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ANALYSIS OF LANDSLIDE RISK IN SOUTH OKU REGENCY, INDONESIA

Abstract: Landslides cause significant economic, physical, and environmental losses. This research aims to analyse landslide risk using hazard analysis, vulnerability analysis, regional capacity analysis, and landslide disaster risk analysis. The study was conducted in South OKU Regency, one of the regencies in South Sumatra Province, which frequently experiences landslides. The method used in this research is a survey method. The data includes DEM data, slope types, land cover type maps, rainfall maps, soil type maps, physical infrastructure, economic losses, environmental damage, development plans, regional capacity index, and data from structured interviews with 19 sub-district heads. Landslide analysis uses the weighting and overlay method; vulnerability analysis uses Multi-Criteria Decision Analysis; capacity analysis refers to the Hyogo Framework for Actions; and risk analysis is based on Perka BNPB No. 2 of 2012. The results of the analysis show that the landslide hazard in South OKU Regency is high and spread across more than half of the sub-districts. This landslide hazard is very vulnerable to the condition of vital physical infrastructure, has the potential to cause significant economic losses, and can damage environmental conditions. On the other hand, regional capacity in dealing with landslide danger is categorized as moderate. The risk of landslides in South OKU Regency is in the medium disaster risk class. Therefore, it is necessary to strengthen community capacity and increase preparedness in facing landslide disasters to minimize the risks posed.

Key words: landslides, hazard, vulnerability, capacity, risk

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Introduction

A natural disaster is an event whose time of occurrence cannot be predicted, but human activities cause most natural disasters. Landslides are natural disasters caused by high rainfall, slope slopes, soil types, and human activities in hilly areas. Indonesia is one of the countries that frequently experiences landslides; most of the landslide-prone regions are located along the Barisan Hills on Sumatra Island. South Ogan Komering Ulu Regency (South OKU Regency) is one of the 13 city districts in the province of South Sumatra, which has a varied topography ranging from plains and hills to dominated by mountains; its area is in the hill range unit with a tropical and wet climate and is dominated by rainfall. fairly high (Ningsih & Handayani, 2023). With a mountainous region with many steep slopes, there is the potential for many landslides in South OKU Regency (Argentin et al., 2022; Dwivedi et al., 2023; Wu et al., 2023). The National Disaster Management Agency (BNPB) noted that from 2013 until now, landslides have continued to occur, with all sub-districts having the potential for landslides. During the last five years, BNPB recorded 34 landslides in Indonesia's South OKU Regency. In 2019, it happened 3 times; in 2020, it happened 4 times; in 2021, it happened 2 times; in 2022, it happened 18 times; and in 2023, it happened 7 times.

Landslide disasters have an impact on land damage, disturbed ecosystems, damage to public facilities such as roads and bridges, damage to residents' houses, economic losses, loss of industrial, agricultural, and forest productivity, as well as tourism income as a result of land damage (Gupta & Satyam, 2022). The terrible impact is loss of life. BNPB noted that several years ago, 14 fatalities were caused by landslides in South OKU Regency. In 2013, seven residents of the Warkuk Ranau Selatan sub-district died, and three people were injured. In 2017, six residents of the Sungai Are sub-district died, and four people were injured. In 2020 in the Pulau Beringin sub-district, one resident died (Abdelrahman et al., 2021; Song et al., 2021; Yoshihara et al., 2022; Fayaz et al., 2022; Cencetti et al., 2020).

The factors causing the landslide disaster in South OKU Regency were caused by high rainfall, which caused the land on the road to shift and threatened to break the road (Lin et al., 2021; Zhang et al., 2020; Pradhan et al., 2022). Landslides can also be caused by earthquakes and other natural events (Shao & Xu, 2022; Marengo et al., 2023; Kitamura et al., 2020). Deforestation, such as turning forest areas into settlements and other human activities, all play a role in causing this dangerous event (Sonker et al., 2022; Sridharan & Gopalan, 2022). Burning forests result in denuded forests, and they can no longer hold water reserves during the rainy season, which can cause landslides (Utomo et al., 2022; Utomo et al., 2023). Another factor that causes landslides is the stability of a slope (Wistuba et al., 2021). Soil type also influences the occurrence of landslides (Khan & Al Shoumik, 2022). Judging from the soil types in general, the soil types in the South OKU Regency area vary and have certain characteristics that can be a potential or an obstacle to land use (Liu et al., 2021; Amato et al., 2021). Based on the problems above, this article aims to analyze landslide disasters starting from the danger, vulnerability, capacity and risk of landslide disasters in South OKU district, Indonesia.

Materials and Methods

Research Sites

South OKU Regency is a district in South Sumatra Province. Regarding coordinates, it is located between 103°22'–104°21' E and 04°14'–04°55' S, directly bordering the provinces of Lampung and Bengkulu (Fig. 1). It has an area of 5,849.89 km² with hilly and mountainous topography. The research location was chosen because South OKU Regency is one of the regencies in Sumatra Province, where landslides often occur.

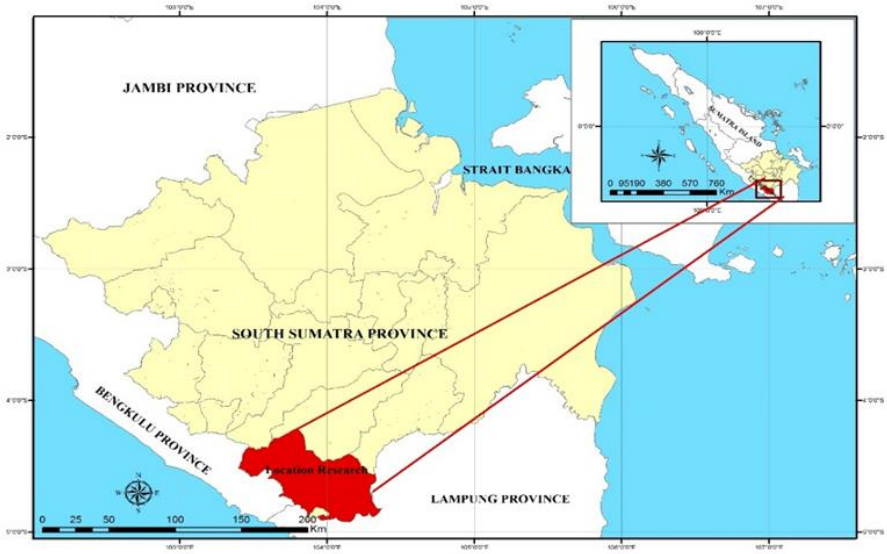

Fig. 1. Location map of South OKU Regency

Research methods

This research uses a survey method with quantitative analysis. The survey method is used to obtain data at a place determined as an object; quantitative analysis is used to describe and test the hypothesis that has been established. The population in this study is the entire administrative area of South OKU Regency, which consists of 19 sub-districts. Meanwhile, the sample in this study used a saturated sample of the entire population as the research sample. The data in this research is in the form of Administrative Boundary: BIG/Bappeda South OKU, DEM 30 Meters, Land Movement Vulnerability Zone Map: LAPAN/BIG/NASA/JAXA and Ministry of Energy and Mineral Resources – PVMBG, Village/Kelurahan Administrative Boundary, Coverage/ Land Use: BIG/Bappeda and BIG/KLHK/Bappeda/Satellite Image Analysis, Regional Functions, GRDP per sector: KLHK/BIG/Forestry Service and BPS. Data collection uses secondary data, which includes documentation in the form of GRDP, productive land, ecological land area, house, public facilities, special facilities, population, and vulnerable groups. Interviews with seven questions were conducted with all heads of 19 sub-districts and soil type surveys, slope, and rainfall.

Data Analysis: This research data analysis uses four stages: hazard, vulnerability, capacity, and risk analysis. The four analyses are as follows.

Hazard

A landslide is a process of moving a mass of soil or rock in an inclined direction from its original position so that it is separated from a steady mass due to the influence of gravity, with types of movement in the form of rotation and translation (PU Ministerial Decree 22/2017). The following (Fig. 2) is a landslide hazard analysis flow diagram.

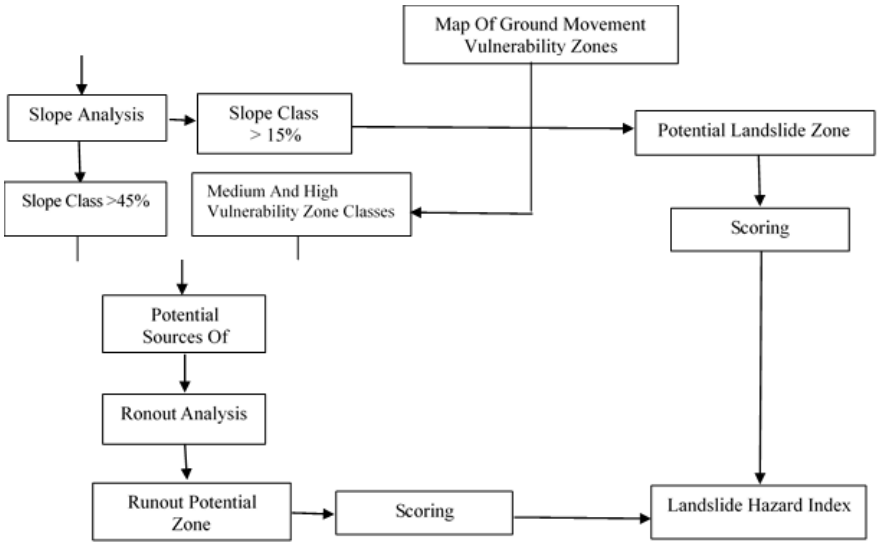

Fig. 2. Flow diagram of landslide hazard analysis

The analysis starts with preparing the DEM data, and the map of the ground movement susceptibility zones has been made into a map. It is immediately classified into slope types using runout and scoring analysis, then overlaying the scores/weights to get the landslide hazard value. The hazard study was carried out to obtain conclusions from the hazard index (H) analysis results in the form of hazard classes. Hazard classes are classified based on the grouping of hazard index values as follows: Low ($H \leq 0.333$), Medium ($0.333 < H \leq 0.666$), and High ($H > 0.666$).

Vulnerability

Spatial vulnerability analysis uses four components: social vulnerability, physical vulnerability, economic vulnerability, and environmental vulnerability. The analysis method used is MCDA (Multi Criteria Decision Analysis), and fuzzy analysis of the mathematical overlapping process with the following formula:

$$V = FM_{linear}((w.v_1) + (w.v_2) + \ldots + (w.v_n)) \quad (1)$$

Where: V: Vulnerability index value or vulnerability component

I: Index of vulnerability components or constituent parameters

W: weight of each vulnerability component or vulnerable sub-parameter

FM: Fuzzy member function

N: number of vulnerability components or vulnerable sub-parameters

Vulnerability classes are classified based on the grouping of vulnerability index values as follows: Low (V ≤ 0.333), Medium (0.333 < V ≤ 0.666), and High (V > 0.666).

Capacity

Capacity starts from an index, and the level of regional resilience is assessed using the HFA (Hyogo Framework for Actions) indicator calculated by Perka BNPB 3/2012. Then, based on the Policy Direction and Strategy of the 2005-2025 RPJMN. These results are known as the Regional Resilience Index (RRI), which will be implemented starting in 2022 in areas in the South OKU Regency. RRI comprises 7 focus areas and 16 performance targets divided into 71 performance indicators. The priority focus in RRI consists of Strengthening policies and institutions, Risk assessment and integrated planning, Development of information systems, training, and logistics. Thematic handling of disaster-prone areas. Increasing the effectiveness of disaster prevention and mitigation. Strengthening disaster preparedness and emergency management, and Development of disaster recovery systems.

The regional capacity index (C) combines RRI. Based on the interview results, spatial analysis of the ability index can be carried out with the following equation:

$$C = (w.\ \text{RRI}) + (w.\ \text{PPI}) \quad (2)$$

The regional resistance index value varies between 0 and 1. The regional resistance level class distribution is as follows: Index = 0.4 is Low, Index 0.4 – 0.8 is Medium, and Index 0.8 – 1 is High.

Risk

Risk analysis uses a mathematical formula which is used to show the relationship between hazard, vulnerability, and capacity, which builds a perspective on the level of disaster risk in an area, which can be calculated using the following formula:

$$R = (H*V)/C \quad (3)$$

The data analysis technique used in this research starts from the hazard being analyse through scoring, and then all the scored results are overlaid to become a landslide hazard level map. To determine the level of landslide vulnerability, there are 4 types of vulnerability, namely social vulnerability, physical vulnerability, economic vulnerability, and environmental vulnerability; then, to choose the regional capacity index, conduct interviews with the heads of 19 sub-districts in South OKU Regency and the surrounding community consisting of seven questions to obtain the regional capacity index. Next, vulnerability uses the MCDA (Multi-Criteria Decision Analysis) spatial method or can be formulated as $V = FM$ (w. v 1) + FM ($w.\ v2$). FM (w. v), while capacity is analyse through interviews with each sub-district head for get the regional capacity index. The final stage of risk is calculated from R= (H*V)/C.

Results

Landslide hazards affect 19 sub-districts in South OKU Regency. Based on the results of a landslide hazard analysis using scoring and overlay, landslide hazards are classified into three classes: low class, medium class, and high class. Each sub-district has a different level of danger, where the results of an analysis based on numbers can be concluded that

the threat of landslides in South OKU Regency is relatively high. By calculation, there is no low-danger class; there are 8 sub-districts in the medium class and 11 in the high-danger class. The highest danger class occurs in Mekakau Ilir, Pulau Beringin, and Sindang Danau sub-districts. For more details, see Table 1 below.

Table 1. Landslide hazard in South OKU Regency

No	Subdistrict	Hazard (Ha)						Class
		Low		Currently		Tall		
		F	%	F	%	F	%	
1	Muara Dua	1,500	6.15%	11,152	9.62%	4,311	1.82%	Currently
2	Pulau Beringin	1,077	4.42%	956	0.82%	29,987	12.66%	Tall
3	Banding Agung	1,014	4.16%	1,576	1.36%	17,907	7.56%	Tall
4	Muara Dua Kisam	1,813	7.43%	7,141	6.16%	10,888	4.60%	Tall
5	Simpang	344	1.41%	1,773	1.53%	449	0.19%	Currently
6	Buay Sandang Aji	1,168	4.79%	4,112	3.55%	5,958	2.52%	Tall
7	Buay Runjung	299	1.23%	1,223	1.06%	870	0.37%	Currently
8	Mekakau Ilir	1,066	4.37%	728	0.63%	41,622	17.58%	Tall
9	Buay Pemaca	4,865	19.95%	20,267	17.49%	20,491	8.65%	Tall
10	Kisam Tinggi	2,906	11.92%	15,533	13.40%	13,986	5.91%	Currently
11	Kisam Ilir	409	1.68%	933	0.81%	132	0.06%	Currently
12	Buay Pematang Ribu Ranau Tengah	1,320	5.41%	4,911	4.24%	12,086	5.10%	Tall
13	Warkuk Ranau Selatan	1,081	4.43%	6,911	5.96%	20,771	8.77%	Tall
14	Runjung Agung	694	2.85%	2,333	2.01%	9,092	3.84%	Tall
15	Sungai Are	500	2.05%	5,568	4.80%	15,541	6.56%	Tall
16	Sindang Danau	592	2.43%	3,783	3.26%	24,436	10.32%	Tall
17	Buana Pemaca	1,399	5.74%	8,238	7.11%	2,750	1.16%	Currently
18	Tiga Dihaji	1,151	4.72%	10,426	9.00%	3,425	1.45%	Currently
19	Buay Rawan	1,188	4.87%	8,317	7.18%	2,092	0.88%	Currently
	Amount	**24,386**	**100.00%**	**115,881**	**100.00%**	**236,795**	**100.00%**	**TALL**

The hazard of landslides has an impact that greatly affects human life, apart from causing land damage and also causing loss of life (Gupta & Satyam, 2022). The factor causing the landslide disaster in South OKU Regency is high rainfall (Lin et al., 2021). This is in accordance with South OKU BPBD data which recorded high rainfall (>100 mm^3) for ten months. The highest rainfall in February, March and December 2020 was recorded at an average of 250.51 mm^3. The impact of high rainfall causes landslides. Landslide hazard assessment is carried out by identifying areas potentially affected by slope failure, calculating the probability of occurrence, and estimating the magnitude

(area, volume, rate of movement) of the event (Petley, 2010). From the results of the analysis It can be seen and concluded that the danger of landslides in the medium class South OKU Regency is 8 sub-districts, namely Kisam Tinggi, Kisam Ilir, Buay Runjung, Muaradua, Simpang, Tiga Dihaji, Buay Rawan and Buay P emaca sub-districts. For the high class, there are 11 sub-districts, namely Mekakau Ilir, Sindang Danau, Sungai Are, Muaradua Kisam, Runjung Agung, Pulau Beringin, Buay Sandang Aji, Appeal Agung, Buay Pemaca, Buay Pematang Ribu Ranau Tengah, and Warkuk Ranau Selatan. In this way, the analysis of landslide hazards in South OKU Regency has a high class. For more clarity, see Fig. 3.

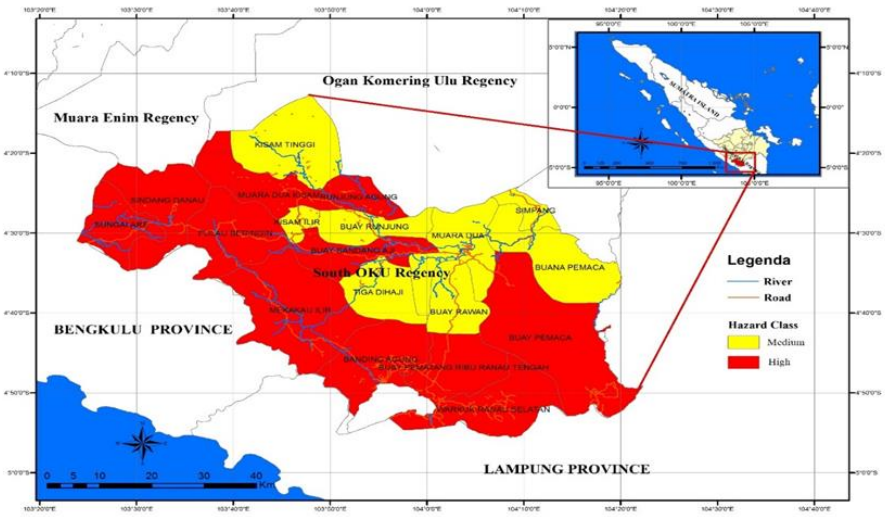

Fig. 3. Hazard Map in South OKU Regency

Apart from hazard, vulnerability is also important in determining disaster risk. The risk of landslides is divided into 3 vulnerabilities, namely physical vulnerability, economic vulnerability, and environmental vulnerability. The results of the physical vulnerability analysis are classified into three classes: low class, medium class, and high class. Each sub-district has a different level of physical vulnerability, where the results of the analysis based on numbers can be concluded that the physical vulnerability to landslides in South OKU Regency is relatively high, and physical losses are estimated at IDR. 605.112 billion. There are sixteen sub-districts in the high category, with the highest loss estimated at IDR. One hundred thirty-six thousand five hundred eighty-eight billion, with the average physical loss from 19 sub-districts being 31,848 billion. The medium physical class is in Buay Runjung District, and the low physical class is in Simpang and Kisam Ilir Districts. For more details, see Table 2 below.

Physical vulnerability is a component of vulnerability in the form of physical objects that can be lost or damaged if exposed to threats. This component is a physical object that is considered to have value (Luo et al., 2023). In this mapping, the physical components consist of house parameters, public facilities, and critical facilities, according to Perka BNPB No. 2 of 2012. The parameters of houses in the physical vulnerability study are the number of homes that have the potential (vulnerable) to

experience damage, the parameters of public facilities in the physical vulnerability study are the number of public facilities, namely buildings that function as places of public services, that have the potential (vulnerable) to experience damage and the parameter of critical facilities in the physical vulnerability study is the number of fakirs. These namely buildings function during very important emergencies (necessary) and have the potential (vulnerable) to experience damage (Nugroho et al., 2019). Based on South OKU Regency data, landslides in the last five years in South OKU Regency caused damage.

Table 2. Analysis of physical landslide vulnerability in South OKU Regency

No	Subdistrict	Physical Vulnerability (IDR Loss (Million IDR))			Class
		Low	Currently	Tall	
1	Muara Dua	-	19,924	13,675	Tall
2	Pulau Beringin	-	3,963	84,183	Tall
3	Banding Agung	-	400	12,806	Tall
4	Muara Dua Kisam	-	4,319	8,419	Tall
5	Simpang	-	89	-	Low
6	Buay Sandang Aji	-	8,539	5,980	Tall
7	Buay Runjung	-	177	2,089	Currently
8	Mekakau Ilir	-	399	71,055	Tall
9	Buay Pemaca	-	13,556	136,588	Tall
10	Kisam Tinggi	-	11,042	21,690	Tall
11	Kisam Ilir	-	495	-	Low
12	Buay Pematang Ribu Ranau Tengah	-	4,175	37,701	Tall
13	Warkuk Ranau Selatan	-	9,111	67,641	Tall
14	Runjung Agung	-	859	18,768	Tall
15	Sungai Are	-	4,814	68,786	Tall
16	Sindang Danau	-	2,014	47,378	Tall
17	Buana Pemaca	-	12,952	5,631	Tall
18	Tiga Dihaji	-	3,072	1,897	Tall
19	Buay Rawan	-	4,765	825	Tall
	Amount		**104,664**	**605,112**	**TALL**

Houses with a total of 8 houses. And public facilities, which suffered a total of 13 damages. From the analysis results, it can be concluded that the physical vulnerability analysis in South OKU Regency is low class in two sub-districts, namely Simpang and Kisam Ilir sub-districts. There is one medium class, namely Buay Runjung District. The high class consists of 16 sub-districts: Buay Pemaca sub-district, Pulau Beringin sub-district, Warkuk Ranau Selatan sub-district, Suangai Are sub-district,

Mekakau Ilir sub-district, Sindang Danau sub-district, Muaradua sub-district, Kisam Tinggi sub-district, BPR Ranau Tengah sub-district, Appeal Agung sub-district, Buana Pemaca District, Buay Rawan District, Tiga Dihaji District, Muaradua Kisam District, Runjung Agung District, and Buay Sandang Aji District. In this way, the physical vulnerability analysis in South OKU Regency has a high class. You can see the following map image (Fig. 4).

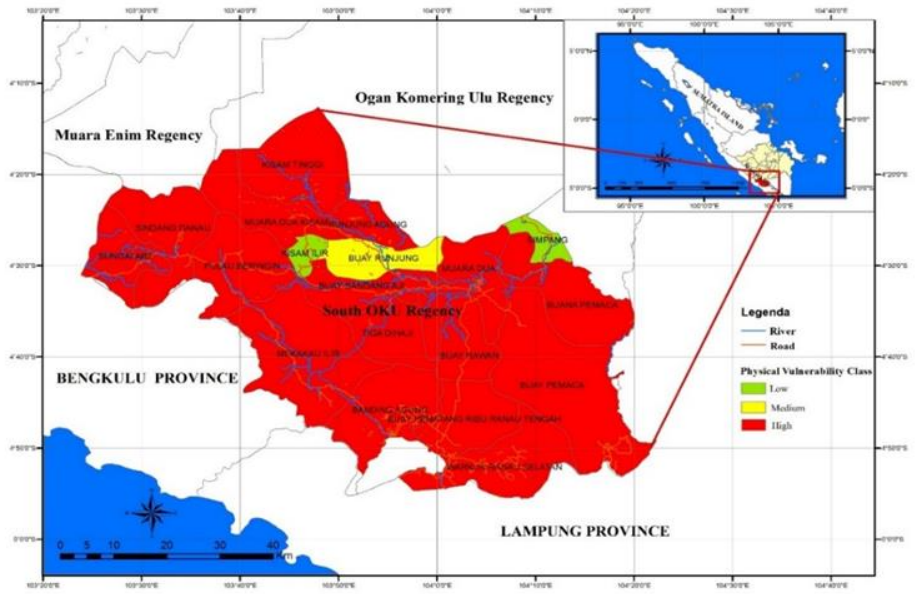

Fig. 4. Physical vulnerability map in South OKU Regency

The results of the economic vulnerability analysis show that 19 sub-districts in South OKU Regency have a high economic vulnerability class; economic losses are estimated at IDR 1.017 trillion. Based on the highest-class figures, it is in Mekakau Ilir District, IDR 158.087 billion. The average economic loss from 19 sub-districts was IDR 53.554 billion. Economic vulnerability is analyse based on gross regional domestic product value and productive land losses. The fruitful land aspect is the indicator with the greatest influence on economic vulnerability. The wider the percentage of productive land, the higher the level of economic vulnerability in the South OKU Regency area. For more details, see Table 3 below.

The component that has the greatest influence on economic vulnerability is the productive land aspect. Land use data also support this; BPS South OKU Regency 2018 is divided into paddy fields at 3.28 percent and non-rice fields at 85.27 percent. It can be concluded that the dominant community in South OKU Regency works in the agricultural sector, so that damage to productive land due to landslides will certainly hamper all economic activities of the community itself. Landslides significantly impact community and household income sources in local areas and require high costs for restoration and subsequent maintenance. Therefore, the severity of the effects on household income also depends greatly on the location of land affected to compensate for lost revenue due to landslides (Perera et al., 2018). The results of the economic vulnerability analysis are high

(Fig. 5). The number of medium classes is 317,359, while the number of high classes is 1,017,543. The data used in the economic vulnerability analysis is data on productive land use in South OKU Regency, while the GRDP and Employment data are data published by BPS South OKU Regency. The following is a map of the economic vulnerability analysis in South OKU Regency.

Table 3. Analysis of landslide economic vulnerability in South OKU Regency

No	Subdistrict	Economic Vulnerability (IDR Losses (IDR Million))			Class
		Low	Currently	Tall	
1	Muara Dua	-	29,730	9,489	Tall
2	Pulau Beringin	-	2,888	147,885	Tall
3	Banding Agung	-	4,550	61,700	Tall
4	Muara Dua Kisam	-	19,394	32,151	Tall
5	Simpang	-	6,517	2,638	Tall
6	Buay Sandang Aji	-	11,243	18,385	Tall
7	Buay Runjung	-	3,351	5,508	Tall
8	Mekakau Ilir	-	2,097	158,087	Tall
9	Buay Pemaca	-	59,631	125,149	Tall
10	Kisam Tinggi	-	34,951	47,296	Tall
11	Kisam Ilir	-	3,319	963	Tall
12	Buay Pematang Ribu Ranau Tengah	-	10,678	53,202	Tall
13	Warkuk Ranau Selatan	-	21,445	104,422	Tall
14	Runjung Agung	-	6,850	47,758	Tall
15	Sungai Are	-	14,497	86,296	Tall
16	Sindang Danau	-	7,785	82,260	Tall
17	Buana Pemaca	-	29,165	18,607	Tall
18	Tiga Dihaji	-	34,557	10,303	Tall
19	Buay Rawan	-	14,710	5,443	Tall
	Amount		**317,359**	**1,017,543**	**TALL**

The results of the analysis of environmental vulnerability based on numbers can be concluded that the physical vulnerability of landslides in South OKU Regency is relatively high, with an area of environmental damage of 4,124 Ha (100%) (Table 4). There are 17 sub-districts that are categorized as high, with the highest estimated loss in Kisam subdistrict being 910 hectares (22.07%), with the average high environmental loss from 19 sub-districts being 217.05 hectares (5.26%). Only two sub-districts are categorized as low, namely Simpang and Kisam Ilir sub-districts.

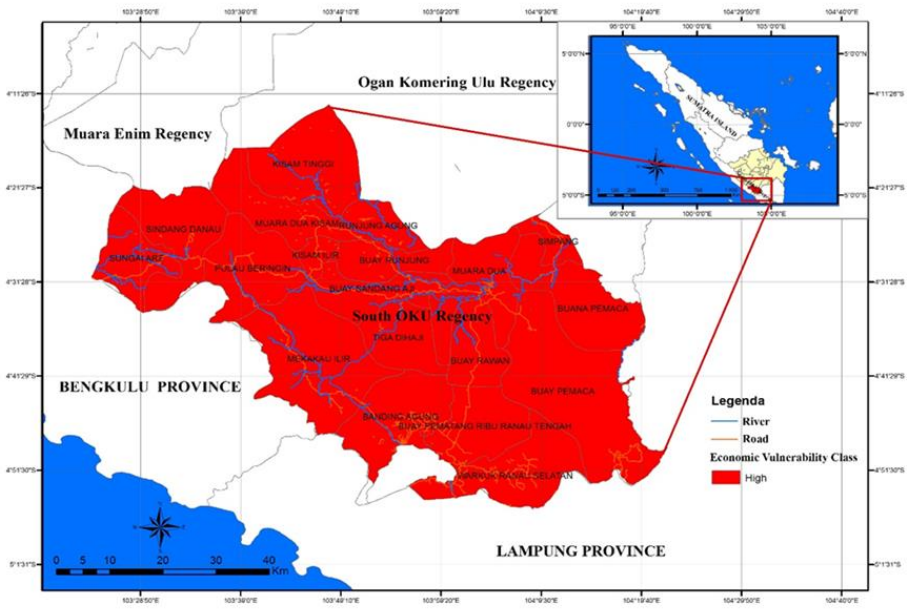

Fig. 5. Map of economic vulnerability in South OKU Regency

Capacity is related to the preparedness of the government and local communities in South OKU Regency to face landslides with seven regional capacity index indicators. First, policies and institutions should be strengthened, namely that there should be regulations governing spatial planning, especially protected forests. Second, risk assessment and integrated planning, namely the absence of an integrated study of the information system for training and training for vulnerable areas. Knowledge also needs to be increased with training and counseling for residents who are vulnerable to the impacts of landslides. Third, the development of information systems, training, and logistics. Fourth, the thematic handling of disaster-prone areas has yet to be continuously carried out through counseling, training, etc. Fifth, the effectiveness of disaster prevention and mitigation must be increased. Sixth, disaster preparedness and emergency management should be strengthened, and a disaster recovery system should be developed. The results of the landslide capacity analysis in South OKU Regency show a medium class, which means that some indicators have been carried out, but the results could be more optimal. Apart from not being implemented optimally, education regarding disasters still needs to be improved.

The risk of landslides in South OKU Regency is categorized as moderate (Fig. 6), even though it has a high level of landslide danger in more than half of its sub-districts. This shows that this area is vulnerable to landslides, which can damage important physical infrastructure. Infrastructure such as roads, bridges, and other public facilities are often located in areas prone to landslides, so every landslide event can potentially disrupt access to transportation, public services, and community mobility (Gupta & Satyam, 2022). In addition, recurring landslides can erode soil and trigger erosion, worsening soil quality and reducing agricultural land fertility, increasing the economic burden on residents who depend on the farm sector.

Table 4. Analysis of landslide environmental vulnerability in South OKU Regency

No	Subdistrict	Environmental Vulnerability (Ha)						Class
		Low		Currently		Tall		
		F	%	F	%	F	%	
1	Muara Dua	-	-	762	14.69%	430	10.43%	Tall
2	Pulau Beringin	-	-	30	0.58%	30	0.73%	Tall
3	Banding Agung	-	-	71	1.37%	69	1.67%	Tall
4	Muara Dua Kisam	-	-	530	10.22%	463	11.23%	Tall
5	Simpang	-	-	4	0.08%	3	0.07%	Low
6	Buay Sandang Aji	-	-	273	5.26%	210	5.09%	Tall
7	Buay Runjung	-	-	88	1.70%	40	0.97%	Tall
8	Mekakau Ilir	-	-	24	0.46%	24	0.58%	Tall
9	Buay Pemaca	-	-	747	14.40%	147	3.56%	Tall
10	Kisam Tinggi	-	-	1,237	0.02%	910	22.07%	Tall
11	Kisam Ilir	-	-	2	0.04%	1	0.02%	Low
12	Buay Pematang Ribu Ranau Tengah	-	-	481	9.27%	399	9.68%	Tall
13	Warkuk Ranau Selatan	-	-	122	2.35%	116	2.81%	Tall
14	Runjung Agung	-	-	65	1.25%	61	1.48%	Tall
15	Sungai Are	-	-	338	6.52%	289	7.01%	Tall
16	Sindang Danau	-	-	451	8.69%	425	10.31%	Tall
17	Buana Pemaca	-	-	89	1.72%	50	1.21%	Tall
18	Tiga Dihaji	-	-	226	4.36%	157	3.81%	Tall
19	Buay Rawan	-	-	883	17.02%	300	7.27%	Tall
Amount		**-**	**-**	**6,422**	**100.00%**	**4,124**	**100.00%**	**TALL**

The economic impact of landslides in South OKU Regency is also significant. Large economic losses can arise from the repair and reconstruction of damaged infrastructure, as well as from disruption of local economic activity. Landslides can cut off road access to markets or distribution centers, hamper the distribution of goods and services, and reduce the income of people who sell or work in these sectors. In addition, damage to agricultural land can cause a decrease in crop yields, directly impacting farmers' income and community food security (Sørlie et al., 2023). In addition to economic losses, environmental damage caused by landslides can also reduce people's quality of life and health, exacerbating their vulnerability to other natural disasters. Therefore, mitigating and adapting to landslide risk is very important to reduce negative impacts on the community and environment in South OKU Regency.

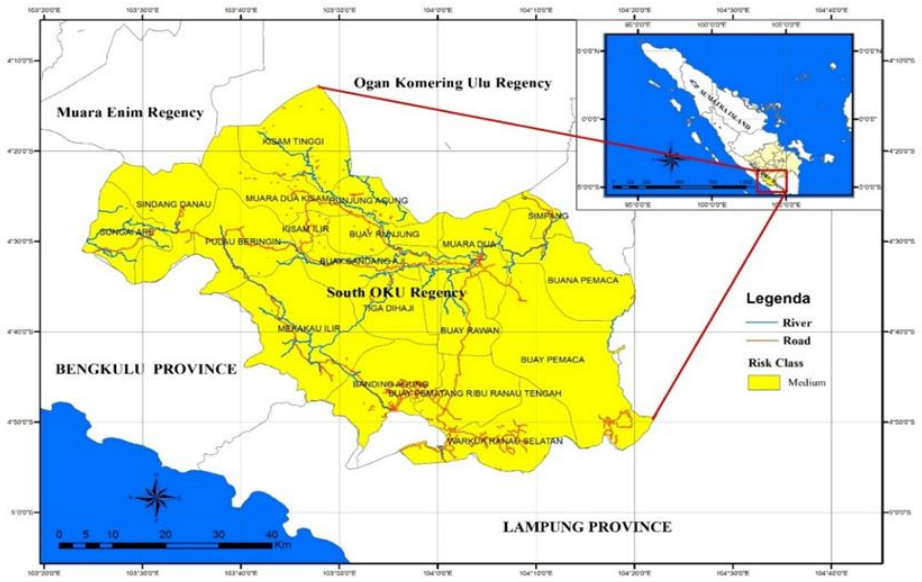

Fig. 6. Landslide disaster risk analysis map in South OKU Regency

Discussion

The danger of landslides has an impact that greatly affects human life, apart from causing land damage and loss of life (Gupta & Satyam, 2022). Based on the analysis, the landslide hazard in South OKU Regency is classified as high; this is because the area is steep, hilly, soil type, human activity, and high rainfall (Zhang et al., 2020. Sonker et al., 2022). The distribution of landslide danger in South OKU Regency varies from low, medium, and high. High areas have the characteristics of steep and sloping regions (Zhang & Li, 2024). Based on the analysis results, there are several sub-districts where the level of landslide danger is classified as the highest, namely in Mekakau Ilir District, Pulau Beringin District, and Sindang Danau District. The causes of landslides apart from the steep, hilly areas, soil type, and rainfall can also be seen from the area's geology.

Mekakau Ilir sub-district has a high class of landslides because geologically, it includes the Ranau formation, namely zeroing tuff, solid clay rock inserted with carbonaceous clay rock, which will cause the land to slip easily, which is made even worse by the sloping and steep area, resulting in the potential for landslides. High (Zhang & Li, 2024). In this area, there are layers of tough rock combined with lembung rock inserts; these inserts are what cause the slip field (Zhang & Li, 2024). Several studies have stated that rock layers are dominated by very high landslide potential, especially since the layers contain clay inserts that create a sliding surface (Apon et al., 2024, Boyd et al., 2024). Apart from that, the high rainfall in the Mekakau Ilir, Beringin Island and Sindang Danau areas has caused landslides to occur frequently in this area (Lin et al., 2021).

This is different from the areas that are categorized as high, namely Pulau Beringin District and Sindang Danau District; these two areas are in one formation with the same regional characteristics, namely because the area is steeply sloping with a slope of 45% and there are also many faults found (Ma et al., 2024). Apart from that, there are also several large mountains with a height of 1899 MASL (Mater above Sea Level) and Mount Cabut Hill with a height of 1803 MASL (Zhang & Li, 2024). Geologically, it includes the Hulu simpang formation, namely lava, breccia, volcanic, and andesite, to an alkaline composition containing sulfide minerals and quartz veins. If you look at the rock, it can be said to be strong, but the problem is that the area is sloping, and several large mountains are found, with steep areas plus many faults or faults (Zhang et al., 2024) which causes frequent landslides in this sub-district. These two areas are geologically strong based on their solid rock originating from volcanic rock breccias. Still, the problem is that the slopes are steep, and there are two mountains above eighteen hundred plus many faults. This is what causes the potential for landslides in these two sub-districts to be high.

Apart from geology, what influences landslides in South OKU Regency is human activity, such as residents who are active daily in plantations on steep slopes (Zhang & Li, 2024). Community activities continue to increase, as seen from population growth in South OKU Regency. This will be even more dangerous for the community if the population continues to grow, the potential for landslides is higher, and the risk of landslides is high for the community (Xiong et al., 2023). Based on South OKU BPS data ten years ago, from 2013-2022, population growth continued to increase; this can be seen in (Fig. 7). Environmental changes caused by human activities create conditions that cause slope instability, thereby causing changes in the frequency, magnitude, and rate of occurrence of landslides (Tran et al., 2024). Apart from that, it causes high risks in the form of physical, economic, and environmental risks, causing many losses for society and the government.

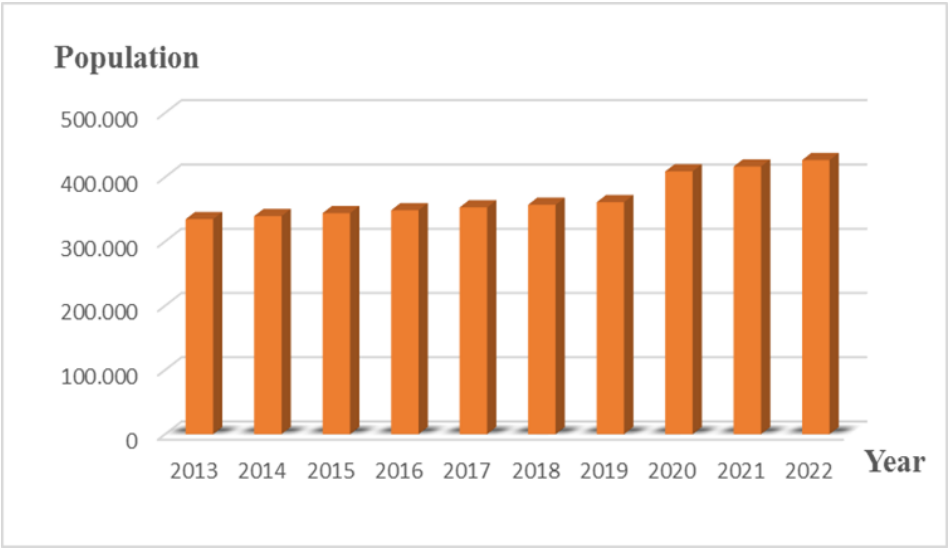

Fig. 7. Population growth graph for South OKU Regency 2013-2022 (Source: BPS OKUS, Population 2013-2022)

The economic vulnerability impact of this landslide event causes huge losses, such as loss of agricultural land, causing a shortage of food stocks, lack of community income because the majority of people in South OKU Regency are farmers or work on plantations, loss of community productivity as a region. Producers of vegetables and fruit (Winter et al., 2016). Added to this are physical vulnerability in the form of infrastructure, such as damage to residential areas, buildings, bridges, and roads (Sørlie et al., 2023, Zhou et al., 2023). If the road is damaged, development becomes hampered, and damage to houses and land results in significant losses and has an impact on the economy; closed road access means that people cannot carry out economic activities and can result in scarcity and rising prices of goods (Marengo et al., 2023). Based on data from South OKU BPS, in the last five years, landslides caused damage to eight houses, thirteen public facilities, and one factory.

Apart from having an impact on economic and physical vulnerability, it also has an impact on environmental vulnerability, such as the destruction of protected forests, loss of protected animals such as elephants, and loss of protected plants and food chains (Wu et al., 2023). Land damage occurs, such as damage to agricultural land and plantations. Loss of land cover vegetation: the main changes in land cover are the loss of shrubs and the increase in agricultural areas with dry land; apart from causing erosion, this also increases the risk of landslides (Guo et al., 2023). When open land increases due to deforestation, water seeps into the soil without protection, making the soil soft and slippery. Then, the balance of the ecosystem is disturbed, such as the extinction of a race or species in an ecosystem of varietal diversity. Land becomes critical, and underground water reserves are depleted. If this landslide is not handled properly, the soil will continue to move down and erode the fertile soil layer beneath it so that what is left is barren land or even rocky or hard soil (Pu et al., 2023).

The actions that need to be taken to reduce the risk of landslides are the need for land management and reforestation; it is necessary to carry out soil conservation if the land is sloping how to regulate it so that it does not cause landslides (Tian & Lan, 2023). There are three types of soil conservation, namely: physical soil conservation, namely the soil is cultivated, if the land is sloping, then it is made with steps like rice plants in hilly areas so that the soil does not easily experience erosion (Li et al., 2023). The second is terracing, which reduces the slope by creating terraced rice fields. And thirdly, vegetational, such as avoiding or reducing illegal logging of trees with deep and strong roots, which function as water and soil storage channels below the earth's surface (Li & Duan, 2024). Apart from that, selective logging is an option to reduce landslide risk (Wang et al., 2023). Meanwhile, chemically mulch and compost diapers are used to increase soil stability.

In addition to land management or soil conservation, it is also necessary to carry out spatial planning in areas prone to landslides, especially in residential areas of relocating communities, so that people living in these places are moved to other places that are not dangerous. Areas prone to landslides can be used as protected forests or as places where green open spaces can be used for different purposes (Matti et al., 2023). Apart from that, there is an early warning system for the construction of steep slopes; for example, in developed countries, to reduce the risk of disaster, there is an early warning, landslide-prone detection equipment is installed in areas that are prone to landslides, so when there is high rainfall it will sound like a siren so that people will leaving or running to another, safer place because they know that a landslide disaster will soon occur (Poddar & Roy,

2024). The last thing is public education and awareness through emergency catch safety training so that if a landslide occurs, the community knows what kind of rescue it is, then an outreach campaign about landslide risks to communities who are vulnerable to landslide impacts (Matpady et al., 2023., Fazeli et al., 2024).

Apart from the physical and economic factors, landslides are also indiscriminate, protected areas are also susceptible to landslides. Landslides not only occur in productive areas but also in protected forest areas. These landslides can occur in protected forest areas where protected forests are supposed to be land or areas where landslides should not occur. Many people still carry out illegal logging of forests, clear land for agriculture or plantations by burning which results in deforested forests, and are no longer able to store water reserves during the rainy season, resulting in landslides (Utomo et al., 2022; Utomo et al., 2023). Deforestation, such as turning forest areas into settlements and other human activities, all play a role in causing this dangerous event (Sonker et al., 2022; Sridharan & Gopalan, 2022).

Conclusion

This research analyses landslide risk in South OKU Regency using a hazard, vulnerability, regional capacity, and disaster risk analysis approach. Based on the analysis, it was concluded that South OKU Regency has a high level of landslide danger, with more than half of its sub-districts at high risk. These landslides have a significant impact on important physical infrastructure and have the potential to cause large economic losses and damage environmental conditions. Vulnerability analysis shows that this area is very vulnerable to landslide impacts, especially considering its physical infrastructure is vital for the welfare of the local economy and environment. On the other hand, regional capacity in dealing with landslide hazards is categorized as moderate, which shows that there are several mitigation and preparedness efforts, but they still need to be improved. Overall, the risk of landslides in South OKU Regency is in the medium risk category. Therefore, this research emphasizes the need to strengthen community capacity and increase preparedness for landslide disasters. These steps are needed to minimize the impact caused by landslides so that economic, physical, and environmental losses can be reduced. To conclude, the future ultimate purpose is a unified vision of a civilized world in which the physical and psychological comfort of the citizens are provided. This purpose will be realized by developing the levels of commercial services in marginal areas away from commercial centres, and achieving the greatest participation in the development and planning of a more efficient and sustainable system commercial apparatus. The following means can contribute to reaching the perceived objectives.

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