Landslide Susceptibility Classification of Musi Banyuasin Regency Using the Storie Index Method

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Abstract. This study aims to produce landslide susceptibility maps as a means of disaster mitigation in Musi Banyuasin Regency. The susceptibility of landslides was determined by analyzing the soil slope, rainfall intensity, soil type, land use type, and earthquake vulnerability parameters. These parameters are then scored and transformed into parameter maps. Each map is then combined with the overlay process and analyzed using the Storie Index method to determine the landslide susceptibility level. The results are divided into two categories: a landslide susceptibility map without an earthquake effect and a landslide susceptibility map with an earthquake effect. Both results show a dominance of very low landslide susceptibility levels, accounting for more than 80% of the total area of Musi Banyuasin. Overall, moderate to high landslide susceptibility occurs in areas with hilly topography, riverbanks, and areas with moderate earthquake vulnerability.

Keywords: Landslide, Storie index, Mapping, Musi banyuasin, Mitigation.

1 Introduction

Musi Banyuasin (Muba) Regency is in the province of South Sumatra. According to the official website of SKK Migas, Musi Banyuasin Regency has large oil and gas reserves, with a total gas reserve of 2 trillion cubic feet [1]. Furthermore, Musi Banyuasin Regency is classified as a medium-risk disaster threat index in the 2020 IRBI (Indonesian Disaster Hazard Index) book by BNPB. The potential risk of landslides in the district is one of the triggers for this. According to data from the BNPB's Indonesian Disaster Information Data (DIBI) page, at least one landslide disaster occurs in Musi Banyuasin Regency each year. Due to a lack of data availability or mapping of an area against landslide susceptibility, errors in choosing the location for development in an area can occur, resulting in development being carried out in areas that are prone to landslides and causing future damage. To avoid similar consequences in the future, it is critical to map landslide-prone areas and conduct stability analyses on local slopes as a form of pre-landslide disaster mitigation.

In this study, the authors use GIS (Geographic Information System) and the Storie Index method to create a landslide susceptibility map. GIS is a system that processes geographic and spatial

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data in an area to produce all information in the form of maps [2]. GIS can process data repeatedly, quickly, and precisely, allowing it to accurately represent the review area [3]. Previous researchers [4, 5, 6, 7, 8, 9] have widely used the Storie Index method in classifying a mapping because the analysis is simple. The simplification of the storie index method allows us to create maps with limited secondary data without having to validate them directly in the field.The analysis is conducted by grouping categories of vulnerability factors that are given weights and then multiplied to produce vulnerability values [6]. The landslide parameters used in this study include soil slope, rainfall, soil type, land use, and earthquakes. In this study, two types of landslide susceptibility maps will be created: one without the influence of an earthquake and one with the influence of an earthquake. The results of this study are expected to be a mitigation effort in the form of a landslide susceptibility map in Musi Banyuasin Regency that can be used as a reference for development in Musi Banyuasin Regency.

2 Methodology

Musi Banyuasin Regency is located at latitude 1.3°-4° South and longitude 103°-105° East. This study relied on basic map data on landslide parameters such as rainfall, slope, soil type, land use, and earthquake vulnerability. In this study, two types of data were used: raw data that needed to be processed before it could be used to generate landslide parameter maps and finished thematic map data that was ready to be used as landslide parameter maps. The raw data that must be processed first are the daily rainfall and DEMNAS data, whereas the data on soil types, land use, and potential earthquake hazards are thematic maps that can be used as landslide parameter maps. The entire mapping process in the study was carried out using ArcGIS 10.8 software. By averaging daily precipitation into annual precipitation, the rainfall parameter map is created. The data is then processed in raster format, and Inverse Distance Weight (IDW) interpolation is used to generate regional boundary polygons with a specific average rainfall intensity level. DEMNAS data covering the Musi Banyuasin area will be processed using slope analysis in ArcGIS 10.8 for the soil slope parameter map. All completed landslide parameter maps are then analyzed and given a score in the form of a weighted average of landslide vulnerability level. The results of this scoring will be used to create polygons that represent the classification of landslides in Musi Banyuasin Regency using the Storie Index method. The scoring in this study is the result of a modification to previous researchers' scoring [5, 6, 9]. This scoring was modified to adjust the causes of landslides based on the study location, where slope and rainfall intensity have a significant influence on landslides in Musi Banyuasin. Following the scoring process, all parameter maps are combined and analyzed to produce a landslide susceptibility map, which is referred to as the overlay process. Table 1 shows the scoring values for each landslide parameter used in this study.

2.1 Rainfall

High rainfall affects the rate of water infiltration into the soil, raising pore water pressure and soil weight. This pore water pressure reduces the effective stress on the soil, making the soil on the slope prone to landslides. Surface runoff caused by heavy rainfall can also cause landslides by scouring the soil on the slope's surface. According to the rainfall map, the average annual rainfall in Musi Banyuasin Regency is dominated by 2000-2500 mm/year. The rainfall value is classified as low in Table 1. The areas with the highest rainfall values, 2500-3000 mm/year, are in the southern part of Musi Banyuasin Regency, as well as a small portion of the north and east. **Figure 1A** depicts the rainfall map for the Banyuasin Musi.

Table 1. Landslide susceptibility parameter score

No	Parameters	Variable	Score
1	Rainfall intensity (mm/year)	>3000	4
		2500 – 3000	3
		2000 – 2500	2
		< 2000	1
2	Slope	>75 %	6
		46 – 75%	5
		31 – 45%	4
		16 – 30%	3
		4 – 15%	2
		0 – 3%	1
3	Land use	Non-vegetation	5
		Grass, shrubs, and rice field vegetation	4
		Mixed Gardens, Yard Plants	3
		Plantation	2
		Forest	1
4	Type of soil	Oxisol	7
		Ultisol	6
		Alfisol	5
		Mollisol	4
		Inceptisol	3
		Entisol	2
		Histosol	1
5	Earthquake vulnerability	High	3
		Moderate	2
		Low	1

Source: modified from [5, 6, 9]

2.2 Slope

The slope is the most important factor in landslide occurrence. The greater the gradient of a slope, the greater the amount of load that must be held by the slope's foot to maintain its stability. When the load exceeds the resistance, the slope is considered unstable and has a high landslide potential. The slopes in Musi Banyuasin Regency range from 0-3% to 16-30%, which is classified as low in Table 1. The low slope gradient in Musi Banyuasin Regency will have an impact on the overall results of this study's analysis. The steeper slope is found in the western and southern parts of Musi Banyuasin Regency, which is hilly. Meanwhile, due to their proximity to the coast, the northern and eastern parts of Musi Banyuasin Regency have the smallest gradient. **Figure 1B** depicts a map of the Musi Banyuasin land's slope.

2.3 Land Use

Figure 1C depicts the land use map. Musi Banyuasin Regency is mostly covered by vegetation classified as grass, shrubs, and rice fields, according to the map. Because this type of vegetation has a weak root system, it is thought to be incapable of increasing the soil's bearing capacity.

Furthermore, shrubs and rice fields grow on soils that are constantly wet and dry. Soils that are subjected to these conditions on a regular basis will weather faster and have a lower shear strength. In clay soils, the wet-dry process causes swelling and shrinkage, causing the soil to crack easily when dry and become very saturated when filled with water. When soil becomes saturated with water, its carrying capacity decreases. According to research conducted by Wibowo et al. [10], swelling soil will experience a decrease in shear strength along with an increase in water content in the soil. This is due to the high pressure of pore water, which reduces effective stress on the soil and makes it easy to slide.

2.4 Type of Soil

The Inceptisol soil type dominates the Musi Banyuasin Regency, as shown in **Figure 1D**. Inceptisol soil is a type of soil that weathers continuously and has a high fertility rate [11], making it easier for vegetation to grow on. This is supported by the land use map results in **Figure 1C**, which show that areas with inceptisol soil types in Bayung Lencir, Tungkal Jaya, Keluang, and Babat Supat sub-districts are covered by plantation vegetation and dense forest. Because of the absorption capacity of a good root system, the density of vegetation that grows on Inceptisol soils can prevent surface runoff on the soil, reducing the potential for landslides caused by rainwater scouring on the slope surface. According to Radja et al. [12], tree roots are also thought to be capable of increasing the parameters of the shear strength of the soil, thereby increasing the slope's stability.

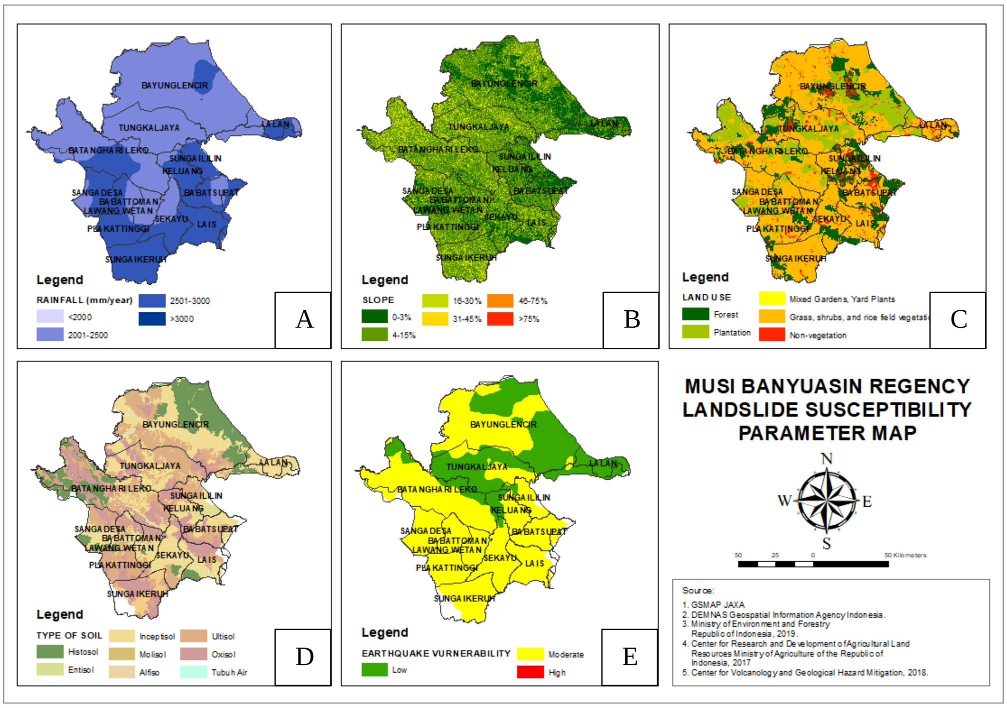

Fig. 1. Musi Banyuasin Regency Landslide Susceptibility Parameter Map

2.5 Earthquake vulnerability

The earthquake parameters are added because the shocks caused by the earthquake will be an additional lateral load on the slope body, causing soil particles to urge against each other, causing thrust and landslides on the sloped plane. Overall, Musi Banyuasin Regency has a moderate level of earthquake vulnerability, with earthquakes occurring in the southeast, south, west, and northwest. **Figure 1E** depicts the earthquake hazard map. The dominant level of vulnerability in this area is due to the location of the fault that runs along the Sumatran Islands, which is located in Musi Banyuasin Regency from the southeast to the northwest. The Dikit fault, Ketaun fault, Musi fault, and Manna fault are among the faults. The level of earthquake vulnerability in Musi Banyuasin Regency can also be validated using the MCEG PGA map contained in SNI 1726: 2019, where the peak ground acceleration (PGA) value is greater in the western part of the district than in the eastern part.

2.5 Susceptibility Calculation

Landslide susceptibility without earthquake effect. This analysis determines the effect of morphological and hydrological conditions in Musi Banyuasin Regency on landslide susceptibility. Based on the cause and location of previous landslides in Musi Banyuasin, this equation has been modified to reflect that the soil slope parameter has the most dominant influence in determining landslides. Furthermore, the rainfall parameter has a lower impact than the soil slope parameter but a higher impact than the land use and soil type parameters. The empirical numbers used in this equation are trial values based on the possibility of impact or influence that occurs in real conditions in the field. The results of the calculation of this equation are then matched with the points of landslides that have occurred in the field, as seen in the map in **Figure 3**. The classification of landslide vulnerability range values without the influence of earthquakes can be seen in Table 2.

$$L = A\ x\ \frac{B}{5}\ x\ \frac{C}{5}\ x\ \frac{D}{2} \tag{1}$$

where
L = Landslide susceptibility value
A = Slope
B = Land use
C = Soil type
D = Rainfall intensity

Table 2. Landslide susceptibility classification value without earthquake effect.

No.	Classification	Value
1	Very low	0,01 – 1,678
2	Low	1,678 – 3,356
3	Moderate	3,356 – 5,034
4	High	5,034 – 6,712
5	Very high	6,712 – 8,40

Landslide susceptibility with earthquake effect. This analysis determines the effect of the earthquake on landslides that occurred in Musi Banyuasin Regency. The soil slope, earthquake susceptibility, and soil type parameters are used in the analysis, but rainfall and land use parameters are not included. The earthquake's ground acceleration will cause additional lateral loads on the soil, making steep slopes prone to landslides. Furthermore, the type of soil on the slope influences the failure of a soil body on the slope. The weaker the bond between soil particles, the easier the soil slides. The classification of landslide vulnerability range values with the influence of earthquakes can be seen in Table 3.

$$L = A\,x\,\frac{C}{10}\,x\,\frac{G}{2} \tag{2}$$

where
G = Earthquake susceptibility

Table 3. Landslide susceptibility classification value with earthquake effect.

No.	Classification	Value
1	Very low	0,05 – 1,34
2	Low	1,35 – 2,63
3	Moderate	2,64 – 3,29
4	High	3,30 – 5,21
5	Very high	5,22 – 6,30

3 Result

3.1 Map of landslide susceptibility without earthquake effect

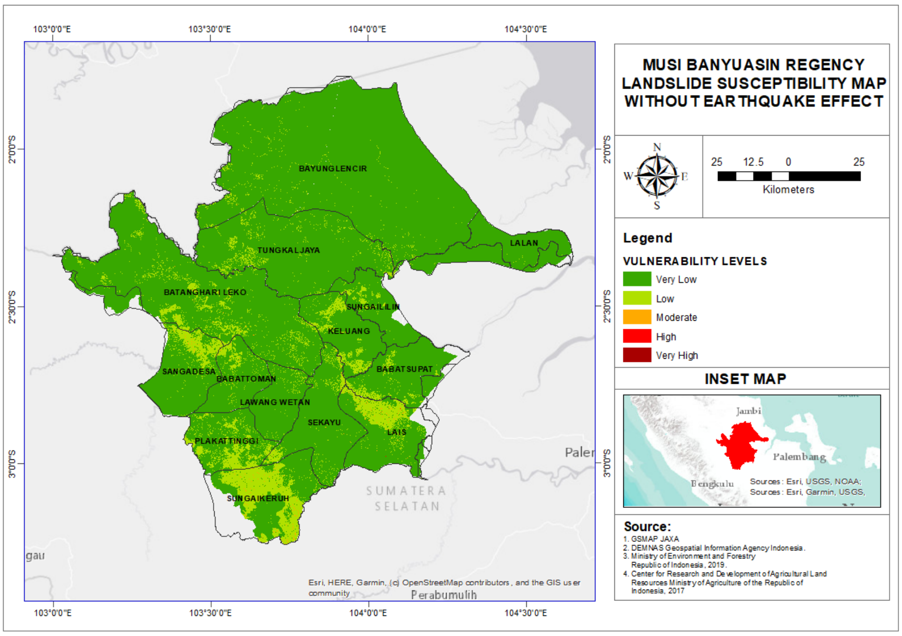

Fig. 2. Musi Banyuasin Regency Landslide Susceptbility Map Without Earthquake Effect

Table 4. Landslide prone area without earthquake effect.

No.	Classification	Area (km^2)	Area (%)
1	Very low	12.000,716	89,584
2	Low	1.375,083	10,265
3	Moderate	20,128	0,150
4	High	0,173	0,001
5	Very high	-	-
Total		13.396,100	100

Figure 2 depicts the results of the landslide susceptibility map, which show that Musi Banyuasin Regency has a very low landslide susceptibility. This is due to the low slope, which is the primary determinant of landslides. This is also supported by the low susceptibility of landslides due to rainfall and soil type. The land use parameter has little effect on the level of landslide susceptibility. This is because the percentage of weight possessed by land use parameters in equation 1 has the smallest value among other parameters.

Figure 3 shows that areas with a high level of landslide susceptibility classification in Musi Banyuasin Regency are located in hilly terrain and along riverbanks. The blue dots and the numbers in **Figure 3** define the time and location of the previous landslides that have occurred in Musi Banyuasin Regency. Table 4 shows the total percentage of each level of landslide susceptibility for the total area of Musi Banyuasin Regency.

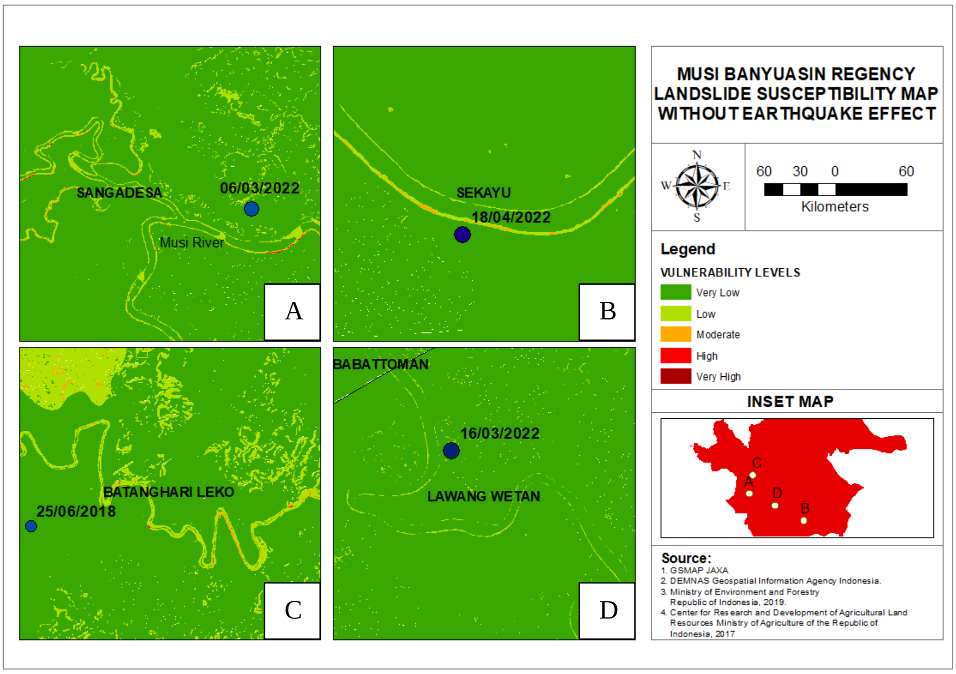

Fig. 3. Landslide Disaster Point that Ever Happened in Musi Banyuasin Regency. (a) Sanga Desa District, Sekayu District, Batanghari Leko District, and Lawang Wetan District.

The findings of this study's landslide susceptibility map without the influence of earthquakes contradict the findings of the IRBI 2020 book [13], which states that Musi Banyuasin Regency has a moderate landslide hazard classification value. This is due to the fact that the IRBI parameters for determining landslide vulnerability are based on the frequency of occurrence, the number of fatalities, the resulting environmental damage, and financial losses. These parameters take the effects felt after the landslide disaster into account, whereas the parameter values used in creating the landslide hazard map in this study are based on the parameters that cause the landslide disaster, such as soil slope, rainfall intensity, land use, and soil type. Furthermore, landslides in Musi Banyuasin Regency were mostly caused by heavy rains that day and soil erosion caused by high river flows, according to information obtained from DIBI (Indonesian Disaster Information Data) by BNPB [14]. However, the landslide susceptibility map made in this study uses the parameters of average rainfall per year and does not take into account the swift flow of rivers that are able to erode the soil along the riverbanks. Therefore, the map shows a low landslide susceptibility classification even at several points that have experienced landslides.

3.2 Map of landslide susceptibility with earthquake effect

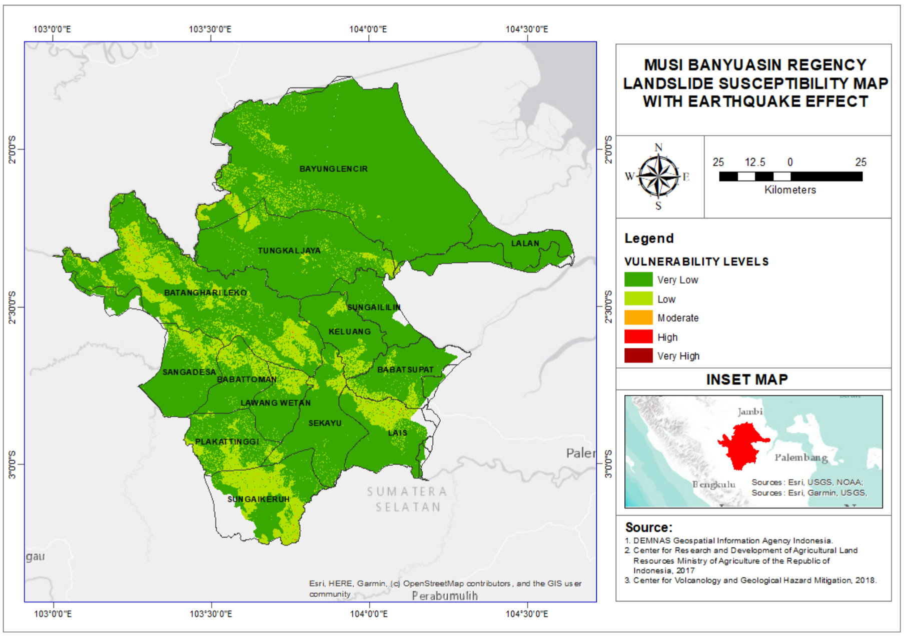

Fig. 4. Musi Banyuasin Regency Landslide Susceptbility Map With Earthquake Effect

Figure 4 depicts a landslide susceptibility map with earthquake effects that shows Musi Banyuasin Regency has a low level of landslide classification. Although the level of earthquake vulnerability in Musi Banyuasin Regency is dominated by moderate vulnerability, the low vulnerability of landslides is caused by the low slope gradient. The type of Inceptisol soil that dominates Musi Banyuasin Regency also contributes to the low level of vulnerability. Inceptisol is a type of soil that has a high rate of vegetation growth and can prevent water erosion from surface runoff.

Areas that have a moderate and high level of landslide susceptibility classification are in some sub-districts of Batang Hari Leko, Sungai Keruh, Lais, Sanga Desa, Babat Toman, Lawang Wetan, Plakat Tinggi, and a small part of Bayung Lencir as shown in **Figure 5**. Because of the hilly topography, some of these areas are more vulnerable to landslides than others, with a higher percentage of slopes. Table 5 shows the total percentage of each level of landslide susceptibility to the total area of Musi Banyuasin Regency.

Table 5. Landslide prone area with earthquake effect.

No.	Classification	Area (km^2)	Area (%)
1	Very low	11.187,450	83,513
2	Low	2.162,897	16,146
3	Moderate	42,078	0,314
4	High	3,674	0,027
5	Very high	-	-
	Total	13.396,100	100

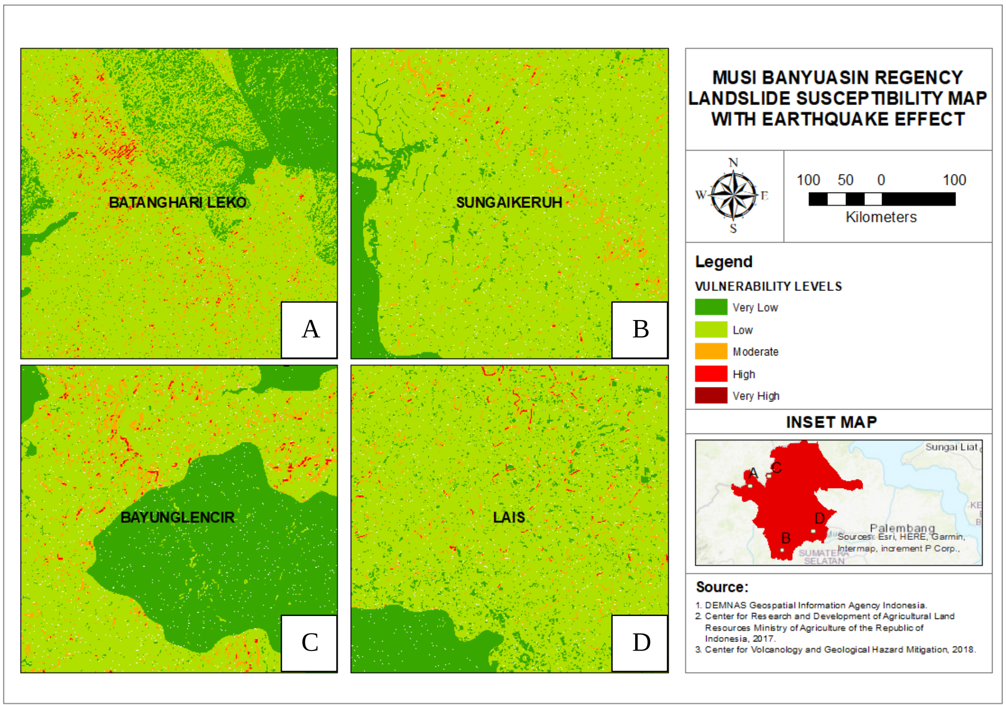

Fig. 5. Areas with Medium and High Landslide Hazards on the landslide susceptibility map with Earthquake Effect (a) Batanghari Leko District, (b) Sungai Keruh District, (c) Bayung Lencir District, and (d) Lais District.

4 Conclusion

Musi Banyuasin Regency's landslide susceptibility maps are generally dominated by very low lansdlide hazard potential. Without the influence of earthquakes, Musi Banyuasin Regency has 89.58% of an area with very low-level landslide susceptibility. Low susceptibility affects 10.26% of the area, while medium and high susceptibility are located on riverbanks and in several areas in Sungai Keruh, Lais, and Sanga Desa sub-districts, with a total area of less than 1% in each sub-district, which are areas with hilly topography. According to the landslide susceptibility map with earthquake influence, 85.51% of the Musi Banyuasin Regency has very low susceptibility, 16.15% has low susceptibility, 0.314% has medium susceptibility and 0.027% has high susceptibility. Several locations in Batang Hari Leko, Sungai Keruh, Lais, Sanga Desa, Babat Toman. Lawang Wetan, Plakat Tinggi and Bayung Lencir sub-districts with hilly topography and medium earthquake vulnerability produce medium and high landslide susceptibility. Each district's overall vulnerable area is less than 2%.

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