The landslide risk analysis based on human activity using Arc-GIS method

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Abstract. This research aims to map the risk level of landslide based on human activity in the Guntur Macan Village, West Lombok. The method used in this study was descriptive quantitative research by mapping and assessing a human activity to classify the risk level of the landslides. The research variables were cropping pattern, excavation, and slope cutting, pond making, drainage, construction, population density, and mitigation. The result showed that the risk level of landslides caused by human activity was divided into three zones. Zone A is a place with a 2.1 risk level of landslides (moderate level), while Zone B is 2.0 (moderate level), and Zone C is 1.3 (low level).

1. Introduction
Guntur Macan is a village in West Lombok that has a risk of landslides. Based on the local regulation (PERDA) No.11/2011 about RTRW of West Lombok, Guntur Macan has been assigned as a protected area because most of the land is a hill with a 40% slope [1]. The rainfall of this village is relatively high (2000-3000 mm). Moreover, the soil is clay and a sandy type that makes it highly vulnerable to the landslides. The landslides in Guntur Macan Village in 2016 had destroyed many properties of the villagers. Therefore, in 2015, many residents were also killed and destroyed their properties. The recent landslides were not the first case in the Guntur Macan Village because in 1974 and 2000 there were landslides occurred that hit the village [2].

The Minister of Public Works Regulation No. 22/PRT/M on Guideline for Spatial Planning of Landslide Area said that the spatial planning need to consider the aspect of space usage by considering the ecosystem balance and the social welfare assurance through the assessment of spatial structure and space pattern of a landslide area based on its typology and the level of its vulnerability as well as maintaining the suitability between the implementation activities and the designated area functions [3]. The risk level classification is determined by 2 criteria, namely natural physical aspect and human aspect [4]. Physical, social, economic and environmental factors play a role in susceptibility to the landslide risk [5] [6].

The landslides that happened in the Guntur Macan village was actively influenced by the community activities, where 270 families (33%) live in the hills. The hills not only used as a residential area but also as farming and stockbreeding. Furthermore, a logging activity by the villagers in the hilly area will deplete the tree vegetation that supposes to conserve the soil and water. A large number of human activities without consideration of environmental sustainability is one of the reasons for the increasing frequency of landslide intensity occurring in the area [7].
Thus, the research aim is to analyze the risk level of the landslides based on the human activities in Guntur Macan Village.

2. Method

2.1 Types of Research

Based on the introduction, the purpose of this research is "to map the risk level of the landslide based on the human activity in the Guntur Macan Village". The method that used in this research was descriptive quantitative by mapping and assessing a human activity to classify the risk level of the landslides. The variables of the human activity were mapped based on The Minister of Public Works Regulation No. 22 / PRT / M on Guideline for Spatial Planning of Landslide Area, namely:

a. Cropping pattern (10%)
b. Excavation and slope cutting (20%)
c. Pond making (10%)
d. Drainage (10%)
e. Construction (10%)
f. Population density (20%)
g. Mitigation (10%)

2.2 Research Focus

The research was located in the Guntur Macan Village, Gunung Sari Subdistrict, West Lombok, with a total area of 2,749 ha, consisting of 7 hamlets: Guntur Macan, Barat Kokoq, Ladungan, North Poan, Pancor, Apit Aik, and Southern Poan.

2.3 Analysis

The analysis steps in this research were divided into several parts, which were:

a. A collection of primary data for the human activity indicator to determine the risk level classification. The data were displayed in the human activities map for each indicator.

b. A typology determination of disaster-prone areas based on the zonation determination by considering the character and the physical condition of nature, such are:
   - Zone type A, a place with a mountain slope, hillside, and riverbank, altitude above 2,000 meters above mean sea level and slope including more than 40%.
   - Zone B type, a place in the mountain foot, foothill, and riverbank, the height of 500 – 2,000 meters above mean sea with the slope between 21 - 40%.
   - Type C zone, a place of the highland, lowland, river banks or river valleys, elevations 0 – 500 meters above mean sea and incline slope between 0 - 20%.

c. An assessment of each zone by using the weight of the predetermined criteria indicators. Each indicator is rated as below:
   - 3 (three) if it is considered to have a significant impact on the landslide
   - 2 (two) if it is considered to have a moderate impact on the landslide
   - 1 (one) if it is considered to have less impact on the landslide

d. An assessment of the risk level of the landslide based on a human activity aspect which was done by calculating the sum of the 7 indicators with a total between 1-3, meanwhile to indicate the risk level of each zona was conducted using these criteria below:
   - Risk level zone with high mudslide potential between 2.4 - 3.0
   - Risk level zone with medium mudslide potential between 1.7 - 2.39
   - Risk level zone with low mudslide potential between 1.0 - 1.69
3. Results and Discussion

3.1 Typology of Guntur Macan Landslide Disaster-prone areas

Geographically, the Guntur Macan Village is a hilly area that forms the "U" letter between the hills (Figure 1). The altitude of the area varies between 57 - 513 meters above sea level (mdpl). The Guntur Macan village is flown by two rivers that flow between the hills and form a basin. 18.11% of the area is used as a residential area, while 67.94% is used as a farming area that spread equally in the hills and the lowland.

![Figure 1. The Illustration of the landform of the Guntur Macan village.](image)

The Guntur Macan Village has hillside slope variation where most of the slope has a 40% tilt with the area around 105.68% ha (30.19%). The area with a slope of 0-8% is 43.63 hectares, 8-15% is 44.75 hectares, 15-25% is 89.19 hectares, 25 - 40% is 89.19 hectares.

According to the guidelines for the spatial planning of landslide areas, the Guntur Macan Village is classified into 3 zones (Table 1), namely:

a. A type zones, it is an area that is located on the slopes, hillside, and river banks with a slope of more than 40% tilt. However, based on the area characteristic, which is hilly, the zone has variation contours which are foothill, hillside, and hilltop. The hillside slope with more than 40% tilt is designated as a type A landslide-prone area, while the area above the hill that has a slope of 0-8% is included conditionally as a type A with the following considerations:
   - The uphills area is adjacent to the hillside that has an extreme slope.
   - The uphills area has a similar characteristic to the hillside in terms of the potential of a landslide disaster.
   - The hillside and the uphills are an area that intrigued a landslide to the below area.

Based on the landscape characteristic, all of the hamlets in Guntur Macan Village are part of type A zone, especially the North Puan Hamlet and the Southern Puan Hamlet.

b. Zone Type B is a foothill that dominated by slope tilt 21% to 30%, although in some residential areas the contour is relatively flat. In addition, the area of the type B zone is the area that is located in the basin between two hills which has a relatively flat slope between 0-15 % which directly adjacent to a slope of above 40%. Thus, the Pancor, Apit Aik, Guntur Macan, Barat Kokoq are included in the type B zone.

c. Zone Type C is a lowland area with a slope of 0- 15%, which are the characteristic of the Barat Kokoq and Apit Aik Hamlet.

| No | Zone Typology | Land surface form | Broad (hectare) |
|----|---------------|------------------|-----------------|
| 1  | Type A        | Hillside         | 229.76          |
| 2  | Type B        | Foothills        | 63.00           |
| 3  | Type C        | Lowland          | 55.90           |

*Source: analysis result, 2018*
3.2 The Landslide Risk Analysis Based on Human Activity Aspects in Guntur Macan Village

3.2.1 Cropping Pattern
The cropping patterns are designed based on the existing land types. The Type A Zones and Type B Zones are mostly utilized for plantation. The hillside is planted with taproot plants such as sengon, and teak where these types of plants are very effective in preventing landslides. Hence, the area will have a low sensitivity to the landslide risk. However, the cropping pattern is not complemented by the community activities in utilizing the logs for sale, mainly sengon and jati. The legal logging in Guntur Macan Village that supported by the government has been depleting the trees which disturbing the hillside stability. On the other side, Zone Type C is a land utilized for paddy fields, planted with fibrous plants such as rice and maize. Although these plants are highly sensitive to the landslides, the plants are planted in a relatively flat slope of 0-8%; hence, the risk sensitivity is low.

3.2.2 Excavation and cutting slopes
Cutting slopes for cultivation, residential area, and road construction activity such as excavation and mining, technically could increase the soil movement. In zone type A, the excavation and the slope cutting are conducted in the natural hillside/artificial hillside, where those activities are used to build houses and roads. However, the construction was done without concerning about the soil/rock layer, and without calculating the slope stability. Hence, the excavation/cutting intensity is considerably high.

At Zone Type B, the intensity of the excavation/slope cutting is also high in which the excavation and cutting slope is conducted for the construction of houses and roads, as well as brick production in the hillside which will increase the vulnerability sensitivity. On the other side, zone type C sensitivity is low due to the absence of excavation and slope cutting activity in the area. Furthermore, the area has a slope characteristic that relatively flat.

3.2.3 Manufacturing and placement of ponds
Pond printing on steep slopes affects the potential for landslides because the water will affect the physical and generical properties of the soil, transforming the soil into soft and loose; hence, the soil strength is decreasing as the soil move quickly. Based on the field identification, the pond printing only found on the zone type C in the flat slope 0-8%. On the other side, zone type A and B has no activity of pond printing; thus, the risk level is low.

3.3.4 Drainage
In the Zone type A, the drainage system is inadequate, covered by dirt soil. There is no effort to repair it either from the government or the community. Hence, based on the drainage condition aspect, this region has high-risk sensitivity. On the other side, Zone Type B and Zone Type C drainages are quite adequate. Moreover, there are efforts to improve drainage; thus, the risk level in both zones is medium.

3.3.5 Construction Build
At Zone Type A, there is construction ongoing with considerably low loads but not exceeded the soil bearing capacity. The construction is conducted to build roads and houses, elementary school buildings, prayer facilities, and health care facilities like Posyandu (Integrated Healthcare Center). Although the construction activity is relatively infrequent, as the growth of the human needs of shelters, the construction will be increasing. Thus, the hillside loads increased as well as the landslide risk level. Even though the villagers are constructing in the flat area, as the hill slope more than 40% tilt, it is considered a steep hill. Hence, the risk level is still high.

At Zone Type B, the construction and the load capacity are considerably small. The construction is focused on the road, houses, elementary schools, health care facilities such as Posyandu (Integrated Healthcare Center) and village health center, and governmental facilities like village offices. Based on the field observation, the construction has been exceeded the load capacity of the land, because most of the residents are building their houses in the slope area (more than 40% tilt) without calculating the
hills. This area is highly vulnerable to landslides compared to other zones. Hence, the risk level is high.

In zone type C, the construction has a relatively small load capacity and has not exceeded the standard. The constructions are focused on houses, roads, elementary school facilities, prayer facilities, and health care facilities such as Posyandu (Integrated Healthcare Center). The landslide sensitivity in this area is medium based on the construction aspects because the area is considerably flat.

3.3.6 Population Density
Based on the area calculation, the population density in this area is considerably low, less than 20 residents/hectare. However, the population density was calculated based on the living area. Based on the number of inhabitants in each zone, the number of houses in Guntur Macan Village is corresponding to the zone typology, which interpreted by satellite imagery and primary survey with the help of ArcGIS, resulting population density in zone A is 34 resident/ha, zone type B is 37 resident/ha, and zone type C is 49 resident/ha. Consequently, the risk level of each zone is considerably medium due to the range of the population in the three zones (20-50 resident/ha).

3.3.7 Mitigation
After the landslide occurred in the Guntur Macan Village that killed the resident and destroyed their properties, the West Lombok government has been trying to keep the disaster away by coordinating the mitigation activities. The government has been forming a community of DESATANA (the resilient village disaster) in Guntur Macan Village. This forum is expected to be a forerunner of disaster management in Guntur Macan Village that vulnerable to the landslides (Figure 2 and Table 2).

The National Disaster Management Agency has been installing a natural disaster detection system (EWS) in the local hilly area. EWS installation is collaborative work between the National Disaster Management Agency and a team from Gadjah Mada University. There are four EWS tool mounting spots. Two spots for ground cracking detection, one spot for the land slope analysis, and the last spot for the rainfall. Disaster detection is expected to give an early warning to the community when the disaster comes. Consequently, all the zones will have a low-risk level of disaster.

Figure 2. (A) Typology of disaster Zone Map, (B) Level of disaster vulnerability based on activity level map.
| Zona | Condition | Sensitivity | Value Point | Total |
|------|-----------|-------------|-------------|-------|
| **Planting Pattern** | | | | |
| A | The slopes planted by the Tree are rooted, but there is a branching tree | High | 3 | 0.1 | 0.3 |
| B | The slopes planted by the Tree are rooted, but there is a branching tree | High | 3 | 0.1 | 0.3 |
| C | The slopes are planted Vegetable rooted, but on a flat area | Low | 1 | 0.1 | 0.1 |
| **Excavation and Cutting Slope** | | | | |
| A | Excavation / Cutting Slope High | High | 3 | 0.2 | 0.6 |
| B | Excavation / Cutting Slope High | High | 3 | 0.2 | 0.6 |
| C | No Excavation / Cutting Slope | Low | 1 | 0.2 | 0.2 |
| **Building and placement of pools** | | | | |
| A | Nothing | Low | 1 | 0.1 | 0.1 |
| B | Nothing | Low | 1 | 0.1 | 0.1 |
| C | There is a Pond printing but in a flat area | Medium | 2 | 0.1 | 0.2 |
| **Drainage** | | | | |
| A | Inadequate and no improvement effort | High | 3 | 0.1 | 0.3 |
| B | Quite adequate and there is an improvement effort | Medium | 2 | 0.1 | 0.2 |
| C | Quite adequate and there is an improvement effort | Medium | 2 | 0.1 | 0.2 |
| **Construction** | | | | |
| A | Construction of construction and load is not too large but has not exceeded the carrying capacity of the land | High | 3 | 0.1 | 0.3 |
| B | Construction of construction and load is not too large but has not exceeded the carrying capacity of the land | High | 3 | 0.1 | 0.3 |
| C | Construction of construction and load is not too large but has not exceeded the carrying capacity of the land | Low | 1 | 0.1 | 0.1 |
| **Population Density** | | | | |
| A | The density of the population in the research area is moderate, ie less than 20-50 people/hectare | Medium | 2 | 0.2 | 0.4 |
| B | The density of the population in the research area is moderate, ie less than 20-50 people/hectare | Medium | 2 | 0.2 | 0.4 |
| C | The density of the population in the research area is moderate, ie less than 20-50 people/hectare | Medium | 2 | 0.2 | 0.4 |
| **Mitigation** | | | | |
| A | there are a landslide mitigation and well-coordinated effort | Low | 1 | 0.1 | 0.1 |
| B | there are a landslide mitigation and well-coordinated effort | Low | 1 | 0.1 | 0.1 |
| C | there is a landslide mitigation effort coordinated with | Low | 1 | 0.1 | 0.1 |

A total risk value of zone A = 2.1 with a medium level of landslide risk (the area is 229.76 ha)
A total risk value of zone B = 2.0 with a medium level of landslide risk (the area is 63.00 ha)
A total risk value of zone C = 1.3 with the low level of landslide risk (the area is 55.90 ha)

Source: analysis result, 2018
4. Conclusion
The landslide risk level in Guntur Macan village based on the human activity assessment is divided into three zones as a result of seven indicator analysis, namely cropping pattern, excavation, and slope cutting, pond making, drainage, construction, population density, and mitigation. Zone A has a risk level around 2.1, while zone B is 2.0 which classified as medium level. On the other side, zone C has 1.3 risk level that categorized as low-risk level of landslide.

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