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PRIORITY SELECTION OF RESIDENTIAL DEVELOPMENT AREAS WITH FLOOD HAZARD IN LIMAPULUH KOTA DISTRICT, WEST SUMATRA

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ABSTRACT: The flood disaster has caused much harm to human life. The Effort to reduce the disadvantages caused by the flood is to develop settlement area priority based natural disaster. The purpose of research to determine the priority zone of settlement development using geography information system method (GIS) with regards to hazard risk. The indicator used in determining of area suitability for the settlement are a slope, flood, drainage, gravel, texture, and effective depth. Meanwhile, the Indicators used to determine of flood hazard zone are kinds of soil, slope, landform, rainfall, elevation, land use, and geology. The result shows that the level of area suitability and flood hazard of Limapuluh Kota district were 46% and 50.6%, respectively, these results are categorized as prone to moderate. The analysis result for priority of settlement area development for Limapuluh Kota district shows that it was suitable for S2 (fourth level priority) and flood hazard to medium. Therefore, in the use of area needs more cost and environmental conservation as disaster mitigation efforts for the future.

Keywords: land suitability, flood hazard, priority zone, GIS

1. INTRODUCTION

The use of land cannot be separated from human life because the use of the area is affected by the number of population in the world. The population growth increases the pressure on the land resource that caused both environmental and social problems. However, the availability of land that is suitable for a living is limited [1]. This limitation is potentially caused the conflict among people [2]. Furthermore, explained that the increasing of the population affect the exploitation of the natural source with less consideration to the environment ability and capacity [3]. This condition increases the environmental degradation and the susceptibility to disaster. Specifically, the changing of land uses affect the increasing of flood disaster risk [4,5]. This condition decreases the quality of land for a living because the flood is harmful to both physical and material

Selecting settlements areas that are away from flood disaster risk zone can be beneficial for urban development and planning. However, the flood hazard was less considered in the development of Limapuluh Kota District. Indonesian National Disaster Board for Disaster Management of Limapuluh Kota district noted that there was an increasing of flood disaster both the frequency area affected by the disaster in the period of 2010-2017. One of mitigation that can be done to minimize the impact of flood risk is determining the direction of mitigation policy in the flood-prone zones in Limapuluh Kota District based on physically characteristics, Limapuluh Kota district has the potential area to get flood disaster, they are: a) morphology, about 25% of the area is flat, b) about 70% the primary forest in that area changed into secondary forest, c) the increasing of rain intensity in the watershed area, and d) the development of settlement areas in the starting zone of the origin of the fluvial process.

GIS can be used for zoning hazard flood areas and then select the suitable areas for settlement outside the hazard zones. Flood can be defined as a relatively high water flow on the surface of the ground and it cannot be accommodated by drainage or river channels, thus transcending the river body and causing puddles or flows out of normal quantities and harms the humans [6,7]. The occurrences of the flood are affected by three factors namely they are meteorology, watershed, and human behavior [8,9]. Meteorologically, flood disaster also influenced by the increasing of rainfall as the impact of the acceleration of the hydrological cycle by climate change [10,11,12, 13,7,14,15]. Moreover, the characteristics of watersheds such as landform, elevation, kind of land, and slope also drive the occurrences of the flood [5,15]. People behavior that can be in the form of changing land uses can worsen those condition and stimulate the occurrence of flood disaster [16,17,5,18]. Hazard map can be produced by analyzing several spatial datasets in GIS such as topography, soil, land system, geology, land cover, and elevation map.

On the other hand, the suitable land for settlement also has typical characteristics that include geomorphology, resource availability, hazard, and policy. Specifically, the settlements areas candidate should: a) has topographically flat to wavy (0-25% slope); b) has availability of sufficient water sources (60-100 liters/ person/day); c) not in disaster hazard areas (landslide, flood, erosion, abrasion, and tsunami); d) has good to medium drainage; e) not in the boundary areas of rivers, beaches, and reservoirs; f) not in a protected area; and g) not in agricultural cultivation and technical irrigation rice fields [19,3].

The combination of both flood hazard analysis and settlement suitability analysis can provide better results of settlement priority zone. This paper aims to determine the priority zone of settlement development using geographic information system method (GIS) with regards to flood hazard. The prioritizing of settlement development area is based on the result of overlay between flood hazard and suitability for settlement area map that is resulted from the process.

2. RESEARCH METHOD

2.1. Location and Time of Study

This research was conducted at Limapuluh Kota District, West Sumatera Province. Geographically, Limapuluh Kota District is located on the longitude of 100°15' E - 100°53' E and latitude of 0°25' N - 0°25' N. The study took place for six months, in July - December 2017. Fig. 1 presented the administrative research location. The study area has administrative boundaries as follows: north bordered by Riau Province, south bordered by Tanah Datar and Agam Regencies, east bordered by Riau Province, west bordered by Pasaman Regency. Limapuluh Kota Regency is divided into 13 districts with an area of 3,315.5 km^2. The most sub-districts are Kapur IX with an area of 906.1 Km^2. Limapuluh Kota morphology has a relatively hilly and mountainous area. The mosaic of Limapuluh Kota Regency is more than 41 percent is an area with a slope of more than 27 percent and the area is relatively steep. The flat area is only about 15 percent of the total area.

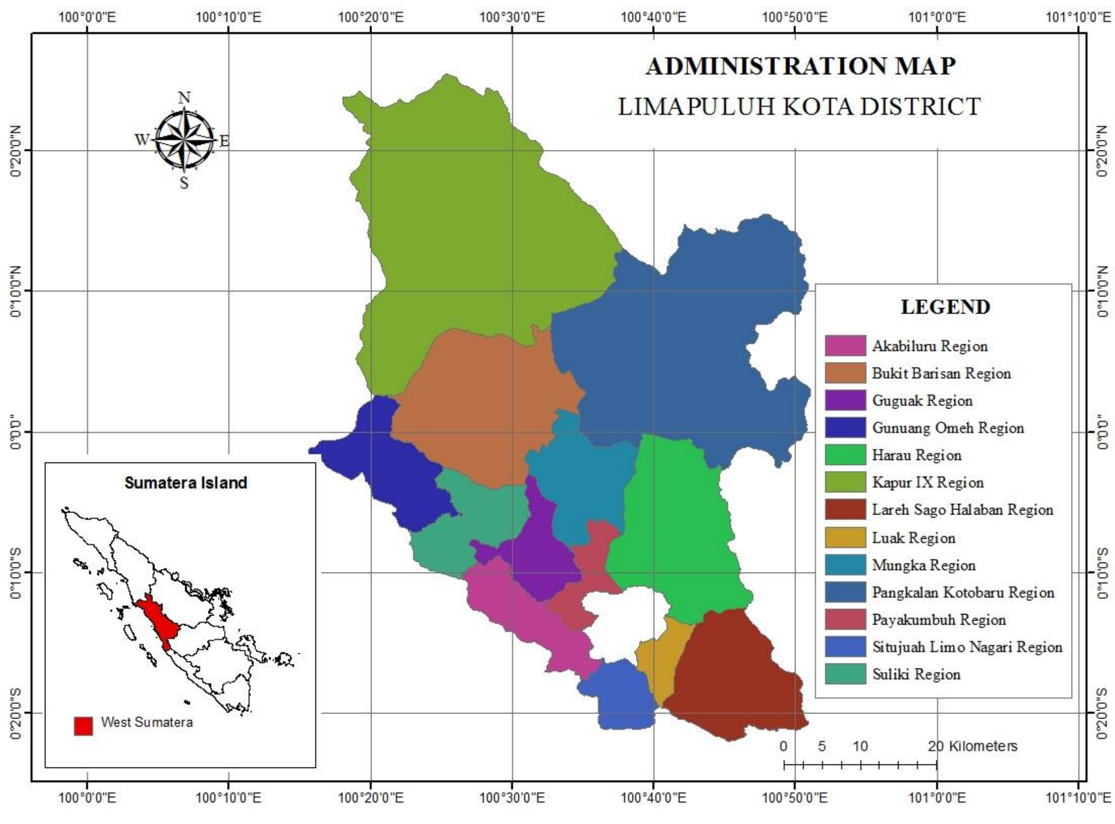

Fig. 1 Administrative Research Location

Limapuluh Kota District has a relatively hilly and mountainous area as morphologically. The morphology of Limapuluh Kota District is more than 41 percent as an area with a slope of more than 27 percent and the area is relatively steep and sheer. The flat area is only about 15 percent of the total area. Besides that, Limapuluh Kota District is the area that located in the Bukit Barisan zone. Geomorphologically this area is largely formed due to the process of lifting and the process of volcanic. So most of the form of land that formed are denudation, structural, and volcanic, and karst. But the process of reshuffling also occurs by the hydropower that forms the form of fluvial origin land. Residential areas for development take several indicators of soil permeability, topography, and geology which are further analyzed through Geography Information System [20,21].

The study area has a varying distribution of intensity of rainfall. The average annual rainfall is relatively high, it is 3500-4000 mm/year. The study area has an orographic rainfall type, it is the rainfall that occurs due to topography factor. The intensity of rainfall is getting higher in the upstream of the river and the rainfall getting lower in the lower area. Land use of the study area results from Landsat ETM + 7 image interpretation in 2016. The result of land use interpretation indicates that the study area still has forest area. However, 70 percent of primary forest areas in the study area has been turned into secondary forest. The Changing of the condition of primary forests into secondary forests can lead to the disruption of the hydrological cycle. Rainfall can take place faster due to the increase in temperature around. An indicator like land use types, elevation, drainage, infiltration, erosion, vegetation, and environmental hazards affect land suitability [22,23].

Table 1. The matrix of kinds and source of data of the study

No	Kinds of data	Source
1.	Map of topography	Citra SRTM Arc second
2.	Map of soil	Map of soil Bogor (1990)
3.	Map of land system	Region Physical Planing Program for Transmigration (1990)
4.	Data of rainfall	BMKG Sicincin 1975-2017
5.	Map of geology	Geology Department Bandung (2007)
6.	Land cover	Landsat 7+ETM 2016
7.	Elevation	SRTM Arc Second

2.2. Datasets

The data used in this study is categorized into two types include primary data and secondary data. Primary data is generated from measurement and collection from the field, while secondary data is obtained from official documents, information, and records from various relevant agencies. Table 1 presented the type matrix and data source. The spatial data needed in disaster-prone zone and land suitability research can be generated from several sources, including [14,15,1,24]: (1) slope maps produced from the Digital Elevation Model (DEM) using the image of Shuttle Radar Topography Mission (SRTM) 1 Arc Second; (2) land type map derived from the Land Map Type 1 (PPT) (1990); (3) A landform map produced from a 1: 25,000 land system developed by the Regional Physical Planning Program for Transmigration (1990); (4) Rainfall data sourced from BMKG Sicincin period 1975-2017 interpolated to isohyet map; (5) Land use is sourced from landsat 8 + ETM image in 2016 and corrected with Quick Bird Image 0.65m in 2013 interpreted to be a land cover map; (6) Geological map sourced from Bandung Geological Agency year 2007; and (7) the elevation map is sourced from the Image Radar Topography Mission (SRTM) 1 Arc Second image that is converted to DEM (Digital Elevasion Model). Geography Information System results in spatial analysis especially flooding calculations more accurately compared with other analyzes [25,26].

Table 2. Criteria of land suitability for settlement

Indicator/Weight	Sub Indicator	Rank	Score
Slope (%)/15.5	0-8	4	62
	8-16	3	46.5
	16-27	2	31
	>27	1	15.5
Flood/25.4	Never	3	76.2
	Seldom	2	50.8
	Often	1	25.4
Drainage/32.1	Good	3	96.3
	Medium	2	64.2
	Bad	1	32.1
Gravel/8.2	Little	3	32.6
	Medium	2	16.4
	Much	1	8.2
Texture/8.6	Rather Coarse	3	25.8
	Rather Fine	2	17.2

	Fine	1	8.6
Effective depth/10.2	Shallow (<50 cm)	3	30.6
	Medium (50-90 cm)	2	20.4
	Deep (>90 cm)	1	10.2

2.3. The technique of Data Analysis

Land suitability for residential areas is selected based on several criteria: slope, flood, drainage, gravel, texture, and effective depth [19,27,14]. Table 2 list the criteria that used for settlement area suitability. The analysis was conducted by multiplying the weight and the score of each criterion (spatial data), overlaying all criteria, and calculate the total score for each land unit. To determine the zoning of land suitability for settlement is used Equation 1. The result of the analysis obtained the highest total score of 323.5 and the lowest total score is 100 then with four groups of classes obtained an interval of 55. Table 3 is the class of land suitability interval for a residential area. Afterward, the land suitability class for settlements categorized into four categories based on approached: very suitable (S1), suitable (S2), marginal suitable (S3), and unsuitable (N)[28].

$$I = \frac{c-b}{k} \tag{1}$$

where,

I = the value of the distance of the class interval
c = the total of the highest score
b = the total of the lowest score
k = the total of desired class

Table 3. Interval Class of Land Suitability for Settlement Area

Class of Suitability	Class of Interval	Index of suitability
Very Suitable (S1)	266-324	Very Suitable Settlement Zone
Suitable (S2)	211-265	Suitable Settlement Zone
Marginal Suitable (S3)	156-210	Marginal Suitable Settlement Zone
Not Suitable (N)	100-155	Not Suitable Settlement Zone

Similarly, the flood hazard map was obtained by overlaying seven indicators, include slope, elevation, land use, rainfall, topography, kinds of soil, and geology. The total score resulted from the addition of all criteria score was used to determine the hazard classification. Equation 1 is used to classify the result. The analysis resulted in 440 as the total highest score and 85 as the total of the lowest score, thus the interval class is 118 that can be seen in Table 5. In table 5 flood hazard class interval divided into 3 classes that shows the hazard from the total score of flood hazard indicator.

Table 4. Flood hazard indicator

Indicator/ Weight	Sub Indicator	Rank	Score
Soil type (5)	Dystric cambisols, haplic acrisols	5	25
	Haplic acrisols	4	20
	Haplic acrisols, dystric cambisols	4	20
	Dystric nitrosols, rhodic ferralsols, dystric cambisols	3	15
	Umbric andosols, humic cambisols	3	15
	Dystric cambisols, dystric geysols	2	10
	Dystric cambisols, ferric acrisols	1	5
Slope (%) (20)	0-8	5	100
	8 -16	4	80
	16-27	3	60
	27- 40	2	40
	>40	1	20
Landforms (15)	Fluvial	5	75
	Karst	4	60
	Structure	3	45
	Volcanic	2	30
	Denudation	1	15
Rainfall (15)	> 5000	6	90
	4500-5000	5	75
	4000-4500	4	60
	3500-4000	3	45
	3000-3500	2	30
	2500-3000	1	15
River elevation (15)	0-5 meter	5	75
	10-15 meter	4	60
	15-20 meter	3	45
	20-25 meter	2	30
	>25 meter	1	15
Used of land (10)	Settlement	5	50
	Rice fields	4	40
	Bare land	4	40
	Mixed Garden	3	30
	Shrubs	2	20
	Forest	1	10
Geology (5)	Alluvium	5	25
	Tuff Pumice	4	20
	Mixed silt stone	4	20
	Andesite stone	3	15
	Limestone	3	15
	Coal	2	10

Quartz mixed slate	2	10
Rock silt, quartz mix silt rock	1	5
Volcanic stone	1	5

Priority development is based on the result of overlay between land suitability for settlement area and flood hazard zone. The priority indicator is the area should be scored as very suitable and should not have high flood hazard. This can be interpreted the more suitable land will be a priority for the development of residential areas, but it also considers the level of hazard to flood disasters. The higher the level of flood hazard will not be a priority [1,24].

Table 5. Flood hazard Class Interval

Hazard class	Interval class	Hazard Index
Low class	85-203	Low hazard zone
Moderate class	204-321	Moderate hazard zone
High class	322-440	High hazard zone

3. RESULT AND DISCUSSION

The results of land suitability analysis for settlement areas indicate that there is 10.3 percent of the very suitable areas (S1), about 40 percent of suitable areas (S2), about 46 percent of the marginal area (S3), and about 3.7 percent of unsuitable areas (N) for settlement areas. Fig 2 presents a map of land suitability for settlements in Limapuluh Kota District. Lands needed for settlement in Limapuluh Kota Regency increased by 0.6 percent per year in the period 2000-2017. Approximately 15 percent of the total settlements are built on zones that not match in their designation.

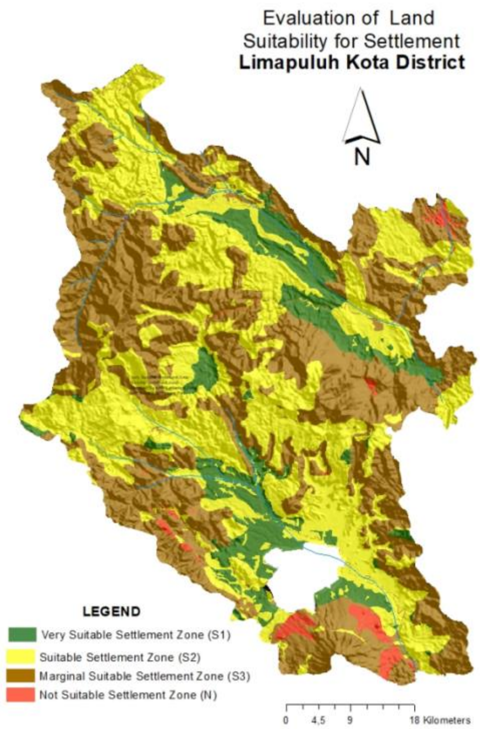

Fig. 2 Evaluation of land suitability for settlement

Explained that the unsuitable utilization of land with its function will need expensive fee [28]. The unsuitable land use does not only need additional fee in utilizing but it also causes the damage of land and environment [29,30]. Flood hazard area zone can be determined based on overlay analysis of land type map, slope map, topography map, rainfall map, elevation or altitude map, land use map, and geological of Limapuluh Kota District. In the study area, flood hazard zone is categorized into three categories, they are high, medium, and low. The analysis shows that in high-risk areas of flood hazard areas are around 6.2 percent of the total area, about 50.6 percent are medium hazard zones, and the rest is about 43.2 percent of low hazard zones. Figure 3 presents a flood hazard zonation in Limapuluh Kota District. The flood disaster and its impact will increase in the future, it happens because of the changing of land use pattern. Thus, it needs a mitigation to reduce the impact of the flood [31].

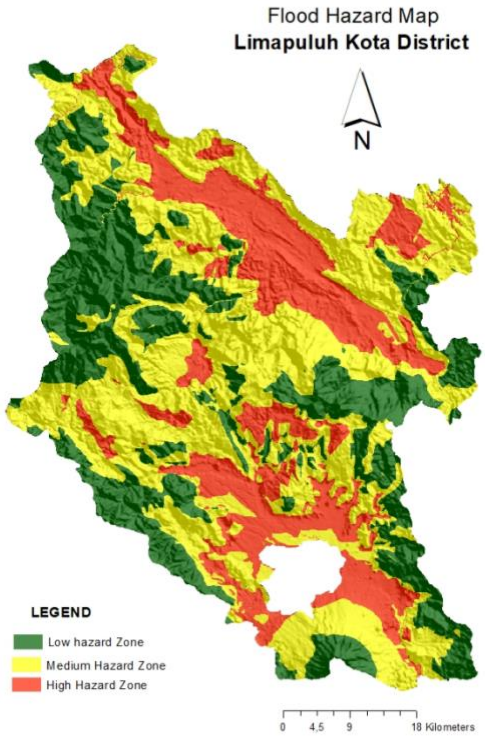

Fig. 3 Flood hazard zone

Settlement area priority zone is resulted from overlaying of the land suitable map for flood hazard zone settlement. The area that becomes the priority to be developed is a very suitable area (S1) and low flood hazard area. It can conclude that the more unsuitable land, it will not become the priority in developing settlement area. The analysis result of the study area shows that most of the area is priority 4, it is suitable (S2) and moderate hazard index. To utilize the land continues, it needs to repair and notice the land characteristics for area development. Settlement areas in 2017 compared to flood zoning, about 21 percent of settlement areas are in high vulnerability zones, 28 percent in medium vulnerability zones and 51 percent in low vulnerability zones

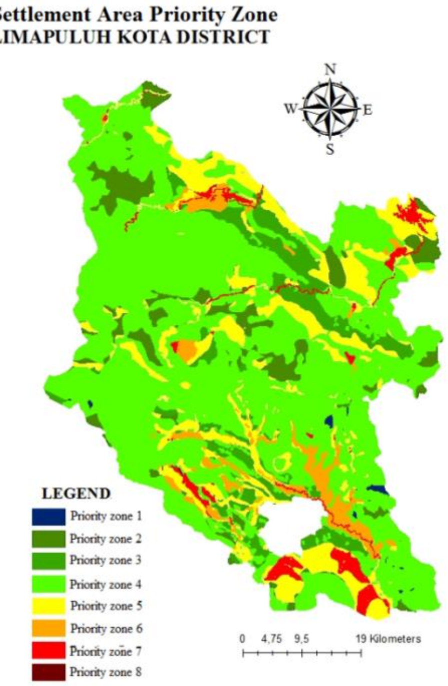

Fig. 4 Settlement area priority zone.

Limitation of spaces that can be developed both geophysics (morphology, slope, forest area, and disaster hazard) with an increasing 1.4 percent of population per year in period 2000-2017 leads to increase in land needed for settlement areas. To reduce the risk of disaster-vulnerability settlements and sustainable land use, it is necessary to develop priority zones of settlement areas. One of the development efforts of sustainable settlement by incorporating vulnerability in regional planning [28,14]. Kabupaten Limapuluh Kota is one of the areas with relatively high flood vulnerability and flood losses about 28% cause of errors in settlement construction. With priority maps of this settlement, the area is expected to reduce the losses incurred. The level of land suitability for settlement in Limapuluh Kota District is mostly marginal (S3). For priority zone, most of the areas in Limapuluh Kota District are in the fourth priority.

4. CONCLUSIONS

Limapuluh Kota district has the area that has disaster hazard characteristic, especially the flood. The conversion of primary forest to secondary forest causes the flood to happen. The level of land suitability for settlement in Limapuluh Kota District is mostly marginal (S3) so that the utilization needs the expensive fee. Besides that, based on the flood hazard level, most of the areas in Limapuluh Kota District are moderate hazard category. For priority zone, most of the areas in Limapuluh Kota District are in the fourth priority.

The land suitability is suitable (S2) and the hazard level is medium. Therefore to the government of Limapuluh Kota District should tighten in giving building permit (IMB) especially in flood hazard area. Besides, that to the society must not destroy the environment in land use.

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