Land suitability based on land function using geographic information system (GIS) in landslide potential area

F Susanti*, R Ridha and A Kurniawan

Department of City and Regional Planning, Muhammadiyah University of Mataram, No 1 K.H.Ahmad Dhalan Street, West Nusa Tenggara, Indonesia 83117

* E-mail : febrita_s@yahoo.com

Abstract. Located in West Lombok, Gunung Sari is an area that frequently experiences landslides. Diverse land characteristics and the incompatibility of land allotment allegedly can be some factors causing the landslides. Therefore, it is necessary to conduct research to analyze the land suitability in some areas with a high frequency of landslides. The research approach used in this research is descriptive quantitative with overlay analysis techniques using Arc Gis application program. Based on the data analysis results, it was discovered that Gunung Sari has an area of 2,376.36 Ha or 29% of the total land area which is not in accordance with its designation, an area of 4,032.49 Ha or 49% of the total land area can be categorized into a conditional land and an area of 1,786 Ha or 22% of the total land might be classified into a suitable area land. According to the land function of this area, it was found that the largest area that is unsuitable land and conditional land are located in the conservation zone covering an area of 2249.48 Ha for the unsuitable land and 2433.24 Ha for the conditional land.

1. Introduction
Since 2000, the landslides in West Lombok have occurred for more than 59 times. West Lombok consists of 10 sub-districts, including Gunung Sari, which is a disaster-prone area. In 2015, the landslides occurred in Gunung Sari causing four deaths and two people injured. It was also reported that five houses were damaged [1].

Differences in the characteristics of the land in Gunung Sari cause some of these areas to be prone to landslides. Based on level susceptibility determination matrix, areas with a high-level susceptibility are Guntur Macan, Bukit Tinggi, Kekeri, Jeringo, Dopang, Taman Sari, Kekait, Gelangsar, Membalan and Mekar Sari [2]. Various factors causing landslides are frequent rainfall, land cutting, and steep slopes as in the case of Gunung Sari sub-district [1]. The landslides that can trigger deaths can also be caused by unsuitable designation of land use [3]. Therefore, it is important to have accurate information about the suitability of land use in disaster-prone areas so that the number of victims due to landslides can be minimized. The purpose of this study is to describe the level of potential susceptibility of landslide disaster and analyze the suitability of land use in areas that are susceptible to landslide based on the area function.

2. Methodology
Geographic Information System (GIS) is used for mapping disaster susceptible areas. These areas consist of five categories, including Very Low susceptible, Low susceptible, Moderate susceptible,
High susceptible and very high susceptible (Table 1) [4]. This categorization is obtained from multiplication of value and scores divided by one hundred [5].

**Table 1. Category of Susceptibility Based on Scoring**

| No | Score | Category of Susceptibility |
|----|-------|---------------------------|
| 1  | >4.3  | Very High                 |
| 2  | 3.5-4.3 | High                     |
| 3  | 2.6-3.4 | Moderate                 |
| 4  | 1.7-2.5 | Low                      |
| 5  | <1.7  | Very Low                  |

The landslide parameter used in this study is in accordance with the landslide susceptibility factors shown in Table 2 [5].

**Table 2. Landslide Susceptibility Factors**

| Classification | Score | Value | Classification | Score | Value |
|----------------|-------|-------|----------------|-------|-------|
| Rainfall       |       |       | Geology        |       |       |
| <50            | 1     | 25%   | Alluvial       | 1     | 10%   |
| 50-99          | 2     |       | Limestone Hills| 2     |       |
| 100-199        | 3     |       | Granit Hills   | 3     |       |
| 200-300        | 4     |       | Sedimentary Hills | 4 |       |
| >300           | 5     |       | Basal Hills    | 5     |       |
| Slope          |       |       | Depth of Soil  |       |       |
| <25            | 1     | 15%   | <1             | 1     | 5%    |
| 25-44          | 2     |       | 1-2            | 2     |       |
| 45-64          | 3     |       | 2-3            | 3     |       |
| 65-85          | 4     |       | 3-5            | 4     |       |
| >85            | 5     |       | >5             | 5     |       |
| Land use       |       |       | Density of settlements |       |       |
| Forest         | 1     | 5%    | <2000          | 1     | 5%    |
| Bush           | 2     |       | 2000-5000      | 2     |       |
| Plantation     | 3     |       | 5000-10000     | 3     |       |
| Moor           | 4     |       | 10000-15000    | 4     |       |
| Settlement     | 5     |       | >15000         | 5     |       |
| Fault          |       |       | Infrastructure  |       |       |
| With fault     | 5     | 5%    | No access      | 1     | 15%   |
| Without fault  | 1     |       | Cutting slope  | 5     |       |

The map of land suitability in disaster susceptible areas will be attained from the overlay results based on susceptibility criteria and land function (cultivation zone, buffer zone, and conservatory zone) [6].

3. **Analysis**

3.1. **Analysis of Land Functions**

The result of area function analysis in Gunung Sari, it is found that the cultivation area covers 2073.41 Ha or 25 percent, buffer area covers 1339.12 Ha or 18 percent, and conservatory area covers 4682.73 Ha or 57 percent (Figure 1).
3.2. **Susceptibility Level of Landslide**

Based on the result of landslide susceptibility analysis in Gunung Sari of West Lombok, it is found that there are four types of landslide susceptible potentials. They comprise a very low susceptible zone, low susceptible zone, moderate susceptible zone, and highly susceptible zone as shown in Figure 2 and Figure 3.

The area of very low susceptible is indicated in green with the area of 51.40 Ha. The low susceptible zone is indicated in blue with the area of 1874.66 Ha. The moderate susceptible zone is
indicated in yellow with the area of 3917.32 Ha. The high susceptible zone is illustrated in red on the map above with an area of 2351.88 Ha.

From the susceptibility analysis results, it can be seen that Gunung Sari is dominated by the range of susceptible to moderate potential areas which are equal to 48% of the total area. While the smallest category is a very low susceptible which is equal to 1% of the total area of the district.

3.3. Land Use
Land use in Gunung Sari covers plantation, paddy planting, field, settlement, production forest, and open land. The dominant land use is production forest, with approximately 4677.29 Ha or 57% of the total area and plantation, with 1931.42 Ha or 24% of the total land area in Gunung Sari. Table 3 illustrates the land use based on landslides susceptibility.

| Susceptibility | Land Use       | Area (Ha) | Location                                      |
|----------------|----------------|-----------|-----------------------------------------------|
| Very Low       | Plantation     | 51.40     | Gunung sari, Dopang, Membalan and DasanGea     |
|                | Open space     | 1.57      | Jatisela, Sesela, Midang, Dopang, Taman Sari, Gunung sari, Guntur Macan, Mambalan, Mekarsari, Penimbung, Keki, DasanGeia |
| Low            | Plantation     | 607.73    |                                               |
|                | Paddy planting | 1034.20   |                                               |
|                | Field          | 19.63     |                                               |
|                | Settlement     | 200.71    |                                               |
|                | production forest | 10.82     |                                               |
| Moderate       | Plantation     | 1077.27   | Gunung Sari, Taman Sari, Guntur Macan, Mambalan, Mekarsari, Penimbung |
|                | Paddy planting | 132.48    |                                               |
|                | Field          | 11.51     |                                               |
|                | Settlement     | 54.07     |                                               |
|                | production forest | 2641.99  |                                               |
| High           | Plantation     | 195.01    | Gunung Sari, Taman Sari, Guntur Macan, Mambalan, Mekarsari, Penimbung |
|                | Paddy planting | 64.03     |                                               |
|                | Field          | 56.31     |                                               |
|                | Settlement     | 12.04     |                                               |
|                | production forest | 2024.48  |                                               |
| Total Area     |                | 8195.26   |                                               |

3.4. Land Suitability Analysis
The land suitability map illustrated from the result of overlaying the function of the area, the potential for landslide susceptibility, and land-use. It can, therefore, be categorized into suitable, conditional and unsuitable areas as presented in Table 4.
Table 4. Suitability Analysis based on Area Function

| Area Function | Susceptibility | Land Use          | Land Suitability | Area (Ha) |
|---------------|----------------|-------------------|------------------|-----------|
| Cultivation Zone |               |                   |                  |           |
| Very Low      |                | Plantation        | Suitable         | 51.40     |
|               | Low            | Plantation        | Suitable         | 334.28    |
|               |                | Paddy planting    | Suitable         | 1026.56   |
|               |                | Field             | Suitable         | 13.00     |
|               |                | Settlement        | Suitable         | 199.21    |
|               |                | production forest | Suitable         | 0.75      |
|               | Moderate       | Plantation        | Conditional      | 155.24    |
|               |                | Paddy planting    | Conditional      | 80.82     |
|               |                | Field             | Conditional      | 4.27      |
|               |                | Settlement        | Conditional      | 29.59     |
|               |                | production forest | Suitable         | 161.20    |
|               | High           | Paddy planting    | Unsuitable       | 15.35     |
|               |                | Settlement        | Unsuitable       | 1.66      |
|               | Conservatory Zone | Plantation     | Conditional      | 233.93    |
|               | Low            | Open Land         | Conditional      | 1.57      |
|               |                | Paddy planting    | Conditional      | 7.64      |
|               |                | Field             | Conditional      | 6.63      |
|               |                | Settlement        | Conditional      | 1.50      |
|               |                | Production forest | Conditional      | 5.23      |
|               | Moderate       | Plantation        | Conditional      | 444.73    |
|               |                | Paddy planting    | Conditional      | 51.01     |
|               |                | Field             | Conditional      | 7.24      |
|               |                | Settlement        | Unsuitable       | 23.50     |
|               |                | Production forest | Conditional      | 569.84    |
|               | High           | Plantation        | Unsuitable       | 36.39     |
|               |                | Paddy planting    | Unsuitable       | 24.06     |
|               |                | Field             | Unsuitable       | 18.60     |
|               |                | Settlement        | Unsuitable       | 6.61      |
|               |                | Production forest | Unsuitable       | 0.71      |
|               | Buffer Zone    |                   |                  |           |
|               | Low            | Plantation        | Conditional      | 39.52     |
|               |                | Forestry          | Conditional      | 4.83      |
|               |                | Plantation        | Conditional      | 477.30    |
|               |                | Paddy field       | Conditional      | 0.64      |
|               |                | Settlement        | Unsuitable       | 0.98      |
|               |                | Production forest | Conditional      | 1910.95   |
|               | Moderate       | Plantation        | Unsuitable       | 158.62    |
|               |                | Paddy planting    | Unsuitable       | 24.62     |
|               |                | Field             | Unsuitable       | 37.71     |
|               |                | Settlement        | Unsuitable       | 3.78      |
|               |                | Production forest | Unsuitable       | 2023.77   |
|               | High           | Plantation        | Unsuitable       | 4682.72   |
|               | Conservatory Zone | Plantation     | Unsuitable       | 8195.26   |

Total Area
Based on the level of susceptibility illustrated above, it is apparent that the land use in Gunung sari is not all necessarily in accordance with its provisions. The appropriate land based on the analysis results in Gunung Sari is 1786.40 Ha or 22% of the total land, the conditional land area is 4032.49 Ha or 49% of total land, and the unsuitable land is 2376.36 Ha or 29% of the total land. Based on its function, the unsuitable land-use area covers approximately 2249.48 Ha and the largest area of conditional land use which is located in the conservation zone covers approximately 2433,24 Ha. A more detailed explanation will be described in the following map. Yellow represents the conditional land use, red illustrates the unsuitable land use and the green shows suitable land use as shown in Figure 4 and Figure 5.

Figure 4. Land Suitability Analysis in the function area

Figure 5. Percentage Land Suitability Analysis

Figure 6 explains the analysis of land suitability in cultivation area which is dominated by yellow, and that is a suitable land with 86% of the total cultivation area (Figure 7).

Figure 6. Land Suitability Analysis in Cultivation zone

Figure 7. Percentage Land Suitability Analysis in cultivation zone
The map in Figure 8 explains the analysis of the land suitability buffer area which is dominated by red and that is a conditional land with 92% of the total buffer area (Figure 9).

Figure 8. Land Suitability Analysis in the buffer zone

Figure 9. Percentage Land Suitability Analysis in buffer zone

Figure 10 explains the analysis of land suitability in the conservation zone. From the map shows red and blue are not much different in area, a red is a conditional land, and a blue is an unsuitable land, when seen in pie chat is dominated by conditional land with 52% while unsuitable land with 48% of the total area of the conservation area (Figure 11).

Figure 10. Land Suitability Analysis in the Conservation zone

Figure 11. Percentage Land Suitability Analysis in conservation zone

4. Conclusions

The dominant function of the area in Gunung Sari sub-district is a protected area with a percentage of 57% of the total area. Dominant land in the Gunung Sari sub-district has a moderate level of vulnerability with a percentage of 48% of the total area. Dominant land use in Gunung Sari is production forest, The largest unsuitable land is in the conservation area with 48% of the total area.
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