Class IV). According to alternative strategy on AHP-SWOT Analysis, it was found that the space matrix is at Quadrant III of the W-O Strategy namely 1) the development of human resources and public role to nourish environmental hygiene and increase the capacity of vulnerable groups by empowering society with several trainings to improve human resources and group capacity and promoting awareness among people who lived in those vulnerable areas to maintain environmental conditions, the formation of climate villages and the formation and development of disaster care communities to minimize the impact of flood disasters that occurred as a result of climate change; 2) Management of climate change risk by local government and stakeholders either structurally or physically (engineering the built environment, technological choices and environment-based services or institutional-based services (choices in law and regulation, economics, policies and programs of government) by involving potential experts; 3) development of flood susceptibility maps and climate change vulnerability risks that are integrated with disaster mitigation maps so that people figure out the areas which have a large impact on climate change disasters.

1. INTRODUCTION

Climate change is currently marked by the increasing frequency of hydrometeorological hazards. Those are catastrophic events caused by meteorological or weather phenomena such as rainfall, humidity, temperature, and wind. The biggest effect of disrupting the hydrometeorological cycle is flooding. Ella Yulaelawati and Usman Shihab (2008) cited in Reza Rachmat (2014) confirmed that a major flood occurs all of a sudden and lasts a short period. The occurrence of flash floods is generally caused by high-intensity rainfall with a short duration which causes the river water discharge to surge rapidly. The research site was a flood-prone area according to the neighborhood head (RT/RW) of Sidenreng Rappang Regency. It covers three Districts namely Panca Lautang, Wattang Sidenreng, and Tellu Limpoe because the research site was adjacent to Sidenreng Lake. The major factors causing the flood hazard at the research site were the occurrence of high rainfall in certain months, low-lying areas, and drainage that was not able to accommodate a large amount of discharge of the lake's overflowing water. Besides, as a result of silting sedimentation at the bottom of the largest lake in South Sulawesi is Sidenreng Lake, which is located in Sidrap Regency, and Tempe Lake based in Wajo Regency leads this area is potentially prone to flooding.

Table 1. History of Floods in Panca Lautang, Tellu Limpoe, and Wattang Sidenreng District

Years	Incidents	Number of sites	Victims
2017	8	7	716
2018	7	5	551
2019	4	4	5.866
2020	8	7	1.770

Source: *BPBD Sidrap Regency 2021*

The local residential area has survived and tried to adapt from the past until now, yet the adaptation process has not been. This area is located on the edge of a lake which becomes a lake water runoff area that overflows when the volume of lake water increases due to rain. Communities continue to adapt to change their environment and behaviors to suit existing conditions in this case, areas with disaster environments. The shape of the existing buildings in the area is evidence of building adaptation and behavior that is carried out continuously. However, there need to be efforts that could be carried out to prevent or minimize the adverse effects of floods, namely adapting and mitigating flood disasters based on vulnerability factors. Adaptation to environmental changes, including climate change, is essential for the community to survive. It is highly needed to deal with change impacts. Furthermore, This study focused on assessing climate and the level of flood vulnerability that occurs in the area and provided alternative strategies to adapt based on the vulnerability assessment, particularly in the residential zones and rice fields of the coastal communities of Sidenreng Lake. Subsequently, these phenomena attracted me as a researcher to study more in-depth under the title "The Adaptation Strategies to Climate Change Impacts in The Area of Sidenreng Lake, Sidenreng Rappang Regency.

2. LITERATURE REVIEW

Floods are events in which land that is usually dry becomes inundated due to high rainfall and the topography of the area in the form of lowlands to concave or low soil infiltration capabilities so that the soil is unable to absorb water (Nuryanti, et al, 2018). Fred R. David in his book (2017) stated that strategy is a potential action that requires top management decisions and a large number of resources. Meanwhile, Mahi and Trigunarso (2017) explained that strategy is a way to achieve the goals and objectives that are already set.

In the process of utilization, a series of policies is needed. The strategy aiming for development is to realize justice in terms of development, while the function of policy is to develop branches in facing any obstacles. According to Karmila (2019), strategy is a very comprehensive approach related to the implementation and execution of activities in the form of ideas and planning within a certain period. Some coordination or work teams are extremely needed to be able to identify the supporting factors that have conformity with the principle to carry out very rational or efficient opinions both to achieve effective goals.

The strategy that aims for development is to realize justice in terms of development, while the function of policy is to develop branches in overcoming any obstacles. The main problem in this study is climate change which has various negative impacts in terms of aspects of life. Gregory et. al. (2005) was in line with the problem of climate change at the research location that had an impact on the agricultural sector of the surrounding community containing that climate change impacts the food system in several ways, which included direct impacts on crop production to changes in markets, the food product prices, and supply chain infrastructure. According to Von Braun (2008), climate change will also have an indirect impact on economic growth, income distribution, and demand for agricultural products. In addition, the food supply will also be affected by uncertain climatic conditions. Physical, economic, and social access to food will be negatively affected by climate change due to decreased food production, increased food prices, and reduced purchasing power which creates vulnerability.

Generally, the availability of agricultural products is influenced by climate change through its direct impact on crop productivity, plant pests, and diseases, as well as the ability of the soil to store water so this indicator is included in the vulnerability factor. Vulnerability is defined as an adverse tendency or influence. Vulnerability to the same risk might differ based on the level of society or social level and mobility affected by adaptive capacity, where the higher the adaptive capacity, the lower the level of vulnerability Daze (2009) cited from Kumalasari, N.R (2014). Adaptive capacity according to Gallopin (2006) cited from Subur, et all. (2018) suggested that adaptive capacity is the ability of a system to adapt to a disturbance or potential damage, while according to Shah, et all. (2013) made the vulnerability of adaptation technology an effort to community resilience in the face of disasters and became a staple in disaster areas.

According to Harjadi, et al (2005), indicators of vulnerability in general in Indonesia can be reviewed by four aspects, namely physical, environmental, social, and economic vulnerability. The indicator is divided into two variables, namely sensitivity and exposure according to the conditions of the research location that in this study the vulnerability indicator refers to the sensitivity variable, namely the first physical vulnerability of buildings and vital infrastructure, secondly the biophysical and hydrological vulnerability of the area. The exposure variable is the first economic vulnerability of the underprivileged community. The second is the biophysical and hydrological vulnerability of the area.

Flood-prone areas are areas that often have a high potential to experience flood disasters according to the characteristics of the causes of flooding. According to Anwari, et all. (2019) the variables that determine vulnerability to flooding are slope data, rainfall data, soil type data, and land use data. The five parameters that become variables can produce a map of flood-prone areas. The following are the research references in this paper:

Table 2. Previous Research Related to Research Title

Research	Research Method	Research Result	Similarities	Differences
Annisa Nur Fauziah (2014) Title: Climate Vulnerability Assessment: A Reassessment in the Coastal Area of Semarang City	The research uses a quantitative approach with climate vulnerability analysis, assessment of the climate vulnerability index in Semarang City	The results of the analysis formulate villages that need to be minimized by exposure factors, namely Panggung Lor, Terboyo Wetan, Trimulyo, Bandarharjo, and Tanjung Mas Villages. The facilitation strategy that can be proposed to minimize exposure in the villages is, among others, increasing the function of the health infrastructure capacity; rain harvesting and paving; beach green belt; wave barrier device; and wetland conservation. Meanwhile, the sub-districts that need to be minimized by factors that increase sensitivity are Mangkang Wetan and Tanjung Mas Villages.	1. Both researches applied quantitative method using the positivistic deductive method 2. The type of climate vulnerability calculation analysis used is the same, namely standardization, mean, grading, presentation of spatial data, and assessment of climate vulnerability	1. The object studied in the previous research is the sea coast of Semarang City, while this study examines the coast of Sidenreng Lake 2. Previous research only aims to determine the level of climate vulnerability on the coast, while this study also discusses the level of vulnerability to flooding caused by climate change
Ridwan Mohammad Lessy, et all. (2017) Title: Adaptive Capacity of Communities in Coastal Areas to Disasters (Case Study of Flood Disasters in Bastiong Karance Village, Terante City)	Forum Group Discussion (FGD), In-depth Interview, Observation, and Literature Review	1. Individual/Household adaptive capacity Shows the ability of each person or family to reduce the risk of harm. 2. The adaptive capacity of the community in groups, the adaptive capacity of the community that has been carried out includes carrying out community service in each RT to clean dirty or clogged drainage channels, as well as providing assistance to residents affected by disasters. 3. Government Adaptive Capacity Several concrete programs to anticipate and reduce the impact of flood disasters. These programs use a hard approach and a soft approach.	1. This type of study has the same object, namely the people living on the coast who have the greatest impact on disasters. 2. The method used is an interview method for those who can provide information that supports the problem in research. Assessing the adaptive capacity of the community to disasters, especially floods.	1. The results of previous studies discussed three types of adaptive capacity, namely individual adaptive capacity, community adaptive capacity, and government adaptive capacity, while in this study only individual and group adaptation strategies were discussed. 2. Previous research only examined the adaptive capacity of floods, while this study examines aspects of climate change and its impacts, namely floods. Previous studies used qualitative types to answer the research objectives while this study used quantitative, using positivistic deductive methods in solving them.
Hanh, et all. (2009) Title: The Livelihood	Quantitative research methods with analytical	Overall, Mabote has a higher LVI than Moma (0.326 versus 0.316, respectively), indicating a	1. Each research uses the composite index	1. The previous research scale was nationwide, while this study it

Research	Research Method	Research Result	Similarities	Differences
Vulnerability Index: A pragmatic approach to assessing risks from climate variability and change A case study in Mozambique	techniques: First calculate LVI: Second alternative method for calculating LVI combines the IPCC vulnerability definition	relatively greater vulnerability to climate change impacts. The results of the calculation of the principal components are presented collectively in the diagram. The chart scale ranges from 0 (less vulnerable), increasing to 0.5 (more vulnerable) on the outer edge in 0.1unit increments. Shows that Mabote is more vulnerable in terms of its socio-demographic profile, while Moma is more vulnerable in terms of water resources and health profiles.	method, namely the weighting scheme that is tailored to the needs of the research location. 2. Equation of the type of climate vulnerability calculation analysis used	examines the coastal area of Sidenreng Lake. 2. Previous research aimed to find the Livelihood Security Index using household surveys to produce community assessments of household livelihood security barriers while this study discusses the level of vulnerability to flooding caused by climate change with several variables and indicators such as the physical vulnerability of buildings and vital infrastructure, vulnerability and vulnerability of community safety, regional biophysical and hydrological vulnerability, community economic vulnerability and vulnerability to education, knowledge and technology adaptation. Then in a comparative study for the proposed strategy based on the results of the assessment of each component/factor of climate vulnerability and the level of vulnerability to flooding
Smit, et all. (2006) Title: Adaptation, adaptive capacity, and vulnerability	The first is a participatory, bottom-up, assessment based on sociology, anthropology, geography, ethnography, risk assessment, rural development, international development, and food security. Both ethnographic methods in the community (semi-structured interviews, participant observation, and focus groups)	Vulnerability is related to the differential exposure and sensitivity of society to disasters such as climate change and also to certain adaptive capacities. Society in the face of the effects or risks associated with the exposure. While exposure, sensitivity, and adaptive capacity are evident at the community or local level, they reflect broader forces, drivers, or determinants that shape or influence local level vulnerability. In the field of climate change, adaptation can be considered local or community-based adjustment to deal with changing conditions within the wider economic constraints of socio-political settings. Where these constraints are very binding, adaptation can be considered as an effort to change the economic, social, and political structure itself.	1. This type of research has the same goal, namely to carry out the concept of community adaptation with indicators of community adaptive capacity and vulnerability. 2. The ethnographic method is conducting interviews with groups or parties that are in contact with the problem being studied which is considered to be able to provide more specific information.	1. Research is qualitative by taking the concept of existing phenomena. 2. Research on a global scale and examines from a political point of view the indicators of adaptive capacitation, sensitivity and exposure produced.

Obtained from several sources, the following are related to the theory based on the appropriate variables at the research location:

Table 3. Linkage of Disaster Vulnerability Theory

No	Source Theory	Variables in Theory	Variables to be Studied
1	Daze (2009) in Kumalasari, N.R (2014)	1. Social vulnerability 2. Mobility vulnerability	1. Physical Vulnerability of Buildings and Vital Infrastructure/Physical Vulnerability (Sensitivity)
2.	Miladan (2009)	1. Artificial physique 2. Socioeconomic 3. Social population 4. Environment 5. Regional economy	2. Biophysical and Hydrological Vulnerability of the Area/Environmental Vulnerability (Exposure) 3. Capabilities and Community Safety Vulnerabilities/Social and Cultural Vulnerabilities (Sensitivity)
3.	Sassa (2009)	1. Physical vulnerability 2. Economic vulnerability 3. Social vulnerability	4. Community Economic Vulnerability/Economic Vulnerability (Exposure)
4.	Shah, et. al. (2013)	Vulnerability of adaptation technology	5. Vulnerability of adaptation technology (Adaptive Capacity)

Table 4. The Correlation of Physical Vulnerability Indicators of Buildings and Vital Infrastructure to Flood Disasters

Research Variables	Source Theory	Indicators in Theory	Indicators to be Studied
Sensitivity	FEMA (2004)	1. Public buildings 2. Important facilities 3. Special facilities	1. Building materials 2. Availability of essential facilities (health, worship, education) 3. Number of houses on stilts (non-permanent) 4. Number of households that depend on private agricultural products 5. Number of households that depend on Sidenreng's Lake capture fisheries 6. Percentage of houses unable to withstand climatic events such as floods
	Jha, et. al. (2012)	1. Residential location 2. Building materials 3. Repair rate 4. Forecasting and warning system	
	Reid (IIED),2007	1. Number of houses on stilts (non-permanent) 2. Number of houses that have a ground floor 3. Strengthen the physical home 4. Placing sandbags along the border	
	Hanh, (2009)	1. Number of households dependent on private agricultural products 2. Number of households that depend on Sidenreng's Lake capture fisheries 3. Percentage of houses unable to withstand climatic events such as floods	

Table 5. The Relation of the Theory of Biophysical Vulnerability Indicators and Regional Hydrology to Disasters

Research variables	Source Theory	Indicators in Theory	Indicators to be Studied
Exposure	Fauziah N.A. (2014)	1. The area affected by erosion 2. Elevation of the building 3. Land subsidence rate 4. Post-flood disease	1. Distance from river/lake 2. Drainage conditions 3. Elevation of the building 4. Post-flood disease
	Peraturan Menteri PUPR RI No. 28 Tahun 2015	1. Distance to river/lake 2. Utilization of lake borders 3. Lake border building	

Table 6. Correlation between theories regarding indicators of capabilities vulnerability and community safety to disasters

Research variables	Source Theory	Indicators to be Studied	Indicators to be Studied
Sensitivity	Pamungkas (2013)	1. Understanding of disaster and disaster management 2. Social interaction in the community 3. Community involvement in disaster management 4. The level of public trust in the leader 5. The level of community togetherness 6. Population 7. Number of elderly and under-five population	1. Total population 2. Old age population 3. Population aged under five 4. Percentage of residential areas experiencing flooding 5. Social interaction in the community 6. Community involvement in disaster management 7. Households experiencing physical asset losses due to floods caused by climate change
	Shah, (2013)	1. Number of dwellings affected by floods 2. Households experiencing physical asset losses due to floods caused by climate change	

Table 7. The relation of the theory of community economic vulnerability indicators to flood disasters.

Research variables	Source Theory	Indicators in Theory	Indicators to be Studied
Exposure	Harjadi, et. al. (2005)	1. Percentage of poor households 2. Percentage of households working in vulnerable sectors	1. Income 2. Percentage of households working in vulnerable sectors such as farmers and fishermen 3. Percentage of houses without certificate ownership
	(APDC) Risk Assessment Module (2005)	1 Poverty 2 Income	
	Shah, (2013)	1. Food 2. Percentage of houses without certificate ownership	

Table 8. Correlation between Vulnerability theories at Education Level, Knowledge, and Adaptation Technology

Research variables	Source Theory	Indicators in Theory	Indicators to be Studied
Adaptive capacity	Fauziah N.A. (2014)	1. Community fishermen who have an adaptation strategy 2. Farmers' livelihoods with adaptation strategies	1. Education 2. Community fishermen who have an adaptation strategy 3. Farmers' livelihoods with adaptations strategies 4. Public livelihood communities that have adaptation strategies 5. People who know the issues and impacts of climate change 6. People who know about flood disaster management 7. People who have side jobs
	Shah, (2013)	1. Education 2. People who know the issues and impacts of climate change 3. People who know about flood disaster management 4. People who have side jobs 5. Public livelihood communities that have adaptation strategies	

3. METHODOLOGY

This research employed a descriptive quantitative method which was based on the positivistic deductive approach. This research intended to examine the planning of an adaptive flood concept under a climate resilience approach. Sampling was carried out by using a simple random sampling technique which referred to Slovin's formula. The sample taken was the population of each village to attain a proportional portion of the overall population of each region. The sample size determination is as follows:

$$n = \frac{N}{1 + Ne^2}$$

Notes:

n = Number of samples
N = Population (number of households)
e = Error tolerance limit

3.1 Climate Vulnerability Analysis

Following the Vulnerability Index analysis in this research, researchers presented data with several analytical techniques as below:

a. Standardization: employing the formula of Hahn (2009) from the Human Development Index using ratio data determined by the minimum and maximum values chosen by the respondents. As for calculating the standardization value, it refers to the following formula.

$$indeks = \frac{Sd - Smin}{Smax - Smin}$$

Notes:
Index = Standardization of index value
SD = Total value per urban village
Smin = Minimum value of respondent's answer
Smax = Maximum value of respondent's answer

b. Mean (the average number): Each index was assessed with the same weight to ensure that it could be applied at various levels (urban village, sub-district, national) to facilitate differences obtained in different places (Sullivan, 2006). The formula employed for calculating the mean (average) is as follows:

$$Me = \frac{\sum_{i=1}^{n} index\ sdi}{n}$$

Me = Mean
Σ = Epsilon
sdi = Component Index Value
n = Number of components

c. Classification: The results of the standardized index assessment were classified into 5 classes by calculating the difference between the lowest and the highest score which was then divided into 5 classes.

d. Spatial Data Presentation: The results of the classification of climate vulnerability components were mapped and presented in gradation colors. The lighter color indicated the lower vulnerability, and the darker one indicates the higher vulnerability.

e. Climate Vulnerability Assessment: this assessment was performed after the level of exposure, sensitivity, and adaptive capacity had been identified in the previous analysis. In this case, it was necessary to calculate the average index of adaptive capacity analysis, sensitivity, and exposure. The average index vulnerability was assessed using the following formula:

$$V = (e \times s)/ac$$

Notes:
V = Vulnerability index
e = Exposure value
a = Adaptive capacity value
s = Sensitivity value

The vulnerability formula was chosen because the measurement results using the formula relatively approached the characteristics of each variable to wit exposure, sensitivity, and adaptive capacity which the higher the exposure and sensitivity obtained, the greater the climate vulnerabilities while conversely the higher the adaptive capacity obtained, the lower the climate vulnerability occurs.

3.2 Analysis of Flood Hazard Mapping

Flood-prone area means a land that is subject to flooding or has a high potential of being inundated by flood disasters according to the characteristics of the causes of flooding as following parameters:

1. Slope
2. Land use
3. Rainfall
4. Soil type

Weighting

Weighting is giving weight on a digital map to each parameter that affects the flood, based on the consideration of each parameter on the flood occurrence. The higher the influence of these parameters, the greater the weight given.

Table 9. Weight Value

No	Parameters	Weights
1	Slope	5
2	Type of soils	3
3	Rainfall	2
4	Land use	2

Source: Procedures for Formulating a Technical Plan for the Rehabilitation
of Forest and Watershed Lands (RTkRLH-DAS). 2009 cited in Aji. 2014

Determination of Class Interval

The class interval was used to classify the overlay results into the level of Flood Vulnerability Class intervals can be calculated using the Sturgess formula, as follows:

$$C_i = \frac{x_t - x_r}{k}$$
$$k = 1 + 3,3 \log n$$

Notes:
Ci = class interval
Xt = largest data
Xr = smallest data
k = number of classes
n = number of data

The value of an area's vulnerability to flooding is determined from the total score of each flood parameter. Areas that are very prone to flooding will have a high total score and vice versa areas that are not prone to flooding will have a low total score.

3.3 Analysis of Adaptation Strategies to the Impact of Climate Change

3.3.1 Analytical Hierarchy Process

AHP is a technique to assist comprehensive decision-making because of its multi-attribute nature to deal with complex problems, both qualitative and quantitative aspects. AHP was first developed by Thomas L. Saaty in the 1970s. In the AHP method, Saaty and Niemira (2006) mentioned three main principles in solving and determining alternative decision choices, namely hierarchical preparation, priority setting, and logical consistency. Regional Disaster Management Agency, Head of the Environment Agency, Regional Apparatus Organization Regional Development Planning Agency, and Regional Apparatus Organization for Residential Public Works of the Sidenreng Rappang Regency Head of the Regional Planning and Development Agency of Sidenreng Rappang Regency. Then the results of the questionnaire will be processed using the help of expert choice 11 software for windows. The last is consistency testing by taking the consistency ratio (CR) of the consistency index (CI) with the right value. The CR value is acceptable if it does not exceed 0.10. If the CR value is > 0.10, it means that the matrix is inconsistent (Saaty, 1980, Hartati & Nugroho, 2012).

3.3.2 SWOT

SWOT analysis is a planning technique to formulate strategies by evaluating strengths, weaknesses, opportunities, and threats in development activity. SWOT analysis includes the identification of various factors systematically to formulate management strategies. SWOT analysis is based on the logic that can maximize strengths and opportunities, but simultaneously minimize weaknesses and threats (Muta'ali, 2015). This study uses a quantitative model of SWOT analysis.

4. RESULTS AND DISCUSSION

4.1 Research Sites

In this case, the limitation of the physical space of the research area refers to the Spatial Plan of Sidenreng Rappang Regency namely areas that have the potential to experience flood natural disasters spread over three Districts directly adjacent to Sidenreng Lake namely: Panca Lautang District, Tellu Limpoe District, and Wattang Sidereng District.
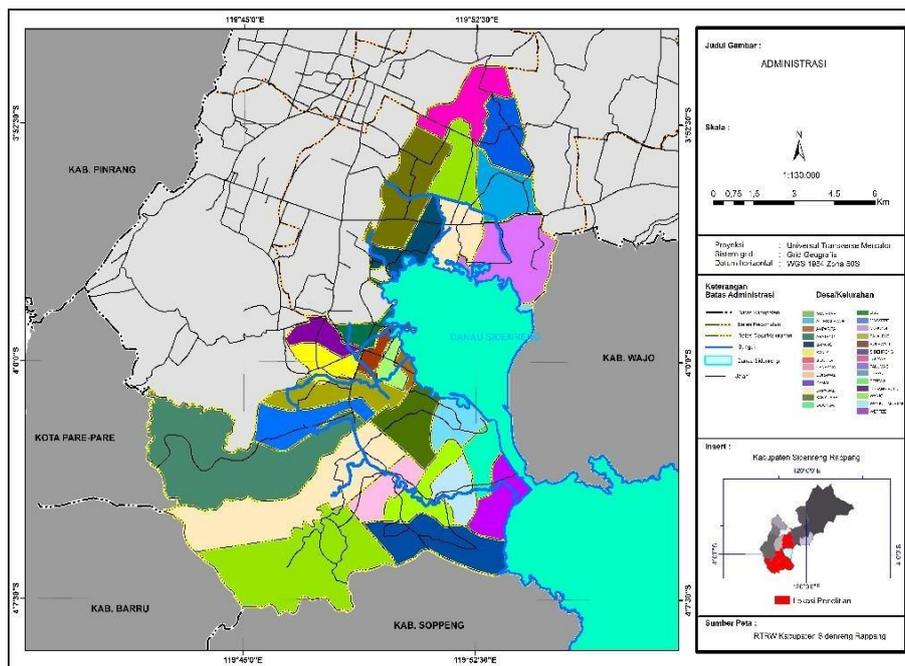

Figure 1: Administrative Map of the Sidenreng lake area

Based on the processing of indicators that determine flood-prone areas, the following values and weights are obtained:

Table 10. Characteristic of types of soil in Sidenreng lake area

No.	Types Of Soil	Value (S)	Weights (B)	Total (SxB)	Land Area (Km)	(%)
1	Podsolic	2	3	6	33,37	8,76
2	Alluvial	5	3	15	117,07	30,74
3	Mediteran	4	3	12	83,24	21,86
4	Regosol	3	3	9	145,43	38,19
5	Grumose	2	3	6	1,71	0,45
	Total	16	15	48	380,82	100

Source: Processed data of Arc. Gis 2022

The table above showed the highest value of the total score and weight, which was 15 for the alluvial soil type, and the lowest is the Grumosol soil type with a value of 6. Meanwhile, the table for the total value of land use types is described in the following table:

Table 11. The Land Use of the Sidenreng lake area

No.	Land Use	Value (S)	Weights (B)	Total (SxB)	Land Area (Km)	(%)
1	Shrubs	3	2	6	20,74	5,45
2	Forest	1	2	2	42,03	11,04
3	Garden	2	2	4	6,02	1,58
4	Residential Area	5	2	10	11,97	3,14
5	Irrigated Rice Field	5	2	10	112,31	29,49
6	Moor	4	2	8	105,48	27,70
	Total	20	12	40	380,82	100

Source: Processed data of Arc. Gis 2022

The type of land use with the most influential total value is the use of residential land and irrigated rice fields with a value of 10 and the lowest total value is the type of forest land use with a total value of 2. The score for the type of rainfall in the research location is described in the table below.

Table 12. Characteristics of the Rainfall in the Sidenreng lake area

No.	Rain Fall	Value (S)	Weights (B)	Total (SxB)	Land Area (Km)	(%)
1.	1501 - 2000 mm	1	2	2	248,06	65,13
2.	2001 - 2500 mm	1	2	2	80,55	21,15
3.	2501 - 3000 mm	2	2	4	48,21	12,66
4.	3001 - 3500 mm	3	2	6	4,04	1,06
	Total	7	8	14	380,82	100

Source: Processed data of Arc. Gis 2022

The table above describes the highest total value with an indication of one of the triggers for the flood disaster, namely the rainfall level of 3001-3500mm with a total of 6 and the lowest with rainfall ranging from 1501-2000mm and 2001-2500 with a total value of 2. research locations as follows:

Table 13. Slopes the Sidenreng lake area

No.	Types of slopes	Value (S)	Weights (B)	Total (SxB)	Land area (Km)	(%)
1.	0-8	5	5	25	268,58	70,52
2.	8-15	4	5	20	18,02	4,73
3.	15-30	3	5	15	64,85	17,03
4.	30-40	2	5	10	15,36	4,03
5.	>40	1	5	5	14,02	3,68
	Total	15	25	75	380,83	100

Source: Processed data of Arc. Gis 2022

Based on the table above, the highest weight value is on the type of slope 0-8 with flat slope conditions so that if a flood hits this area, it becomes the area that is first inundated with a total value of 25, and the lowest type of slope is very steep or >40 with a total value of 5. The table of the total value of the overlay results for each parameter of the flood-prone map. By using the Sturgess formula, each type of class is calculated by the following equation formulas:

$$k = 1 + 3,3 \log n$$
$$k = 1 + 3,3 \log 20$$
$$k = 1 + 4,2 = 5,2 \approx 5$$

The number of classes that will be used is 5 classes. The narrower the interval between classes, the more specific the results obtained. Following are the range of class intervals obtained by using the Sturgess formula:

$$C_i = \frac{x_t - x_r}{k}$$
$$C_i = \frac{52 - 18}{5}$$
$$C_i = 6,8 \cong 7$$

Regarding the above calculation, the total score of each parameter determines the flood vulnerability potential, using an interval range of 7 with a regional classification of 5 classes of flood vulnerability, namely very low, low, medium, high, and very high by using the highest and lowest score data based on the standard

sourced Procedures for Formulating a Technical Plan for the Rehabilitation of Forest and Watershed Lands (RTkRLH-DAS). The results of the classification of flood vulnerability levels can be seen in the following table.

Table 14. Classification of the flood vulnerability level

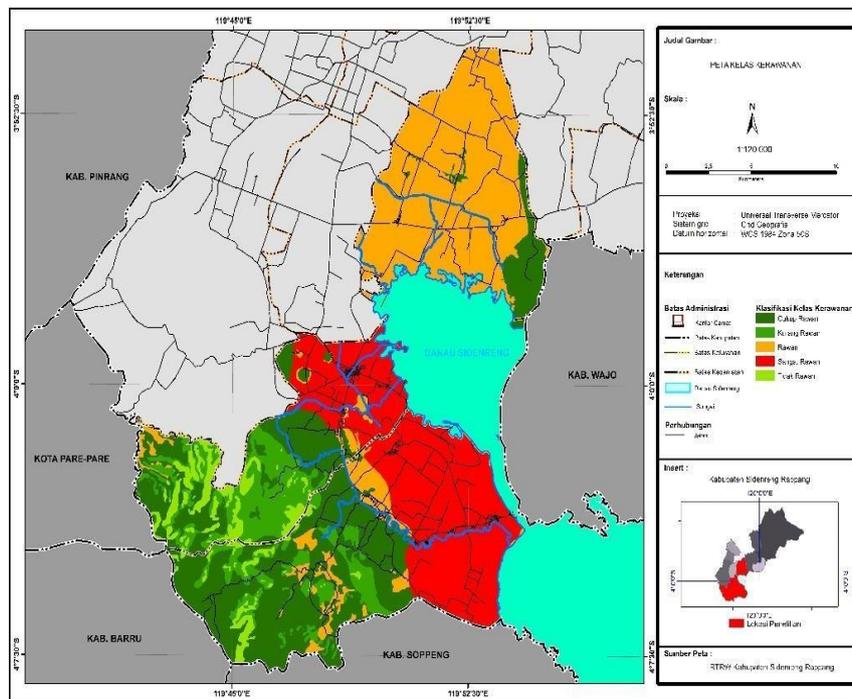| No	Description	Value
1	Very vulnerable	55 – 48
2	Vulnerable	47 – 40
3	Quite vulnerable	39 – 32
4	Less vulnerable	31 – 24
5	Not vulnerable	23 – 16

Source: Analysis Result of 2022

Figure 2: Flood Hazard Map in Sidenreng lake area

Table 15. Potential Flood Hazard by Village/Urban Village the Sidenreng lake area

| Districts | Urban Village | Classification of Flood Prone Level | | | | | Total (Km²) |
		Very Vulnerable	Vulnerable	Quite Vulnerable	Less Vulnerable	Not Vulnerable	
Panca Lautang	Cenrana	0,49	9,69	16,81	4,78	-	31,77
	Bapangi	12,03	5,27	2,27	1,16	-	20,73
	Wanio Timoreng	7,78	0,1	-	-	-	7,88
	Wanio	5,74	3,11	0,6	-	-	9,45
	Bilokka	2,92	5,94	3,07	-	-	11,93
	Corawali	0,49	10	14,64	5,33	0,29	30,75
	Lise	9,79	4,48	-	-	-	14,27
	Alesalewo	5,93	9,56	1,91	-	-	17,4
	Lanjonga	7,09	0,72	-	-	-	7,81
	Wette'e	9,28	0,18	-	-	-	9,46
Tellu Limpoe	Teppo	-	4,77	24,01	11,24	2,7	42,72
	Massepe	0,47	4,5	5,35	0,46	0,04	10,82
	Pajalele	8,78	6,92	0,69	-	-	16,39
	Baula	4,88	0,31	0,84	-	-	6,03
	Teteaji	3,26	1,58	-	-	-	4,84
	Polewali	1,63	3,81	-	-	-	5,44
	Toddang Pulu	3,87	0,16	1,22	-	-	5,25
	Amparita	3	2,93	0,05	-	-	5,98

Districts	Urban Village	Classification of Flood Prone Level					Total (Km²)
		Very Vulnerable	Vulnerable	Quite Vulnerable	Less Vulnerable	Not Vulnerable	
Wattang Sidenreng	Arateng	3,59	3,06	1,82	-	-	8,47
	Kanyuara	15,36	0,21	0,07	-	-	15,64
	Sidenreng	8,42	0,31	5,97	-	-	14,7
	Empagae	7,94	0,61	2,99	-	-	11,54
	Mojong	0,48	13,61	6,41	-	-	20,5
	Talumae	1,24	9,73	0,05	-	-	11,02
	Aka-Akae	6,38	2,77	0,16	-	-	9,31
	Damai	-	19,89	-	-	-	19,89
	Talawe	0,1	10,76	-	-	-	10,86
	TOTAL	130,94	134,98	88,93	22,97	3,03	**380,85**

Source: Analysis Result of 2022

4.2 Climate Vulnerability Index

The determination of the range of climate vulnerability class values is as follows.

Table 16. Climatic Vulnerability Class Value Range

No	Range Value	Class
1	0,01 - 0,20	I
2	0,21 - 0,40	II
3	0,41 - 0,60	III
4	0,61 - 0,80	IV
5	0,81 - 1	V

Source: Analysis Result of 2022

Based on the average index value obtained from the three variables, namely exposure, sensitivity and adaptive capacity, the vulnerability class values obtained for each village in the three sub-districts are as follows:

Table 17. Vulnerability Level

Vulnerability Level	Urban Village/ Village	Exposure		Sensitivity		Adaptive Capacity		Vulnerability	
		Index	Class	Index	Class	Index	Class	Index	Class
Very Low	Carawali	0,14	I	0,18	I	0,28	II	0,09	I
	Cenrana	0,12	I	0,18	I	0,28	II	0,08	I
	Lise	0,20	I	0,26	II	0,27	II	0,19	I
	Wanio	0,13	I	0,13	I	0,33	II	0,05	I
	Pajalele	0,18	I	0,15	I	0,26	II	0,10	I
	Teppo	0,13	I	0,17	I	0,22	II	0,10	I
	Massepe	0,12	I	0,27	II	0,27	II	0,12	I
	Toddang Pulu	0,17	I	0,16	I	0,21	II	0,12	I
	Aka-Akae	0,08	I	0,51	III	0,26	II	0,16	I
	Damai	0,09	I	0,20	I	0,25	II	0,07	I
	Kanyuara	0,15	I	0,20	I	0,24	II	0,12	I
	Sidenreng	0,12	I	0,32	II	0,28	II	0,14	I
	Talumae	0,09	I	0,16	I	0,30	II	0,05	I
	Talawe	0,09	I	0,17	I	0,32	II	0,05	I
Low	Empagae	0,26	II	0,36	II	0,26	II	0,36	II
	Bapangi	0,20	I	0,34	II	0,29	II	0,23	II
Medium	Amparita	0,47	III	0,39	II	0,31	II	0,58	III
	Arateng	0,41	III	0,38	II	0,27	II	0,58	III
	Baula	0,20	I	0,30	II	0,11	I	0,51	III
	Bilokka	0,50	III	0,32	II	0,34	II	0,47	III

Vulnerability Level	Urban Village/ Village	Exposure		Sensitivity		Adaptive Capacity		Vulnerability	
		Index	Class	Index	Class	Index	Class	Index	Class
High	Alessalewoe	0,49	III	0,55	III	0,34	II	0,78	IV
	Lanjonga	0,55	III	0,54	III	0,40	II	0,75	IV
	Wanio Timoreng	0,46	III	0,59	III	0,36	II	0,75	IV
	Mojong	0,48	III	0,45	III	0,28	II	0,77	IV
	Teteaji	0,45	III	0,58	III	0,35	II	0,74	IV
	Polewali	0,51	III	0,59	III	0,42	III	0,72	IV
Very High	Wette	0,63	IV	0,67	IV	0,43	III	0,99	V

Source: Analysis Result of 2022

The following diagrams and maps of climate vulnerability illustrate the level of climate vulnerability determined by exposure, sensitivity, and adaptive capacity. The index that is closer to 1 indicates a higher level of vulnerability. On the other hand, an index that is closer to 0 indicates a lower level of climate vulnerability. The following is a radar diagram based on villages in the three sub-districts in the research location:
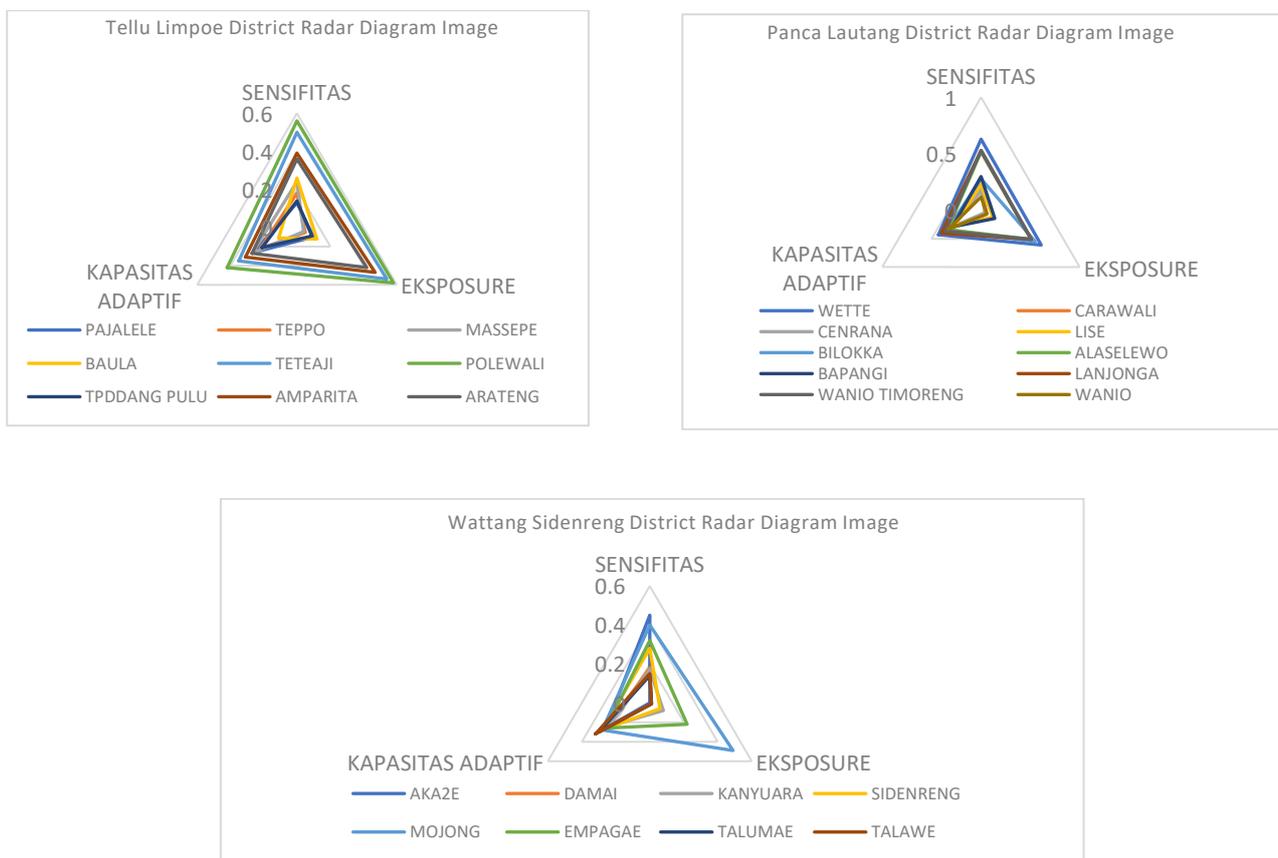

Figure 3. Radar Diagram

From the radar diagram of the Panca Lautang District, it is clear that the level of adaptive capacity is in the average low vulnerability level or class II as seen from the darker and denser color gradations due to overlapping between urban village/ village. In contrast to the level of sensitivity and exposure which has begun to show clear colors in every urban village in Panca Lautang Sub-district, namely Wette Village, Alessalwoe Village, Lanjonga Village, and Wanio Timoreng Village, it is close to 1 which indicates the highest level in Panca Lautang District.

In the radar diagram of Tellu Limpoe Subdistrict, it is clear that Polewali Village has the highest value for the sensitivity and exposure variables. Meanwhile, Pajalele Village, Teppo Village, Massepe Village, and Toddang Pulu Village are in the safe class level, namely low vulnerability but adaptive capacity still needs to

be improved. Meanwhile, the radar diagram of Wattang Sidenreng District shows color degradation for darker adaptive capacity due to the overlapping of each urban village/ village. For the exposure variable, it can be seen that Mojong Village has the highest value for Wattang Sidenreng District, which means the level of vulnerability is high and other urban village such as Aka-Akae Village, Damai Village, Kanyuara Village, Sidenreng Village, Talumae Villages, and Talawe Village is at a low vulnerability level. Meanwhile, the sensitivity variables of Damai Village, Kanyuara Village, Talumae Village, and Talawe Village have a low level of class I.
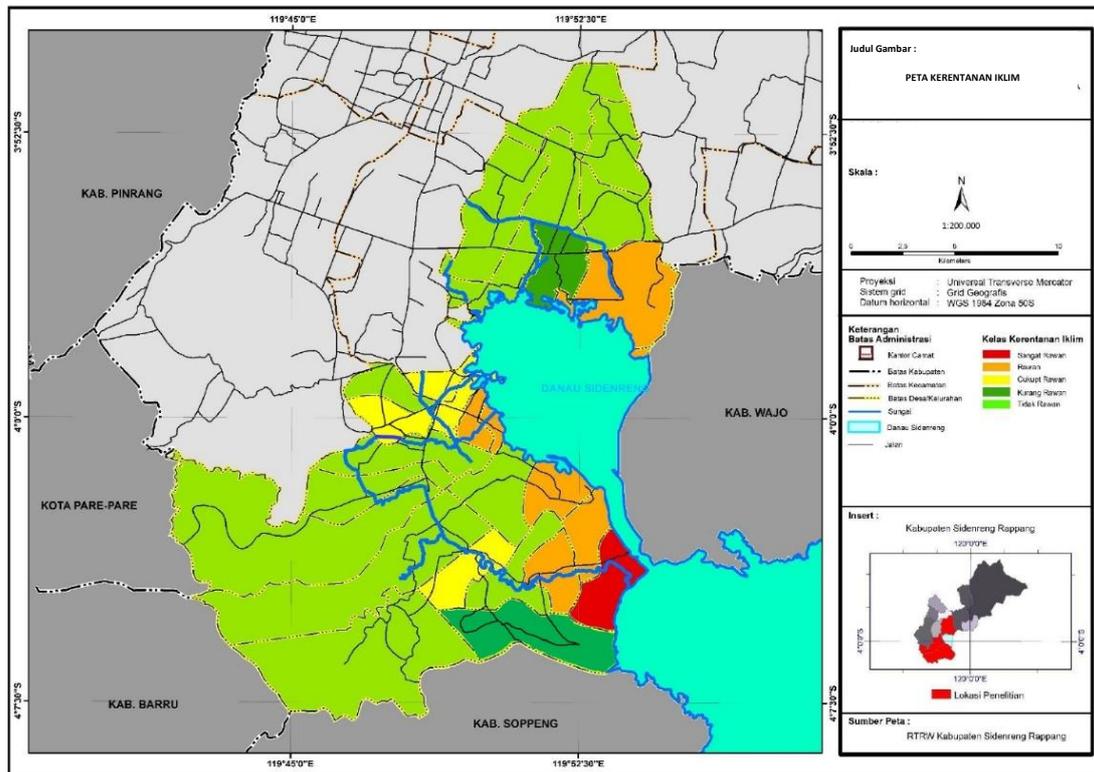
Figure 4. Climate Vulnerability Map of Lake Sidenreng

4.3 Analytical Hierarchy Process AHP - SWOT

The level of urgency from the results of the analysis of disaster vulnerability and climate vulnerability, expert respondents consisting of four sources are formulated strengths, weaknesses, opportunities, and threats.

The data obtained were processed using the Analytical Hierarchy Process (AHP). Each factor of strength, weakness, opportunity, and threat will be assessed for its level or weight of importance using a weighted comparison scale, where the weighting is based on the answers to questionnaires from respondents who are experts in their fields using the Analytical Hierarchy Process (AHP) to reduce subjectivity in the weighting of each factor. The weights of each internal and external factor were also obtained by processing data with the support of Expert Choice 11 and Microsoft Excel programs.

Based on the results of the weighting of the SWOT factor, it is known that for external factors in the form of opportunities for collaboration between the government and the private sector to deal with disasters, the location is directly adjacent to Sidenreng Lake so that it becomes the main focus of important attention. The threat factor is the emergence of material losses for affected groups such as farmer groups. While the internal factors in the form of the most influential strength are adaptation efforts carried out independently, followed by local wisdom factors that are still maintained such as the Bugis ethnic building model (house on stilts). The weakness factor is the lack of knowledge about climate change. For more details, see the following image:
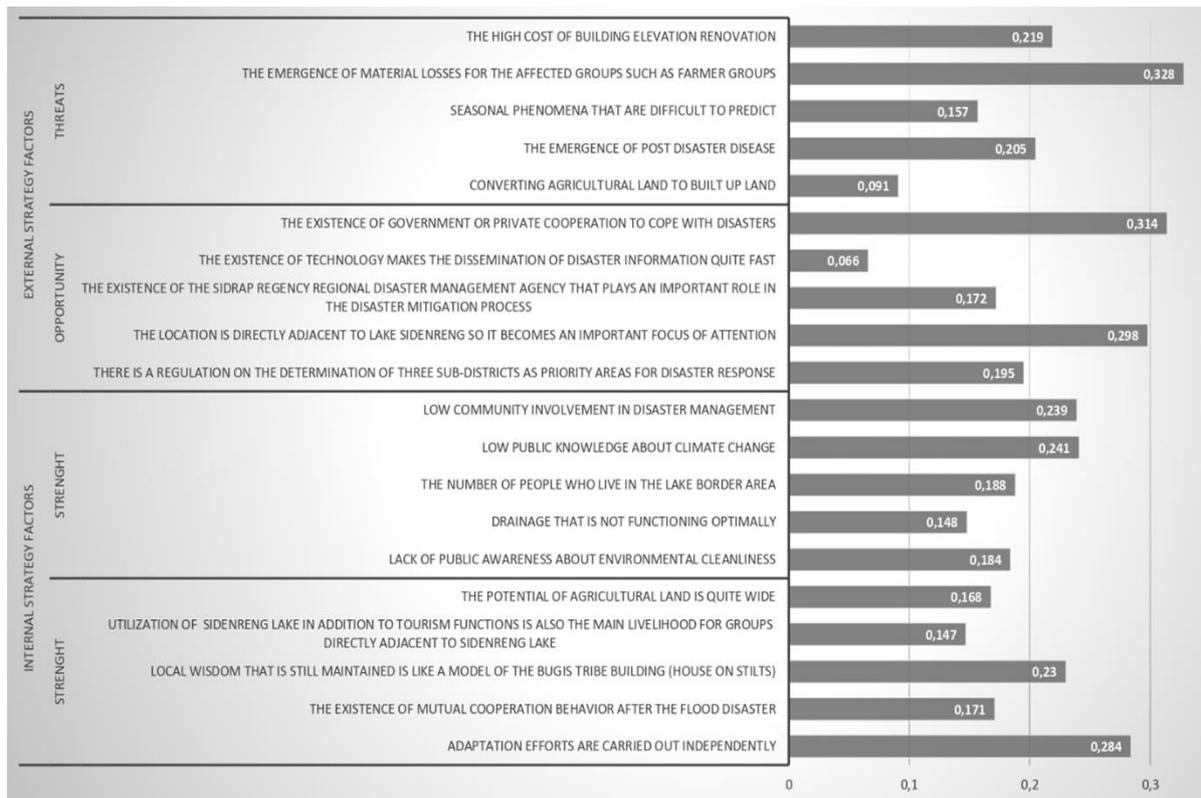
Figure 5. Results of AHP Analysis of Internal and External Factors by the author

Based on the results of the analysis of the IFAS and EFAS matrices, the difference in the scores of strengths and weaknesses in the IFAS matrix is 0.1487 and the difference in the scores of opportunities and threats in the EFAS matrix is -0.1685. The difference between the IFAS and EFAS factors will fill the position of the x and y values of the space matrix quadrant. The combination of these values results in a quadrant III position, which is a turnaround strategy, which means minimizing weaknesses by taking advantage of opportunities.
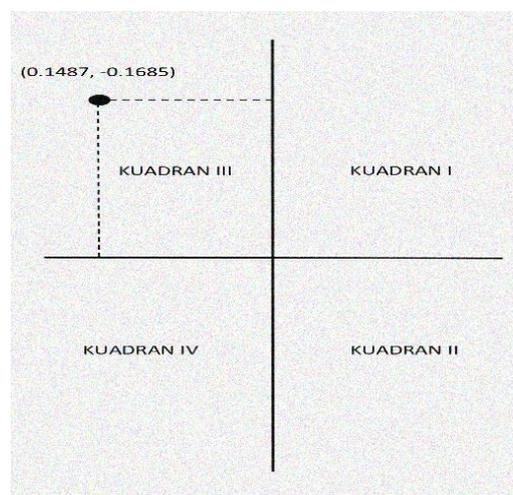
Figure 6. Results of the Space Matrix Analysis

The last stage of strategy formulation in the SWOT analysis is the decision-making stage, using a SWOT analysis matrix by collaborating various strength and weakness factors with opportunity and threat factors. Strategy formulation consists of 4 (four) components, namely:

Internal / External	Strength 1. Adaptation efforts are carried out independently 2. The existence of mutual cooperation behavior after the flood disaster 3. Local wisdom that is still maintained, such as the Bugis ethnic building model (house on stilts) 4. Utilization of Sidenreng Lake as a tourism function and become the main livelihood for groups directly adjacent to Sidenreng Lake 5. The potential of agricultural land is quite wide	Weakness 1. Lack of public awareness about environmental cleanliness 2. Drainage that is not functioning optimally 3. The number of people who live in lake border areas 4. Low public knowledge about climate change 5. Low community involvement in disaster management
Opportunity 1. There is a regulation on the determination of three sub-districts as priority areas for disaster response 2. The location is directly adjacent to Sidenreng Lake so that it becomes an important focus of attention 3. The existence of an agency for the Regional Disaster Management Agency of Sidenreng Rappang Regency which plays an important role in disaster mitigation 4. The existence of technology makes the dissemination of disaster information quite fast 5. There is cooperation between the government and the private sector to deal with disasters	**S – O** 1. Arrangement of permit facilities for investors/communities who will and have carried out area-scale land elevation (reclamation) as a form of adaptation to climate disasters. 2. Strengthening institutional capacity in seeing tourism potential and natural potential in the Sidenreng Lake area 3. Management of the risk of climate change impacts by the city government and related stakeholders or the private sector both structurally/physically and institutionally by involving potential experts.	**W – O** 1. Development of human resources and community participation to maintain environmental cleanliness and increase the capacity of vulnerable groups, Formation of Climate Villages, Formation and development of disaster aware communities. 2. Management of the risk of climate change impacts by the city government and related stakeholders or the private sector, both structurally/physically and institutionally by involving potential experts. 3. Development of flood susceptibility maps and climate change vulnerability risks that are integrated with disaster mitigation maps
Threat 1. Conversion of agricultural land into built-up land 2. The emergence of post-disaster diseases 3. The phenomenon of unpredictable seasons 4. The occurrence of material losses for affected groups such as farmer groups 5. The high cost of building elevation renovation	**S – T** 1. Tightening the implementation of environmental laws including monitoring and evaluation to suppress land conversion, control green open space and suppress development in disaster-prone areas. 2. Application of appropriate technology for farmer's cropping pattern system 3. Determination of the retreat / move area in the lake border area 4. Optimizing the tourism function of Lake Sidenreng for the economic growth of the surrounding community	**W – T** 1. Providing socialization related to the environment and the impacts caused by climate disasters 2. Empowerment for people with vulnerable livelihoods such as farmers and fishermen

Figure 7. Results of SWOT Matrix Analysis for Sidenreng Lake

4.4 Alternative Strategy for Flood Disaster Management Due to Climate Change

Based on an assessment of each internal and external factor in the Adaptation strategy to the impacts of climate change on the Sidenreng Lake area, there are 11 development strategies, where based on the results of the SWOT matrix analysis, a combination strategy between strengths and opportunities (S-O) is obtained, namely:

1. Arrangement of permit facilities for investors/communities who will and have carried out area-scale land elevation (reclamation) as a form of adaptation to climate disasters.
2. Strengthening institutional capacity in seeing tourism potential and natural potential in the Sidenreng Lake area.
3. Management of the risk of climate change impacts by the city government and related stakeholders or the private sector both structurally/physically and institutionally by involving potential experts.

A combination strategy between strengths and opportunities (W-O) is a strategy that takes advantage of all weaknesses and opportunities as much as possible. The strategies include:

1. Development of human resources and community participation to maintain environmental cleanliness and increase the capacity of vulnerable groups, and Formation of Climate Villages, Formation and development of disaster-aware communities.
2. Management of the risk of climate change impacts by the city government and related stakeholders or the private sector, both structurally/physically and institutionally by involving potential experts.
3. Development of flood susceptibility maps and climate change vulnerability risks that are integrated with disaster mitigation maps.

A combination of strengths and opportunities (S-T) strategy is a strategy that utilizes all strengths and threats. The strategies include:

1. Limitation of permits for conversion of productive agricultural land, namely the government narrows the movement for the conversion of agricultural land functions and all its uses into non-agricultural interests.
2. Application of appropriate technology for farmers' cropping pattern systems, namely providing access for farmers to weather forecasts that are correct, accessible, and can rely on technical knowledge to use information.
3. Determination of the retreat/moving area in the lake border area using the government providing understanding to the community based on the Law on spatial planning that the lake border is a protected area for the preservation of the river/lake by providing options for choosing a safer and more suitable location to be used as a residential area.
4. Optimizing the tourism function of Sidenreng Lake for the economic growth of the surrounding community with good planning and management, the tourism function of Sidenreng Lake can be developed.

A combination of strengths and opportunities (W-T) strategy is a strategy that utilizes all strengths and threats. The strategies include:

1. Providing socialization related to the environment and the impacts caused by climate disasters is very necessary to provide understanding and capacity building to the community about the importance of climate change adaptation and concrete efforts to contribute to climate change adaptation.
2. Empowerment for people with vulnerable livelihoods such as farmers and fishermen where the purpose of this empowerment is to create community independence in the economy in various sectors considering the challenges faced by people who are in a disaster environment.

5. CONCLUSION AND RECOMENDATIONS
5.1 Conclusion

This study used components to assess climate vulnerability obtained by combining data and information locally through questionnaires and through supporting data to produce a more specific assessment village. In this study, the results of climate vulnerability at the research location on sensitivity variables, namely indicators of physical vulnerability of buildings and vital infrastructure as well as the vulnerability of community safety and capabilities had the lowest level of vulnerability when compared to the exposure and adaptive capacity variables so that the results of the assessment were used as consideration for compiling climate vulnerability strategy while the results of the assessment of the exposure variable show a low-class average, namely indicators of regional biophysical and hydrological vulnerability and economic vulnerability of the community where this variable must be minimized by the impact on climate change. In Low average or Class II where the local community had tried to adapt to the disaster environment but had not been optimal in terms of vulnerability to education, knowledge, and adaptive technology. Meanwhile, for flood-prone areas, the percentage was Very Vulnerable at 130.94 km^2, Vulnerable at 134.98 km^2 quite vulnerable at 88.93 km^2, and Less Vulnerable at 22.97 km^2, and not vulnerable at 3.03 km^2 with a total amount of 380.85 km^2. Subsequently, the resulting strategy is based on quadrant III SWOT analysis namely a Turn Around strategy where internal weaknesses come from sensitivity variables, namely the physical vulnerability of buildings and vital infrastructure and socio-cultural vulnerabilities, while from exposure variables, namely environmental vulnerability and community economic vulnerability. Then the WO strategies are obtained, namely 1) Human resource development and community participation to maintain environmental cleanliness and increase the capacity of vulnerable groups, Formation of Climate Villages, Formation and development of disaster-aware communities; 2) Management of the risk of climate change impacts by the city government and related stakeholders or the private sector both structurally/physically and institutionally by involving potential experts; 3) Development of flood susceptibility maps and climate change vulnerability risks that are integrated with disaster mitigation maps.

5.2 Recommendations

Following the conclusions that have been stated, several recommendations are proposed to overcome the flood disaster due to climate change, namely:

1. For Sidenreng Rappang Regency Government

To immediately implement various policies and strategies in mitigation/adaptation efforts in the Sidenreng Lake area to potential climate change disasters, through zoning and regional regulations that are by the results of climate vulnerability and flood disaster vulnerability and provide an understanding of mitigation and adaptation to local communities so that people will fully aware of the steps that must be taken in dealing with this potential disaster. At this time the Government of Sidenreng Rappang Regency has provided socialization of climate change disaster mitigation and adaptation to local communities, but it is not optimal and the programs that have been carried out by the government are currently only oriented to flood management and have not discussed the impacts of climate change which must be anticipated from now on.

2. For Local Communities

Local communities need to participate in disaster management by strengthening the institutional system for handling potential disasters, namely developing community institutions for disaster preparedness specifically to anticipate these problems. Currently, there are several villages that have started to develop community institutions for flood disaster preparedness, namely Wette Village, but the effectiveness of the programs carried out has not been maximized and climate disaster management has not been included because people think that the impact has not been felt by the wider community. So it is necessary to transfer knowledge about climate disaster risk to the community so that awareness of the management of community institutions for disaster preparedness will run actively and strongly. Meanwhile, the things that can support the policy strategy can be discussed/deliberate between the community and the city government. With this, it is hoped that the impact of the disaster on local communities can be minimized.

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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.
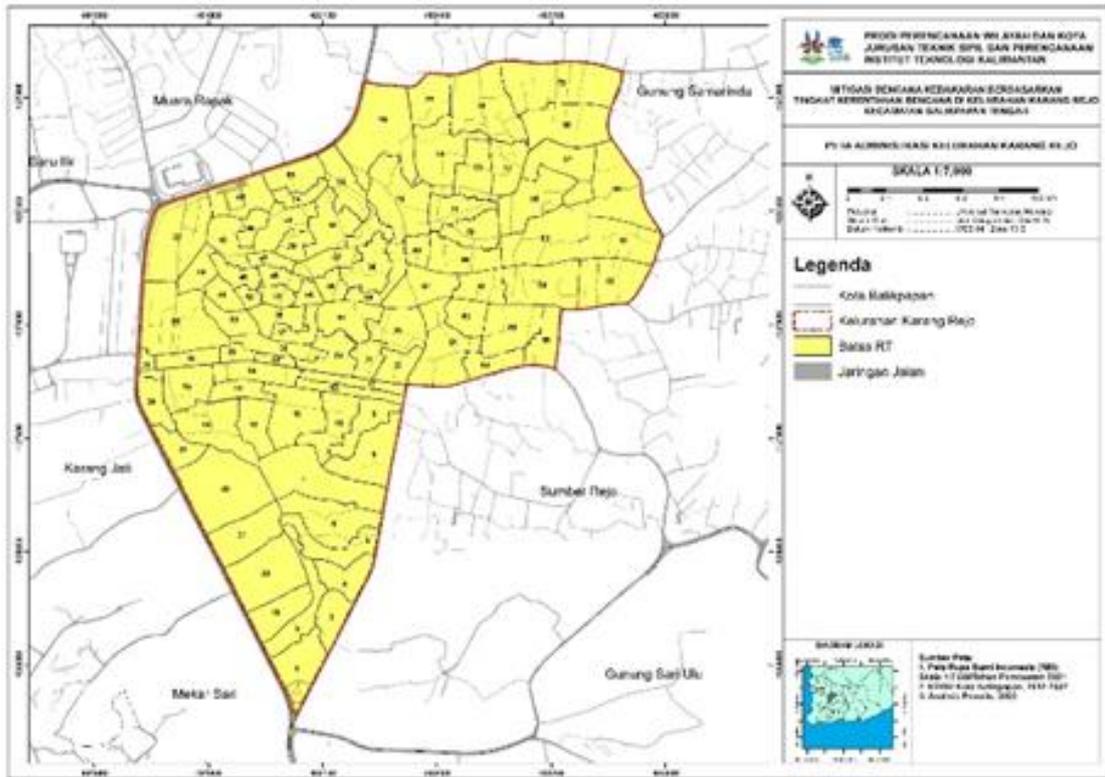
Figure 1. Research Sites

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	Low	<20 %	1
	Population	Currently	20% - 40%	2
	Ratio	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.
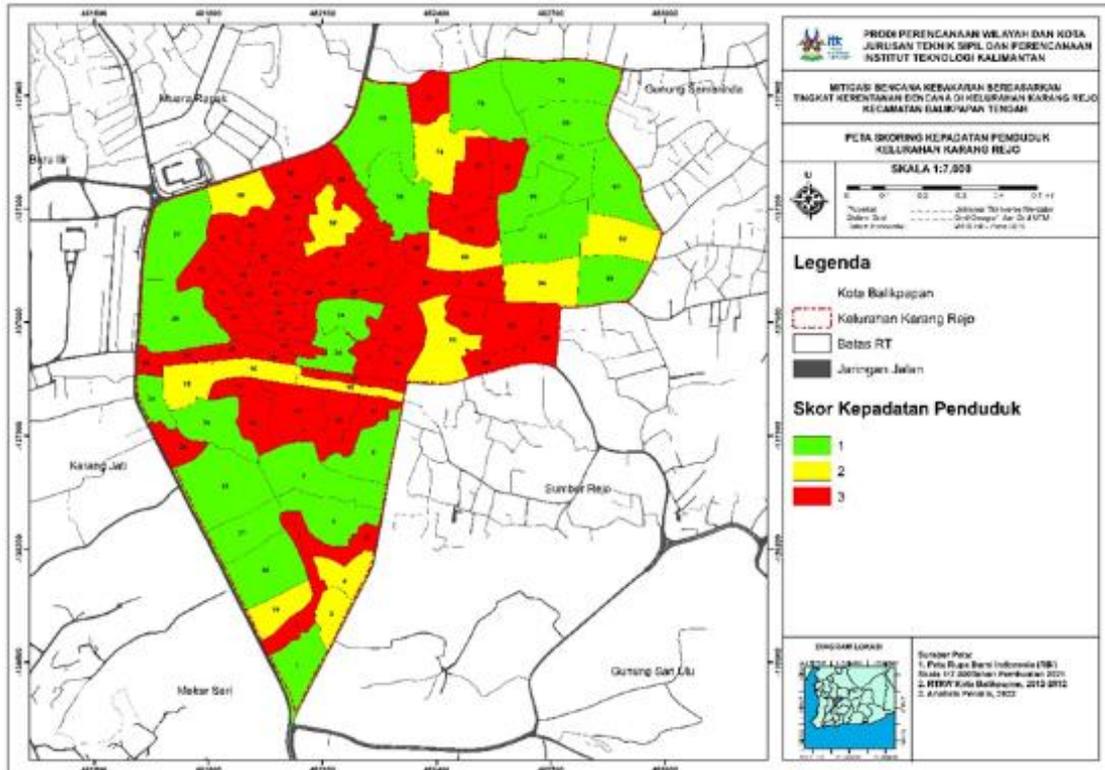
Figure 2. Population Density Scoring Map for Karang Rejo Village

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.
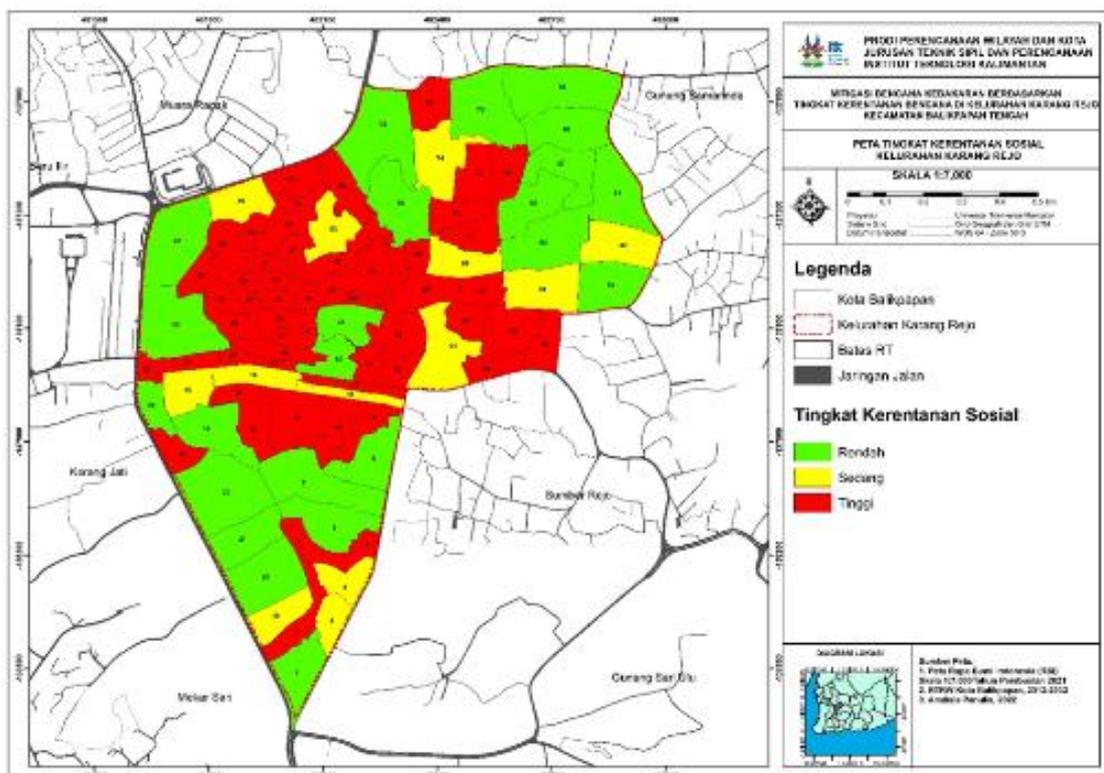

Figure 3. Map of Social Vulnerability Levels in Karang Rejo Village

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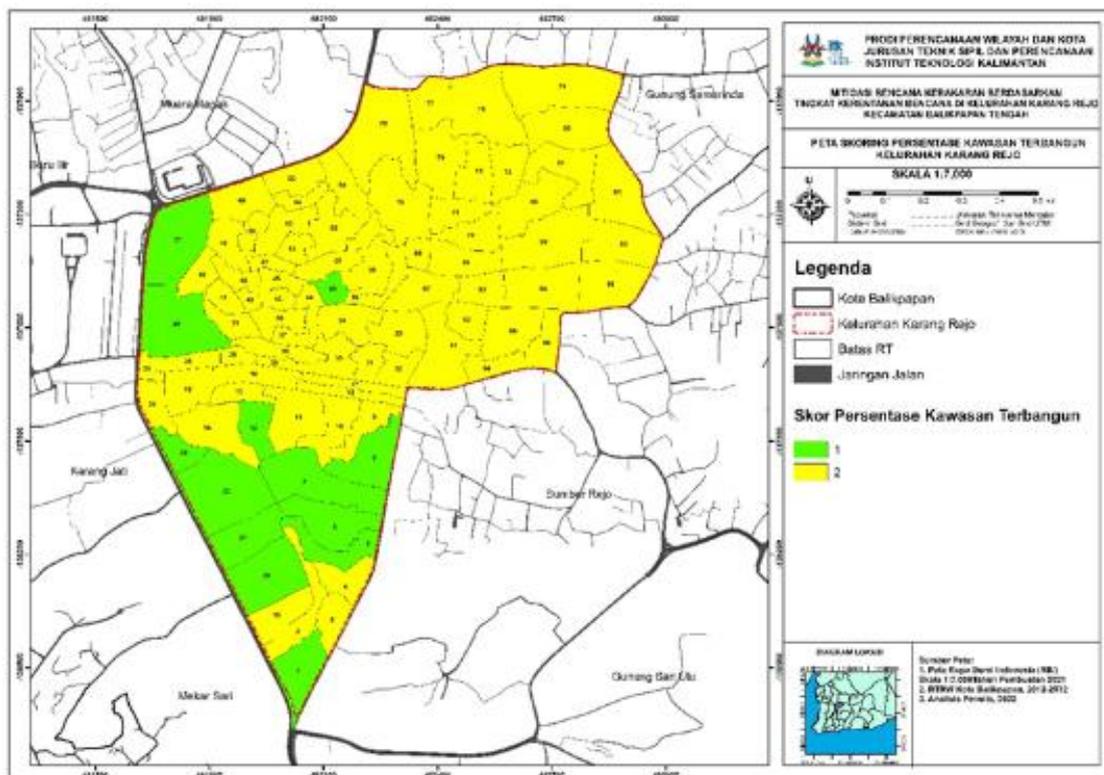
Figure 4. Scoring Map of the Percentage of Built-up Areas in Karang Rejo Village

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.
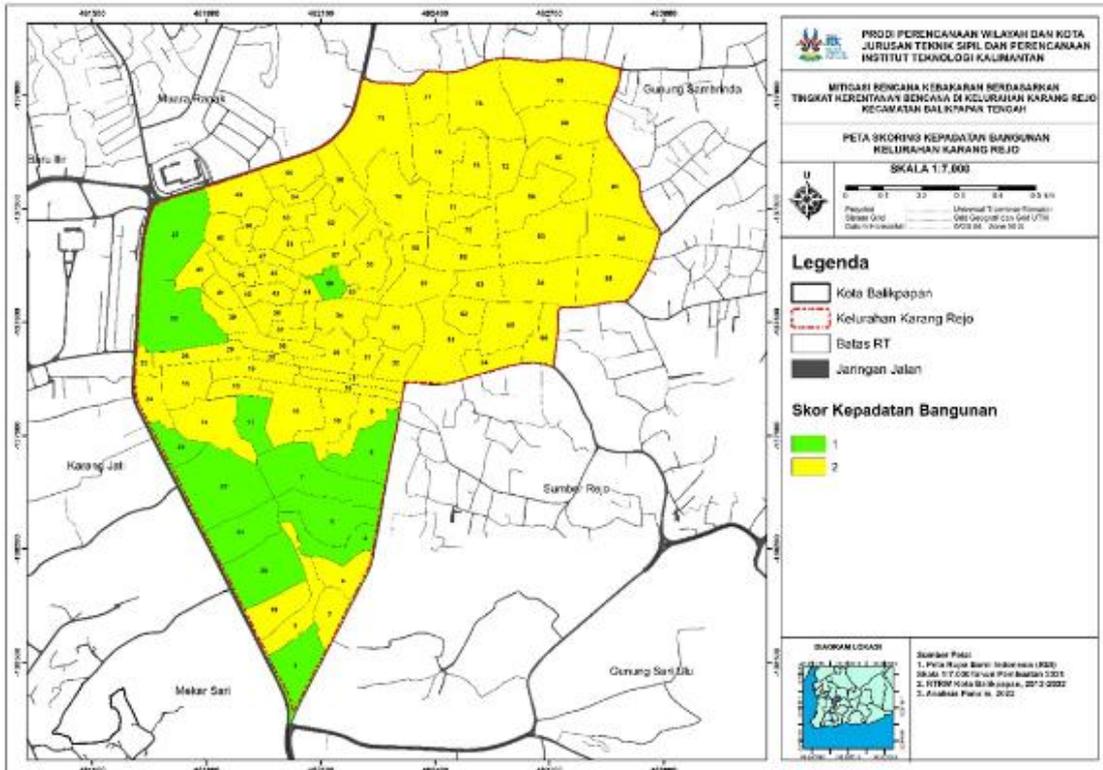
Figure 5. Building Density Scoring Map in Karang Rejo Village

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.
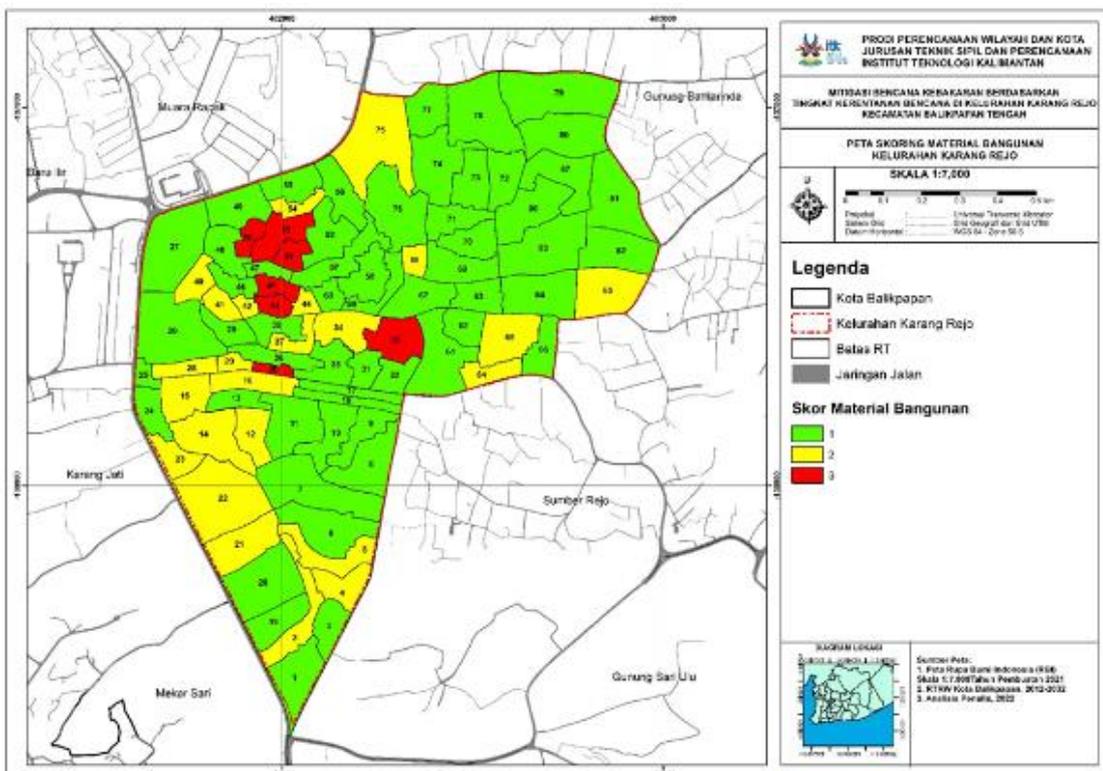

Figure 6. Scoring Map of Building Materials in Karang Rejo Village

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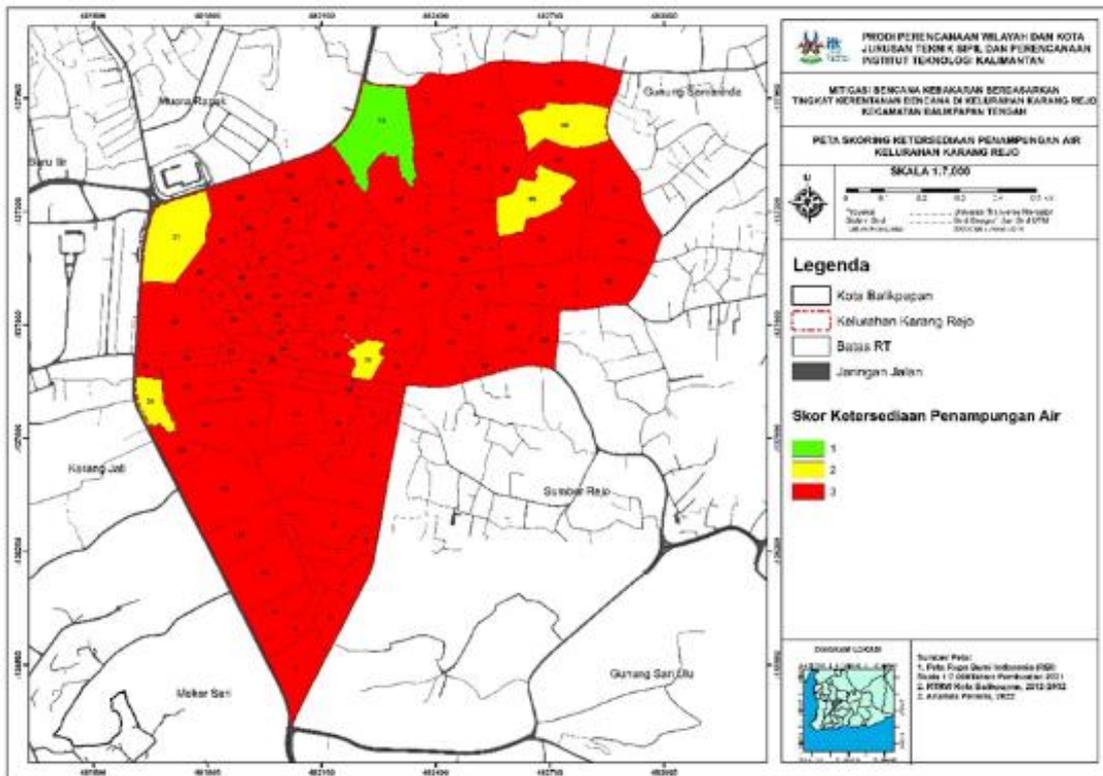
Figure 7. Scoring Map of Availability of Water Storage in Karang Rejo Village

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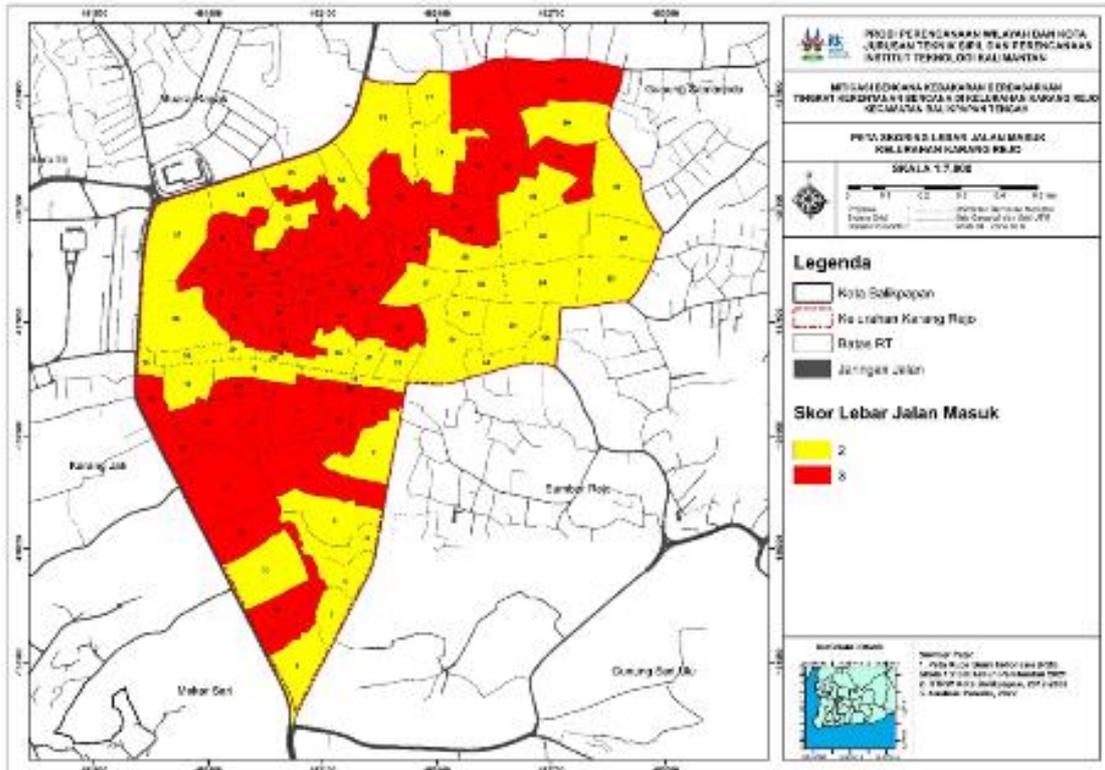
Figure 8. Scoring Map of Fire Car Entryway Width
Fire in Karang Rejo Village

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*.
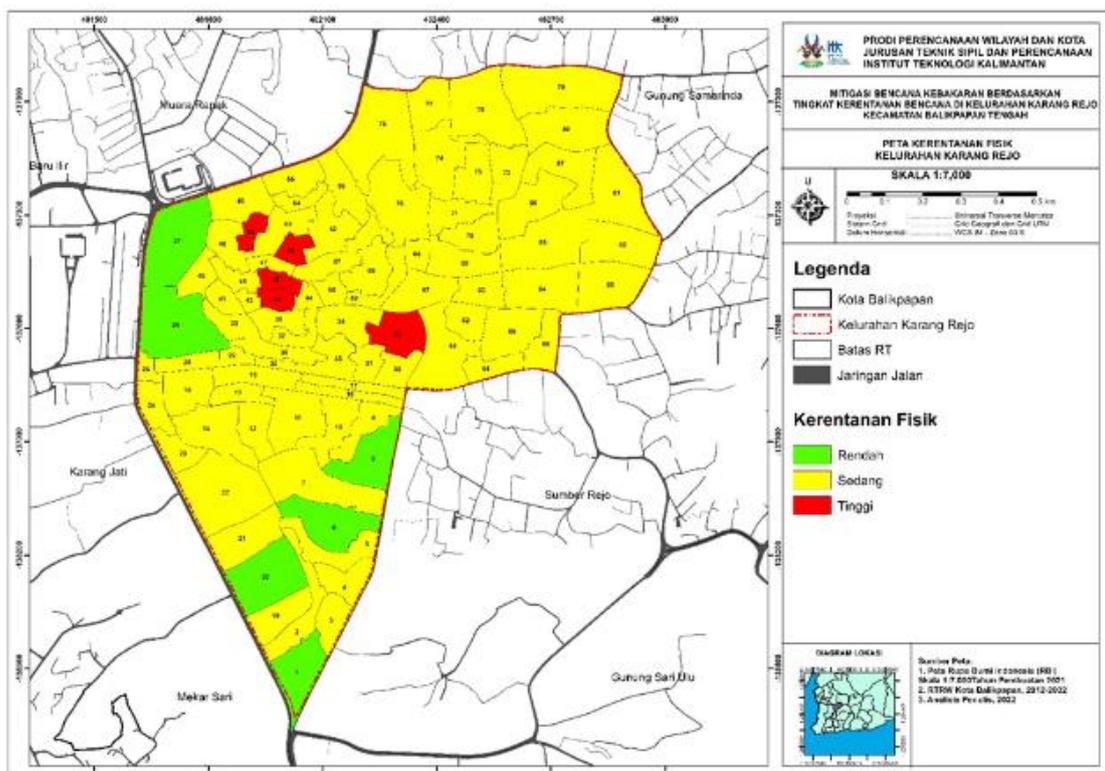

Figure 9. Map of Physical Vulnerability in Karang Rejo Village

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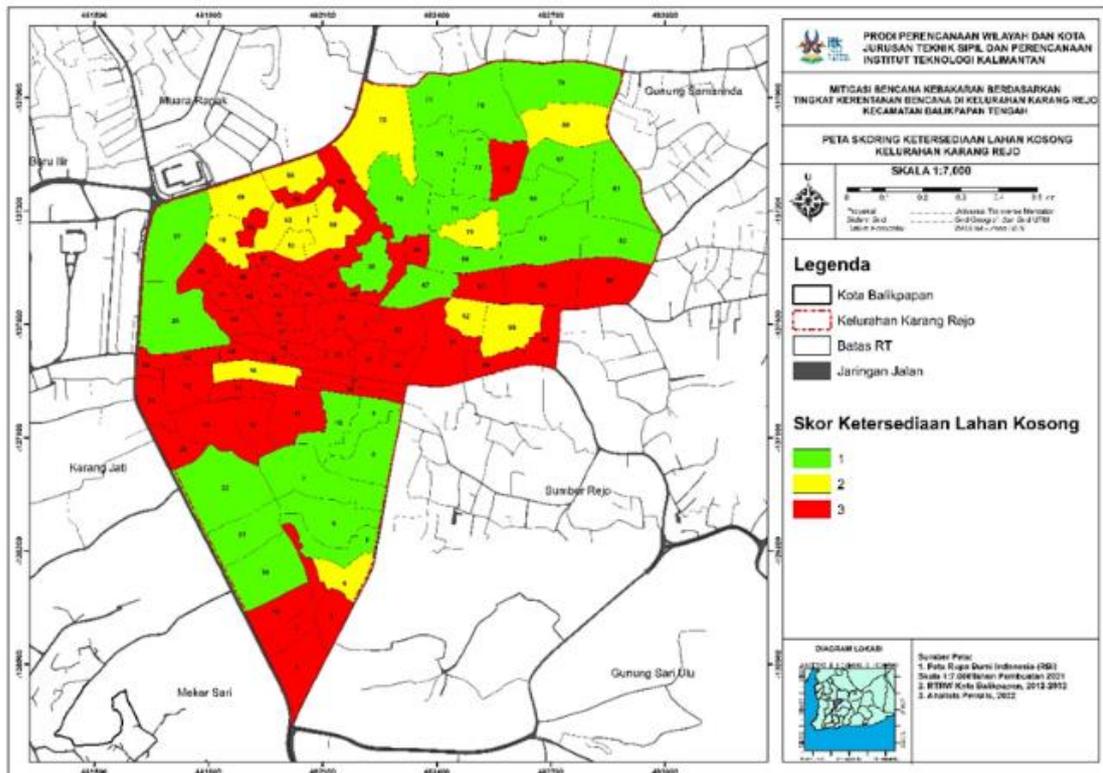
Figure 1. Map of Scoring Availability of Vacant Land in Karang Rejo Village

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.
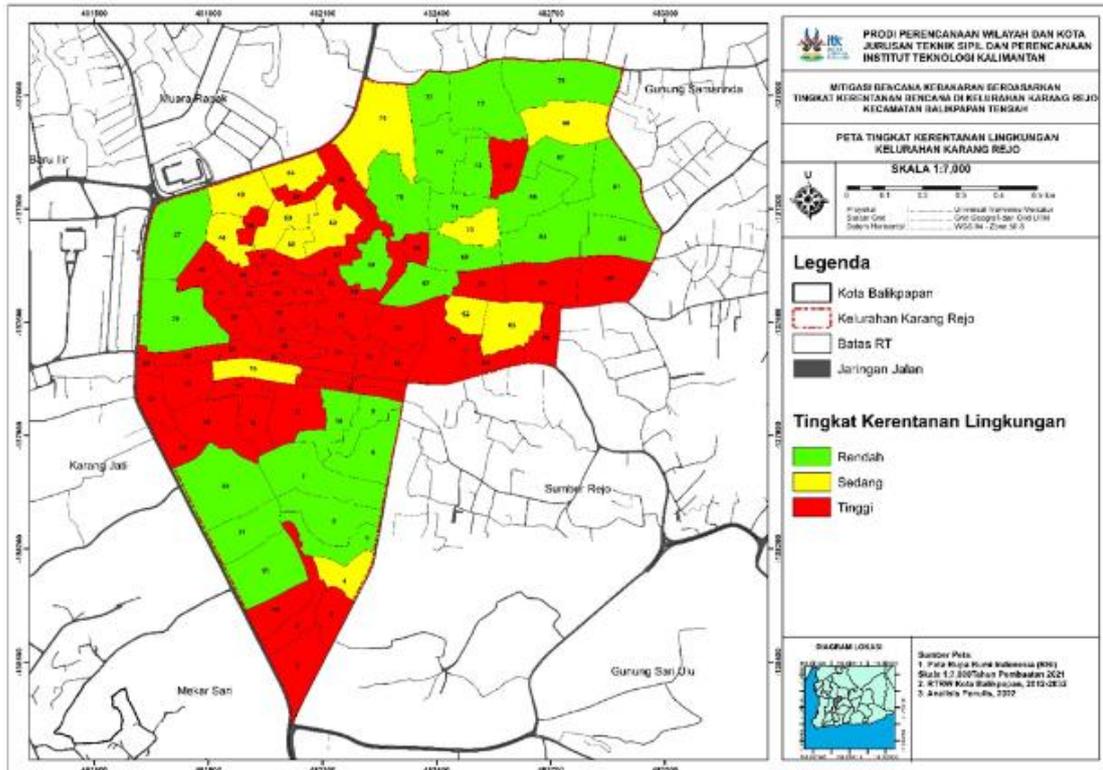
Picture 11. Map of Environmental Vulnerability in Karang Rejo Village

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%.
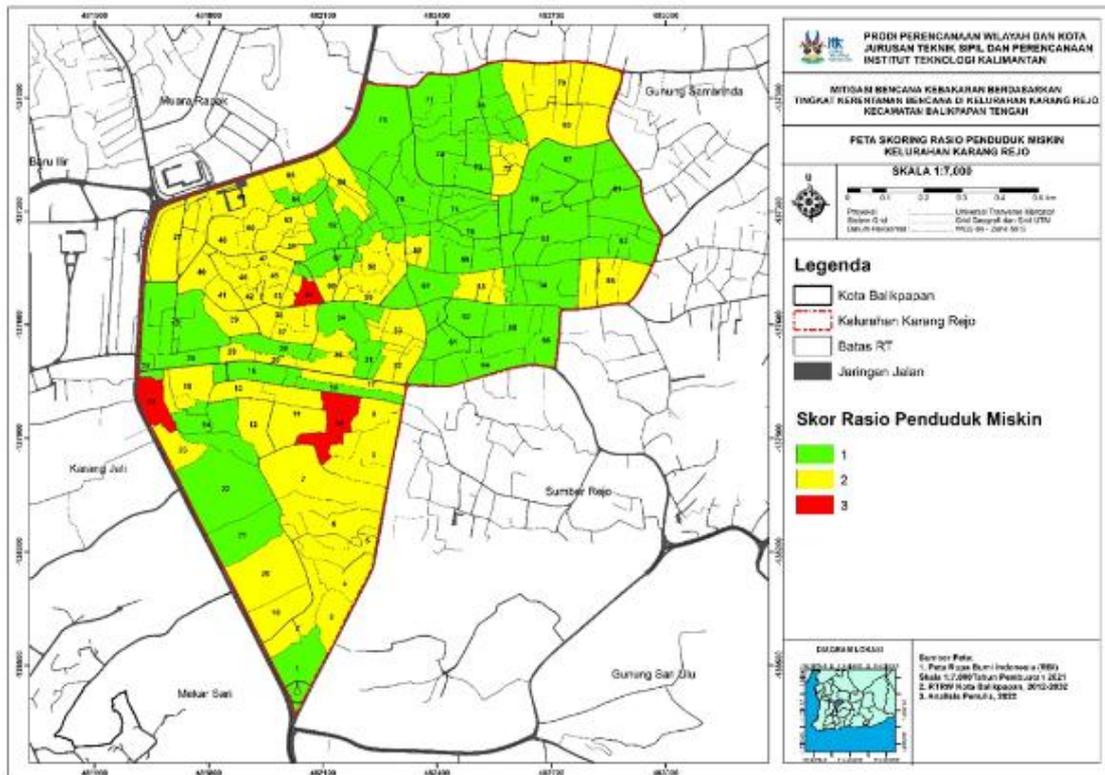
Figure 12. Poor Population Scoring Map in Karang Rejo Village

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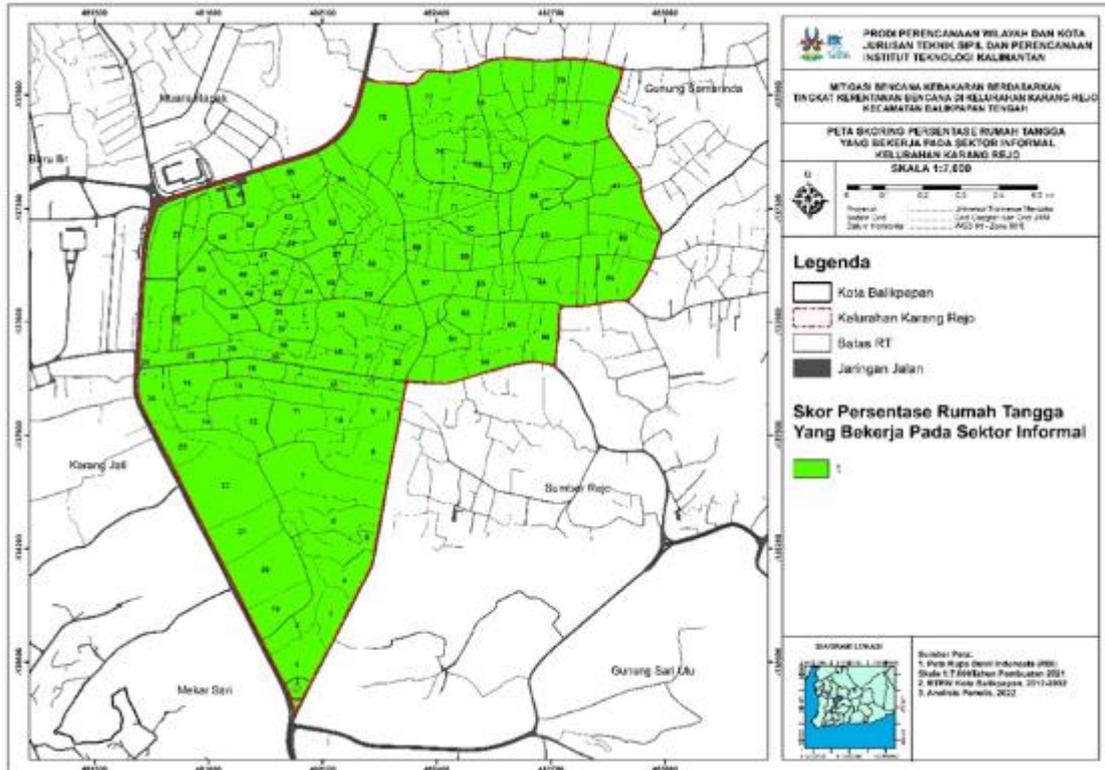

Figure 13. Scoring Map of the Percentage of Households Working in the Informal Sector in Karang Rejo Village

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.
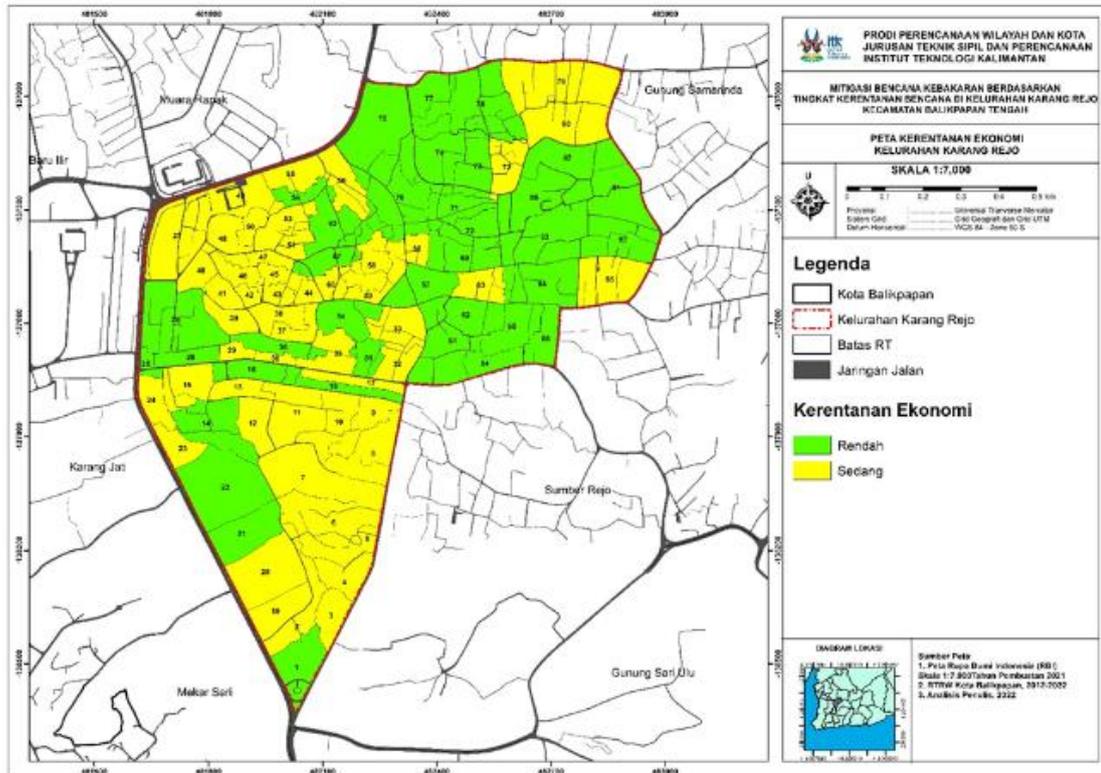

Figure 14. Map of Economic Vulnerability Levels in Karang Rejo Village

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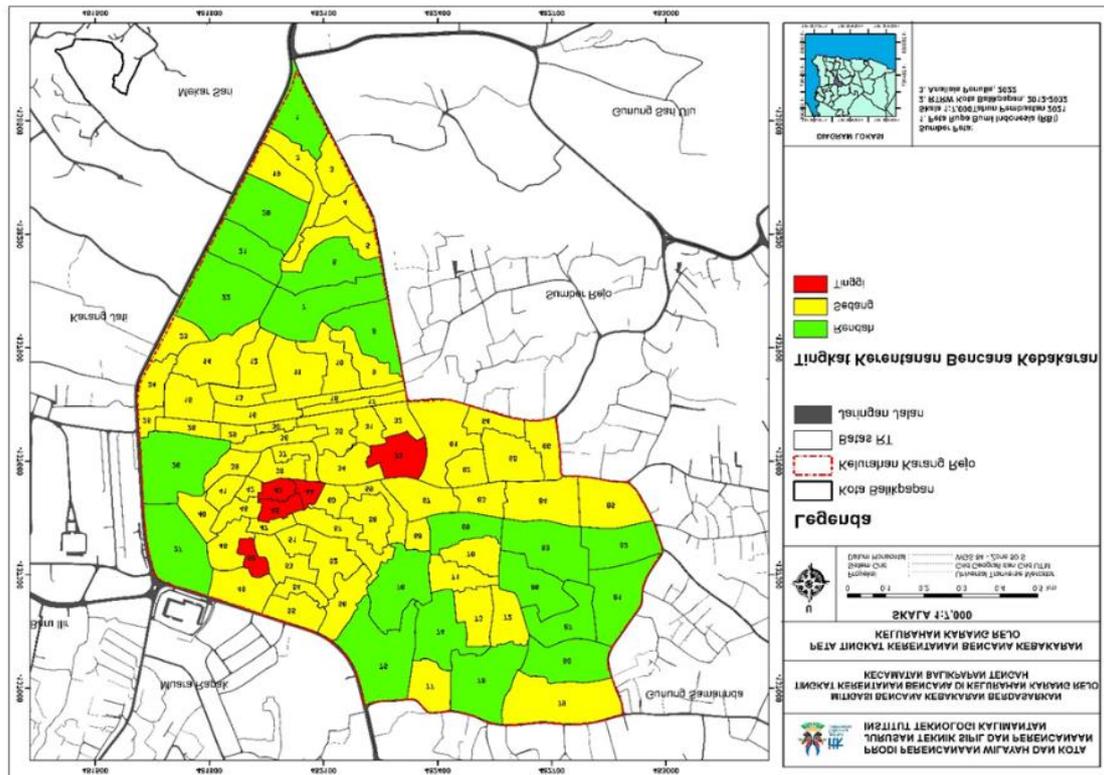
Figure 15. Map of Fire Disaster Vulnerability Levels in Karang Rejo Village

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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