Vegetative conservation for landslide mitigation in bungaya sub-district, gowa regency, south sulawesi province

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Abstract. Landslides disaster that occurred in Indonesia has caused environmental damage and claimed many lives. Bungaya has a high risk of landslide threat and includes areas affected by severe landslides, so landslide mitigation needs to be done. Landslide mitigation is an effort to reduce the risk of landslides, which can be applied by doing soil conservation. This study aims to find out the spatial pattern of vegetative conservation to prevent landslides in Bungaya. Slope morphology and slope gradient variables used to determine the potential area of landslide, obtained from BIG in 2018 and processed by the SMORPH Method. Data of vegetative conservation variables obtained by observation and interview. Analysis that used is an overlay technique on landslide potential areas, land use, and location of landslides. The highest potential of the landslide, clustered in the southern part of Bungaya, and moderate to low potential is randomly scattered. The highest potential is in Rannaloe and the lowest in Bissoloro. In Bungaya, several types of soil conservation techniques have been carried out using the vegetative method, namely crop rotation of paddies and secondary crops. Besides, agroforestry techniques are also carried out, namely yard garden and talun-garden by planting annual crops and seasonal crops.

1. Introduction
Landslides are mass movements of soil, rocks, or materials that fall down the slope [1]. Landslides disaster that often occurs in Indonesia has caused severe environmental damage and claimed many lives [2]. One of the landslides disasters that caused severe damage occurred on January 22, 2019, in 13 districts/cities in South Sulawesi Province [3].

According to data from BNPB in 2014, in South Sulawesi Province, there were 19 districts/cities which included areas that had a high risk of landslide threat, and one of them was Gowa Regency [4]. In Gowa Regency, landslides disaster occurred in 34 points that spread across seven sub-districts, one of them is Bungaya Sub-district [3]. Bungaya Sub-district has a high risk of landslide threat and includes areas affected by severe landslides. According to WALHI of South Sulawesi Province in 2019, landslides that occurred in Bungaya Sub-district caused by poor management of natural resources and spatial planning and triggered by high rainfall [5].

Therefore, to reduce the risk of landslide threat, disaster mitigation needs to be done. Disaster mitigation is an effort to reduce disaster risk, both through physical development or awareness and enhancement of ability to face the threat of disaster [6]. Landslide mitigation that implemented can be based on community’s independence, such as increased alertness during the rainy season and covering the fracture on the ground level, and soil conservation (stabilization and protection of slopes) [2]. Soil conservation is the act of using land-based on its ability, and treat it to maintain land for still productive and not damaged, and optimal for an unlimited period [7].
The basic principle of soil conservation is to reduce the amount of soil loss due to erosion [7]. The vegetative method is one of the conservation efforts by planting various types of plants, that aims to reduce the rate of erosion and surface flow [8]. The function of that plant is to protect the soil against the impact of rainwater grains, protect the land against the destructive force of water flow above the surface, and improve water absorption by plants [9]. Conservation efforts using the vegetative method are an alternative to reduce or prevent landslides [10].

There are various techniques in the vegetative method, and two of them are crop rotation and agroforestry. Crop rotation is a system of planting multiple plants in rotation in a particular time sequence on one plot of land [11]. Agroforestry is a soil conservation effort that combines tree crops, or annual crops with other commodity crops that are planted together or alternately [9]. Vegetative conservation with crop rotation and agroforestry aims to reduce the potential for soil movement, which is the implementation of landslide mitigation [12].

To reduce the risk of landslide threats, a proper and sustainable disaster mitigation, and accurate information about the potential for landslides is needed. In this case, it is necessary to mapping landslide potential areas as one of the essential things to reduce the risk of landslides, that has been done by previous studies [1][4][14]. One of the ways to determine the potential area of landslide is by the SMORPH method. In the SMORPH method, slope morphology gradient/angle of the slope was used to identify the potential area of landslide [14]. Based on the results of processing landslide potential areas, furthermore, it can be known how the spatial pattern of vegetative conservation was carried out as an effort to prevent landslides in Bungaya Sub-district.

2. Methods

This research conducted in five villages/kelurahan in Bungaya Sub-district, which are Mangempang, Bontomanai, Sapaya, Bissoloro, and Jenebatu. Bungaya Sub-district is a mountain area that bordering the Manuju Sub-district in the North, in the South with Tompobulu Sub-district, in the West with Takalar Sub-district, and Bontolempangan Sub-district in the East [13]. Bungaya Sub-district is located at 5°17'43.7" - 5°26'14.4" south latitude and 119°35'06.5" - 119°42'27.8" east longitude. The variables that is used in this study are slope gradient, slope morphology, landslide potential area, and vegetative conservation.

2.1. Material

The primary and secondary data used in this study. The primary data in this study are the location of the landslides, vegetative conservation types, and types of plants used for vegetative conservation. Primary data were collected by conducting observations, interviews, questionnaires, and documentation studies which were analyzed descriptively. Determination of respondents done by sampling technique that is stratified random sampling. Determination of the sample based on this type of sampling technique based on the area with a low, medium, or high level of landslide potential. Secondary data that used is administrative boundary shapefile, DEM Nasional, and land use shapefile of Bungaya Sub-district that is sourced from Website of Badan Informasi Geospasial (BIG) in 2018.

2.2. Method

The method used to identify the potential area of landslide is the SMORPH method developed by [15]. The SMORPH method requires input parameters consisting of slope morphology and slope gradient [14]. By combining these two parameters, the SMORPH matrix formed by combining the slope gradient (in % units) and slope morphology (consists of concave, convex, and planar forms) [14]. The landslide potential classification using the SMORPH method based on the matrix between the slope gradient and the slope morphology that can be seen in Table 1 [15]. To process the landslide potential map, DEM Nasional data obtained from BIG in 2018 and processed using ArcGIS 10.4 software. The overlay results between slope gradient and slope morphology are classified based on the SMORPH matrix to produce a landslide potential map. Then, landslide potential map combined with land use. Analysis that used is an overlay technique on landslide potential areas, land use, and location of landslides.
Table 1. SMORPH Matrix

| Slope Morphology | Slope Gradient |
|------------------|---------------|
|                  | 0 – 15 %      | 15 – 25 %     | 25 – 45 %     | 45 – 65 %     | >65%          |
| Convex           | Low           | Low           | Low           | Low           | Moderate      |
| Planar           | Low           | Low           | Low           | Moderate      | High          |
| Concave          | Low           | Moderate      | High          | High          | High          |

Source: [15]

3. Results and Discussion

3.1. Landslide Potential Area

Based on the landslide potential map that has been obtained using the SMORPH Method, it can see that approximately half of the area of Bungaya Sub-district (52.21%) has a low potential of landslides, that can see in Figure 1 and Table 2. The leftover of it (47.79%) has a moderate to the high potential of landslides. The highest potential of landslides clustered in the southern part of Bungaya, and moderate to low potential is randomly scattered. The highest potential of landslides is in Rannaloe and the lowest potential in Bissochoro. Rannaloe has the highest potential of landslides because most of its area has a steep slope with a concave shape.

Table 2. Landslide Potential Area in Bungaya

| Potential | Area (km²) | Percentage (%) |
|-----------|------------|----------------|
| Low       | 106.59     | 52.21          |
| Moderate  | 48.53      | 23.78          |
| High      | 49.02      | 24.01          |

Figure 1. Map of Landslide Potential Area in Bungaya
3.2. Landslide Events in Bungaya Sub-district in 2019

On Tuesday, January 22, 2019, landslides disaster occurred in Bungaya Sub-district that was triggered by high rainfall that reached 110 mm/day accompanied by strong winds since Sunday, January 20, 2019, until Tuesday, January 22, 2019 [16] [17]. Landslides disaster have caused severe environmental damage and endanger people’s lives in Bungaya Sub-district. Based on the results of the survey, landslides that occurred scattered in many locations which caused resident’s settlements, buildings, agricultural and plantation land to buried by landslides and closed several road accesses in Bungaya Sub-district. The highest number of landslide events is spread extensively starting from Mangempang, Bontomanai, to Sapaya. Meanwhile, in Jenebatu and Bissoloro, landslide events are scattered randomly, and there are not as many as in Mangempang, Bontomanai, and Sapaya (Figure 2 and Figure 3).

In Mangempang (Figure 3a), paddy fields of 72.70 ha (7.86%) and plantation land of 74.38 ha (8.04%) damaged by landslides. In Bontomanai (Figure 3b), paddy fields of 117.97 ha (4.86%) and plantation land of 58.29 ha (2.40%) damaged by landslides. Next, in Bissoloro, paddy fields and plantation land were destroyed by landslides of 7 ha (0.26%) [17].

![Figure 2. Map of Location of Landslide in Bungaya](image1)

![Figure 3. Condition of Landslide Events in (a) Mangempang; (b) Bontomanai; (c) Sapaya](image2)

The most severe landslide area is in Mangempang (Figure 3a), Bontomanai (Figure 3b), and Sapaya (Figure 3c). The area of paddy fields and plantation land that were damaged by landslides in
Mangempang is 147.08 ha (15.90%), in Bontomanai is 176.26 ha (7.27%) and in Bissoloro is 7 ha (0.26%) [17]. The number of victims died in Sapaya are 20 people, in Mangempang 9 people, and one person in Bontomanai [17]. Based on the results of interviews with respondents, the impact of landslides that was quite severe in the three villages because of there is a lot of transition of forest land functions of 2258.04 ha (27.62%) into agricultural/plantation of 1290.75 ha (15.79%) and settlements of 66.02 ha (0.81%), so that the potential for landslides will be even higher. The amount of landslide events in Jenebatu and Bissoloro is not as much as in Mangempang, Bontomanai, and Sapaya, because in Jenebatu and Bissoloro has only a few settlements of 10.68 ha (0.25%), and most of the area dominated by forests of 2446.39 ha (57.07%), plantation land 1.47 ha (0.03%), and agricultural land 558.84 ha (13.04%).

3.3. Soil Conservation with Vegetative Methods

Bungaya Sub-district has a high risk of landslide threat and includes areas affected by severe landslides. So, to reduce the risk of landslide threat, disaster mitigation needs to be done. Landslide mitigation that implemented can be base on the community’s independence, such as doing soil conservation. The implementation of soil conservation is carried out by the vegetative method, which can be do by planting various types of plants, that aims to reduce the rate of erosion and surface flow [8]. In Bungaya Sub-district, which are in Mangempang, Bontomanai, Sapaya, Bissoloro, and Jenebatu several soil conservation techniques with the vegetative method done by crop rotation and agroforestry.

3.3.1. Crop Rotation. Crop rotation is a system of planting various plants in rotation in a particular time sequence on one plot of land [11]. The purpose of rotating planting systems is to prevent erosion, maintain soil fertility, and increase crop production [11]. In Mangempang, Bontomanai, Sapaya, Bissoloro, and Jenebatu, crop rotation is carried out by planting paddy (Figure 4), corn (Figure 5), soybean, peanut, cassava or sweet potato on a plot of land that planted alternately.

Based on the results of interviews with respondents, the planting period for paddies (Figure 4) is carried out twice a year. The first planting period starts from November to January, and then paddy can be harvested in March. The second planting period begins from April to June, and then paddy can be harvested from July to August. If paddies have collected, the crop rotation will be carried out on that land by planting other seasonal crops such as corn, soybean, peanut, cassava, or sweet potato. In cornfields (Figure 5), the planting period for corn is carried out twice a year too. The planting period of corn starts in April and November. After about two months after the period time of planting, corn can be harvest. Usually, around October when Bungaya Sub-district is having a dry season, because of water availability is slightly, then the agricultural land is used for planting peanuts.

Based on the results of interviews with respondents, most of the agricultural land and plantation land that is buried by landslide material for 3 to 6 months are still left behind or not planted with crops, and this aims to restore the soil's fertility. After the land has been left behind for some time, if the land is considered to be able to plant with crops, then the land will be replanted with certain crops. Some of the former landslides area in Sapaya (Figure 6a), Mangempang (Figure 6b), and Bontomanai (Figure 6c) has been reuse for corn plants.

Based on the results of the interview with Sapaya’s Village Chief, in several recent landslides area in Sapaya, mahogany trees were also planted, as an effort to prevent landslides. Mahogany tree
(Swietenia macrophylla) is a plant that has the height from 5 - 40 meters with a diameter that reaches until 120 cm [18]. Mahogany trees can survive on dry land, and even if it doesn't rain for months, mahogany still able to survive [18]. Location requirements for mahogany growth include a maximum land height of 1.500 masl, rainfall of 1.500 - 5.000 mm/year, and the temperature is 11°C - 36°C [19]. Mahogany trees can live up to yearly, and not easy to attack by pests or diseases [18]. Mahogany trees have strong roots and can hold the soil from erosion or landslides so that the soil will be stable [20].

Figure 6. Corn Planted in Former Landslides Area in (a) Sapaya; (b) Mangempang; (c) Bontomanai

3.3.2. Agroforestry. Agroforestry is a soil conservation effort that combines tree crops, or annual crops with other commodity crops that are planted together or alternately [9]. Agroforestry intentionally planted on the same land with seasonal plants or animals, which is spatially arranged or in temporal order [11]. There are various techniques in agroforestry, in Mangempang, Bontomanai, Sapaya, Bissoloro, and Jenebatu in Bungaya Sub-district, in the form of yard garden and talun-garden.

Yard garden is mixed gardens that consist of irregular mixtures of annual crops that produce fruits and vegetables and seasonal crops that located around the house [11]. Talun-garden is a traditional agroforestry system where a plot of land planted with various types of plants that are spatially arranged and temporal sequence [11]. In talun-garden, the dominant plants are annual crops, but among annual crops, there are also various types of low plants or seasonal crops [11].

Yard garden and talun-garden can prevent erosion well because the land covers conditions is tight so that the rainwater does not directly hit the surface of the ground so that the surface flow rate can reduce [8]. The yard garden and talun-garden in Mangempang, Bontomanai, Sapaya, Bissoloro (Figure 7a), and Jenebatu (Figure 7b) planted with annual crops such as coffee, cacao, coconut, cloves, cashew, candlenut, kapok, and seasonal crops such as corn.

Figure 7. Talun-garden in (a) Bissoloro; (b) Jenebatu

Based on the results of interviews with respondents, annual crops that planted in Mangempang, Bontomanai, Sapaya, Bissoloro, and Jenebatu dominated by cacao and coffee. Cacao plants start to bear fruit when they reach the age of around 2.5 - 3 years [21]. In the first year, the amount of cacao fruit production is not much, but fruit production will continue to increase as cacao gets older [21]. Optimal
productivity of cacao is achieved at the age of 7 - 11 years, but productivity will continue to decrease until the plants become older and die [21]. The process of pollination until the cacao fruit is mature and ready to be picked, takes around 5 to 6 months [21]. The type of coffee that planted in Mangempang, Bontomanai, Sapaya, Bissoloro, and Jenebatu (Figure 8) is robusta coffee. Robusta coffee starts to produce its fruit at the age of 2.5 – 3 years [22]. The productivity of robusta coffee starts to increase maximally after reaching its age of 5 years above [22]. Robusta coffee takes 8 - 11 months from the bud until the seeds are mature and can be harvested [22]. Based on the results of interviews with respondents, in Jenebatu usually, coffee can be collected from May to June. However, in other villages besides Jenebatu, coffee can be obtained in August.

4. Conclusion
The results of the landslide potential map processing using the SMORPH Method show that approximately half of the area of Bungaya Sub-distriict (52.21%) has a low potential of landslides, and leftover of it (47.79%) has a moderate to the high potential of landslides. The highest potential of landslides is clustered in the southern part of Bungaya Sub-district, which is in Rannaloe, meanwhile moderate to low potential is randomly scattered, with the lowest potential is in Bissoloro. Landslides that occurred caused by poor management of natural resources and spatial planning and triggered by high rainfall, so it created the most severe landslide area in Mangempang, Bontomanai, and Sapaya.

The most severe landslide in those three villages happened because there is a lot of transition of forest land functions into agricultural/plantation land and settlements. The risk of landslide threat can reduce by doing landslide mitigation, which can be applied by doing soil conservation with the vegetative method. In Bungaya Sub-district, the technique is carried out by crop rotation and agroforestry. Crop rotation is carried out by planting paddy, corn, soybean, peanut, cassava or sweet potato on a plot of land alternately. Agroforestry is carried out in the form of yard garden and talun-garden, that planted with annual crops such as coffee, cacao, coconut, cloves, cashew, candlenut, kapok, and seasonal crops such as corn.

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