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

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Alternative Adaptation Strategies; Climate Vulnerability; Flood 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. Biophysical and Hydrological Vulnerability of the Area/Environmental Vulnerability (Exposure) 3. Capabilities and Community Safety Vulnerabilities/Social and Cultural Vulnerabilities (Sensitivity) 4. Community Economic Vulnerability/Economic Vulnerability (Exposure) 5. Vulnerability of adaptation technology (Adaptive Capacity)
2.	Miladan (2009)	1. Artificial physique 2. Socioeconomic 3. Social population 4. Environment 5. Regional economy	
3.	Sassa (2009)	1. Physical vulnerability 2. Economic vulnerability 3. Social vulnerability	
4.	Shah, et. al. (2013)	Vulnerability of adaptation technology	

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.

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

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:

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

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.

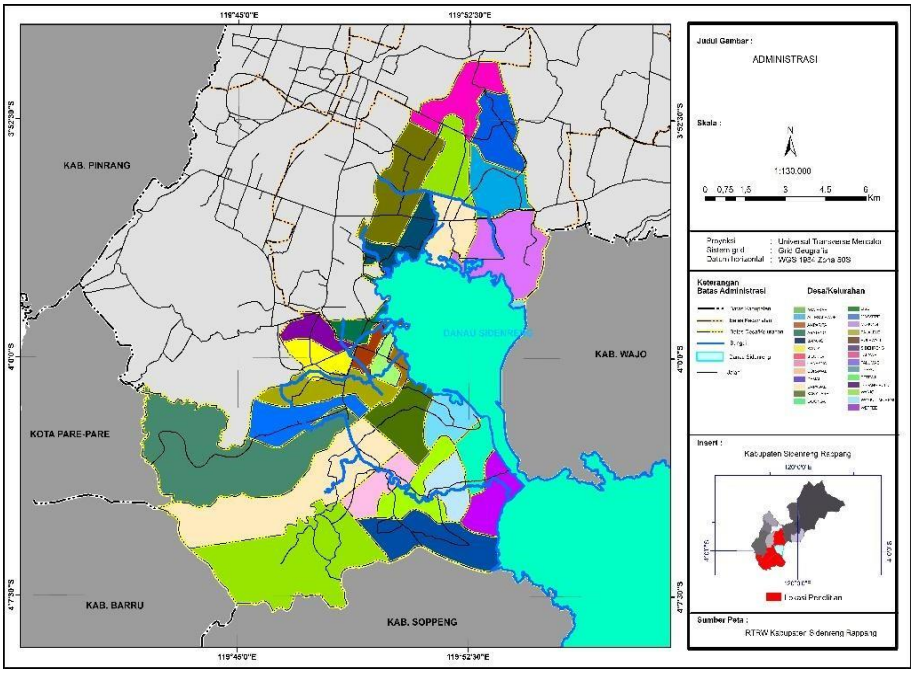


Figure 1: Administrative Map of the Sidenreng lake area

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

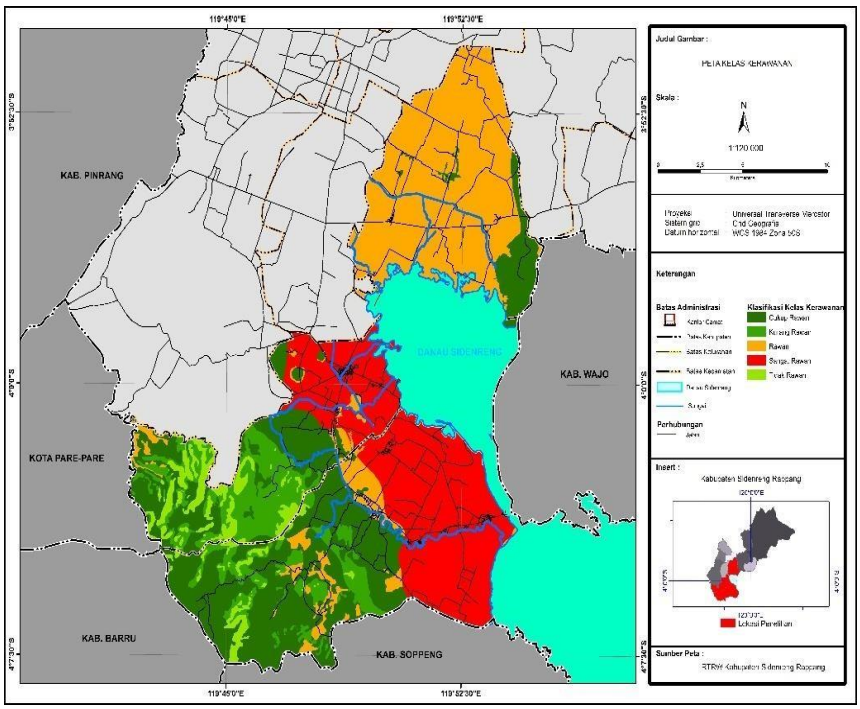


Figure 2: Flood Hazard Map in Sidenreng lake area

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

Districts	Urban Village	Classification of Flood Prone Level					Total (Km^2)
		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 (Km^2)
		Very Vulnerable	Vulnerable	Quite Vulnerable	Less Vulnerable	Not Vulnerable	
	Arateng	3,59	3,06	1,82	-	-	8,47
Wattang Sidenreng	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.

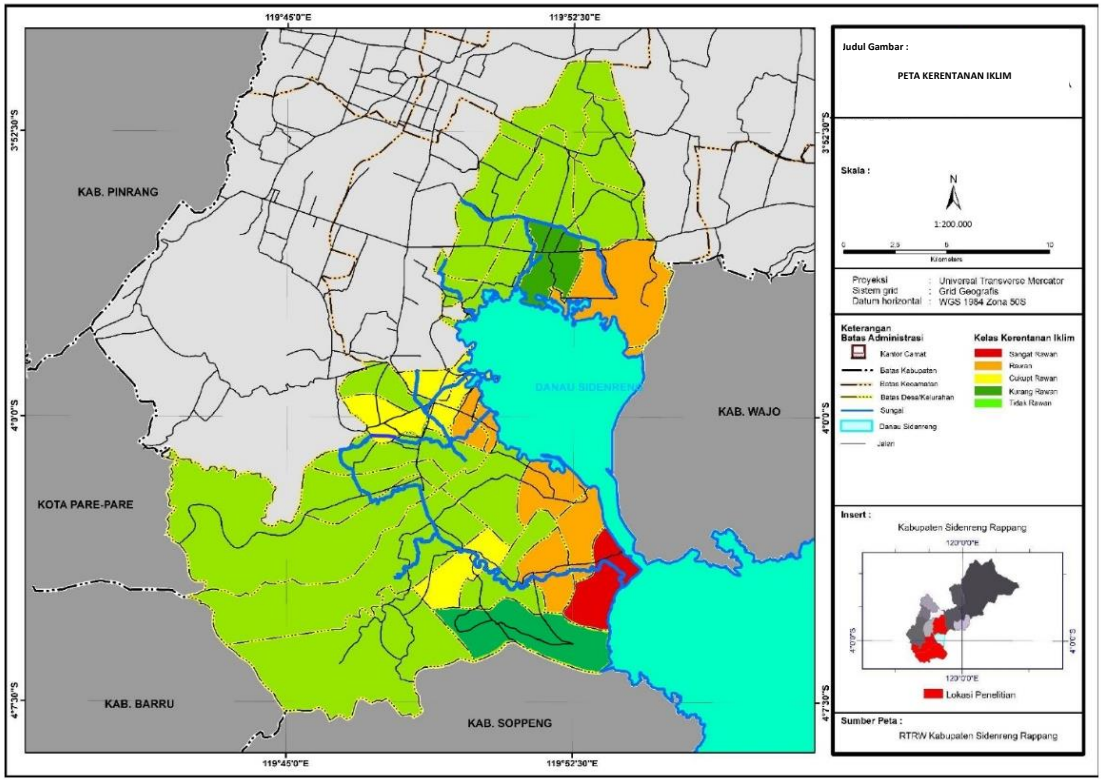


Figure 4. Climate Vulnerability Map of Lake Sidenreng

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:

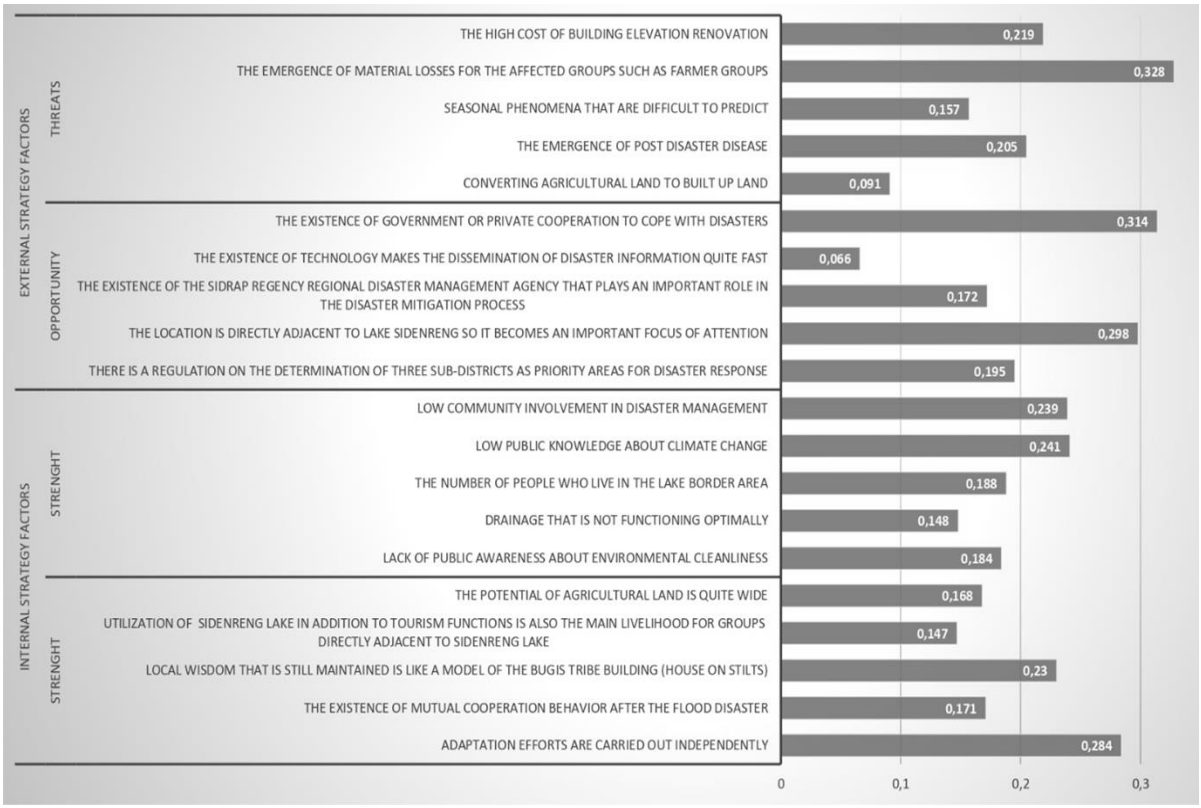


Figure 5. Results of AHP Analysis of Internal and External Factors by the author

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.

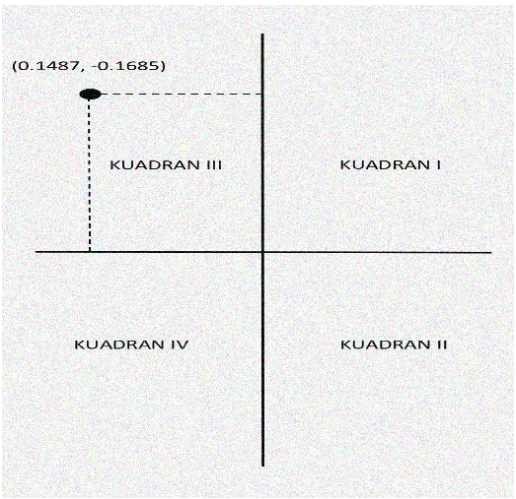


Figure 6. Results of the Space Matrix Analysis

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**	**Weakness**
	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	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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