Vegetative conservation of landslide prone areas in the Cidadap Watershed Area, Sukabumi Regency

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Abstract. The sub-district of Cidadap has a high level of vulnerability to landslides, with a characteristic slope of more than 25% and is overgrown with vegetation. This study aims to identify the effect of changes in land use with vegetative conservation methods that have been carried out in landslide-prone areas in Cidadap watershed. The method used in this research is the Storie Index method. Temporal analysis was carried out on changes in land cover in 1999 and 2019, while spatial analysis was carried out on landslide-prone areas, as well as soil conservation that had been carried out. In this study, there are five variables, namely rainfall, land cover, slope, soil type, and location of landslides. Conservation identification is carried out by overlaying between vegetative conservation and the distribution of landslide-prone areas in the study area. The results of this study indicate that in 1999–2019, land use in the form of settlements and moor/fields has increased. Whereas for the land use class, the types of water bodies, forests, gardens, rice fields, shrubs and empty land decreased. In 1999–2019, Cidadap watershed was dominated by a moderate landslide hazard level with an area of 10,080.49 Ha or 84.92% of the area of the Cidadap watershed. The conservation that has been carried out in Cidadap watershed uses several combinations of vegetative conservation techniques, namely crop rotation, crop and agroforestry, and agroforestry rotation.

Keywords: Cidadap watershed, landslides, storie index, vegetative conservation

1. Introduction
Landslides can occur due to static factors (slope) and dynamic factors (land use) [1-2]. In the research area based on the occurrence of landslides that have occurred, preventive efforts can be made to reduce landslides. One of these efforts can be done by mitigating landslides [3-5]. This mitigation can be in the form of a landslide-prone area mapping carried out by utilizing the Geographical Information System (GIS) using the Storie Index method [6, 7]. Soil conservation is closely related to the conditions of the slopes where landslides occur. In conditions of slope stabilization, it is generally carried out on a slope in a land using the vegetative method [8-10].

In this study, Cidadap watershed is one of Cimandiri watershed in Sukabumi Regency which was chosen as the research area, where on January 2018 there was a landslide disaster in Cidadap Village which resulted in the closure of a number of road accesses, as well as a number of semi-permanent house damage. This is caused by high rainfall intensity [11]. In this study, the Index Storie method is used to determine the level of landslide risk in an area with the physical variables of a phenomenon with the weight of each variable [7, 12, 13]. This study uses dynamic land use data in 1999 and 2019 which can
provide a temporal analysis, as well as with the Stories Index method to provide a spatial analysis of the distribution of landslide-prone areas. Vegetative conservation mapping in landslide-prone areas in 2019, was built based on data on landslide prone areas and vegetative conservation in 2019. By mapping vegetative conservation in landslide-prone areas in 2019, it is hoped that this research can inform about vegetative conservation as landslide mitigation for conservation evaluation of vegetative in further research in Cidadap watershed.

2. Methodology
This research was conducted in the sub-district of Cidadap, which is located on the coast of Palabuhanratu Bay, Sukabumi Regency. The land use data used are 1999 and 2019. This data is used for temporal analysis of dynamic land use change. Then to map landslide prone areas using five variables: land use, slope, rainfall, soil type, and landslide locations. To reduce the occurrence of landslides, disaster mitigation is carried out. One of the landslides mitigations that can be applied is the conservation method with vegetative conservation. Based on the mapping of landslide prone areas and land use in 2019, it can provide an analysis of soil conservation carried out in landslide-prone areas in the Cidadap watershed.

2.1. Data collection
This research was conducted with visual interpretation through the interpretation of the Cidadap Topographic Map of the Geospatial Information Agency (BIG) at a scale of 1:25,000 sheets 1208–433 in 2000 and digitizing CNES Airbus images from Google Earth to create land use maps for 1999 and 2019. Map of slope originating from the Alasca Satellite Facility in the form of a DEM (Digital Elevation Model) with slope tools; annual rainfall data originating from Cisadea-Cibareno Watershed Office (BBWS) in 2005–2019, is made based on tabular daily rainfall data which is then processed into an annual rainfall map using Thiessen's tools; soil type map from BIG in 2013; which is then processed to obtain a landslide-prone map. This variable uses the Storie Index method for mapping landslide-prone areas in 1999 and 2019. Furthermore, field survey data are used to validate the location of landslides and soil conservation. Soil conservation methods obtained from the results of field observations will create a vegetative soil conservation map in 2019. Vegetative conservation mapping in landslide-prone areas in 2019, built based on an overlay on landslide-prone area data and vegetative conservation in 2019, is used as the basis for analysis of the distribution of conservation vegetative area in landslide prone areas.

2.2. Landslide-prone area models
In this study, the Storie Index Method was used for processing landslide data which produced a map of landslide-prone areas in Cidadap watershed area. The level of landslide-prone areas in Cidadap watershed area consists of 3 classes: low, moderate (prone), and high (very vulnerable).

2.2.1. Storie Index. The Storie Index method is one of the semi-quantitative methods for assessing (rating) land [12]. To determine landslide-prone areas using the Storie Index method, the parameters used are given a grade or score first, then the analysis weight is calculated for all the parameters used [3]. In its development, the Storie method can also be used to study landslides, with a function of several parameters of the factors causing landslides, including climate (rainfall), topography (slope), vegetation (land use), soil (soil type), and conservation (land management) [14]. The use of the Storie Index Method can be carried out using the following parameters [15],

\[ L = \frac{A \times B}{10} \times \frac{C}{10} \times \frac{D}{10} \times \frac{E}{10} \ldots \]

where: \( L \) = Land movement potential, \( C \) = Rocks type, \( A \) = Land use, \( D \) = Rainfall, \( B \) = Slope, \( E \) = Fault buffer/distance from fault
Table 1. Storie Index classification of landslide prone

| Rainfall intensity | Landuse | Slope gradient | Soil type | Score of class | Classification     |
|-------------------|---------|----------------|-----------|----------------|-------------------|
| 1                 | 1       | 1              | 1         | \(< 0.001\)    | Not Prone         |
| 2                 | 2       | 2              | 2         | \(0.001–0.016\)| Low               |
| 3                 | 3       | 3              | 3         | \(0.016–0.081\)| Moderate (Prone)  |
| 4                 | 4       | 4              | 4         | \(0.081–0.256\)| High (Very vulnerable) |
| 4                 | 5       | 5              | 5         | \(> 0.256\)    |                   |
| 4                 | 5       | 6              | 6         | \(> 0.256\)    |                   |

Source: Modified from [13]

Table 1 shows the classification for potential land movement using the Storie Index method.

2.3. Vegetative conservation model data processing

The vegetative conservation method is obtained from the results of field observations which will produce a vegetative conservation map in 2019. The results of processing landslide-prone areas, maps of dense forest and plantation land use, and types of vegetative conservation obtained from field surveys are used as a reference in making vegetative conservation maps. The vegetative conservation map is obtained by overlaying the landslide-prone area map and the dense forest and agricultural land use map processed using ArcGIS 10.4 software. Landslide-prone area maps that are overlaid with dense forest and plantation land use will result in landslide-prone areas found in dense forest and plantation lands. Then, based on the classification of landslide-prone (not prone, low, medium, and high), it will be seen how the types of vegetative conservation carried out on dense forest lands and plantations that are prone to landslides will then be made into a vegetative conservation map.

3. Results and discussion

3.1. Land use changes analysis Cidadap Watershed Area in 1999 and 2019

Based on figure 1, it shows that the land use for shrub species has been expanding every year, it can be seen that the Central and Northern parts of the study area are dominated by shrubs. This is because the area has a steep and mountainous topography, causing the area to be used as an area for vegetation growth, such as conservation and natural areas [16]. Then, it can be seen that in the western part of the research area, the dominant land use types are rice fields adjacent to settlements and moor/fields. This is because in the west area Cidadap watershed is directly adjacent to Palabuhanratu Bay, where the type of land use for rice fields is found in coastal areas because it is located in a sloping area.

Landslide prone areas in Cidadap watershed area using the Storie Index method with variables of land use, slope, soil type, and rainfall. Data processing on these four variables resulted in landslide prone areas in the Cidadap watershed area. In this study using land use data in 1999 and 2019, it is adjusted by the year used to analysis changes in land use in the study area. Based on data processing carried out in the study area, it produces three levels of landslide-prone, namely low, medium, and high.

Based on figure 2, it can be seen that the landslide-prone levels in 1999 and 2019 in the Cidadap sub-district were dominated by moderate landslide-prone levels. During 1999 to 2019, the level of landslide prone is low and is experiencing a wide increase every year. Meanwhile, the high landslide-prone area has decreased every year. The level of landslide prone is increasing every year, because the area of residential land is increasing, while the area of forest, plantation and agricultural land is decreasing, there is also a shift in the use of plantation land to moor.
Figure 1. Land use maps for 1999 and 2019 in Cidadap Watershed Area. Source: Data Processing, 2020

Figure 2. (a) Landslide prone map, and (b) landslide prone levels for 1999 and 2019. Source: Data Processing, 2020
The increasing area of residential land can affect the level of landslide-prone, especially if the land use is in an area with a fairly steep slope [17]. The high landslide-prone area in Cidadap, it is dominated by slopes between 8–65 %, this includes a steep slope. One of the factors that can cause landslides in an area is a fairly steep slope, so that it can affect the high level of landslide-prone [18]. In areas with steep slopes, there has been a decrease in the area of plantation, agricultural and forest land. This results in reduced land cover in the form of plants on slopes which can reduce the rate of water surface at the surface, as well as a soil binder.

Low-prone areas are on the slope between 2–45 % with yellowish brown latosol soil types. This type of soil has high soil moisture, so it can make the soil able to absorb and store water properly to reduce surface runoff that can trigger landslides. With a slope that is not steep and yellowish-brown latosol soil type which has the greatest soil moisture causes the southernmost part of the study area to have a low level of landslide prone. Then in the type of land use shrubs become dense forests and plantations. Likewise in Mekarasih village, there was a change in land use from dry fields/fields to rice fields.

High prone areas are mostly found on slopes between 8–15 % with rainfall > 3,000 mm/year, as well as with the Mediterranean Complex type of Reddish Brown and Lithosol, and the Association of Gray-Brown and Gray-Brown Alluvial. Alluvial soil types can be found in rivers, beaches and basins. This is in line with the characteristics of alluvial soil types in the northern part of the study area. Farming and plantations are carried out by the community on hilly slopes which were originally water infiltration forests, then converted to agricultural land, while rice fields are widely used by the community, which are alluvial types of land located under hills. Some people build residential houses on a fairly steep slope, so that these conditions can disturb the stability of the slopes [19, 20]. Then, the reddish brown and lithosol Mediterranean complex types have characteristics of low to medium productivity, a loam to loamy texture, and a sensitivity to landslides which is quite sensitive with moderate permeability. With the use of inappropriate land types (moor/fields), right on a fairly steep slope (15–45 %) and in high rainfall. The use of dry land/fields that are used for planting fiber roots, on steep slopes, with high rainfall can cause the northern part of the study area to be included in a high landslide prone area.

3.2. Level of vulnerability of land movement

3.2.1. Vegetative conservation methods as landslide mitigation in Cidadap watershed area. Implementation of landslide disaster mitigation with vegetative methods that are applied independently by the community (figure 3) [21]. Landslide control by applying vegetative methods can provide protection for the soil surface due to falling rain and reduce the amount and flow power that can damage

![Figure 2 (continued).](image-url)
the soil surface [22, 23]. The vegetative conservation method applied by the community to mitigate landslides based on field surveys is by rotating crops and agroforestry.

From a soil conservation perspective, crop rotation can provide an opportunity to maintain soil cover, as a second crop is planted after the first crop has been harvested (figure 4). The method of vegetative conservation carried out in Cidadap watershed by rotating the plant is rice-secondary crops. Rice can be harvested in March. The rice-secondary crop rotation is carried out after the harvest period in Cidadap watershed. Cidadap watershed has a type of secondary crop which is planted after the rice harvest period, the secondary crops planted are sweet potato, maize, soybeans, and peanuts. This is done so that throughout the year it can maintain land cover.

![Figure 3. Vegetative conservation methods as landslide mitigation in Cidadap Watershed Area. Source: Data Processing, 2020](image)

![Figure 4. Crop rotation system in Cidadap Watershed Area. Source: Field Survey, 2020](image)
Vegetative techniques as well as a form of landslide adaptation and mitigation through increasing sustainable land production are known as agroforestry systems [24]. In the agroforestry system applied in Cidadap watershed area, there are *talun* gardens, mixed gardens, and yard systems. The three systems can be seen in figure 5, the Cidadap watershed is planted with annual crops such as rice and annual crops such as bananas, papayas, acacia, and coconut.

3.2.2. Vegetative conservation in landslide prone areas. Vegetative conservation in landslide prone areas was obtained through an overlay of information on vegetative conservation maps for 2019 and maps of landslide prone areas in 2019. Conservation that has been carried out by the community in the Cidadap watershed area consists of three combinations, namely crop rotation, crop rotation and agroforestry, and agroforestry. The vegetative conservation method that dominates the three classes of landslide-prone areas is agroforestry. The category of vegetative conservation with agroforestry is mostly done by the community, this can be due to the fact that agroforestry conservation is one of the easy independent conservation for the community. In addition, a vegetative conservation category that is rarely found in landslide prone areas in Cidadap watershed area is a combination of crop rotation and agroforestry methods (figure 6).

**Figure 5.** (a) Talun gardens system; (b) Mixed gardens system; (c) Yard systems.
Source: Field Survey, 2020

**Figure 6.** Vegetative conservation in landslide prone areas.
Source: Processing, 2020
Efforts made by local communities in high landslide prone areas in 2019, that in the middle of the research area in 1999 had a high landslide-prone level, which then turned into a moderate landslide-prone level by carrying out vegetative conservation efforts of crop rotation systems with rice harvests and the palawija crops planted are sweet potatoes, corn, soybeans, and peanuts. High ground cover crops in the area are found on slopes that are quite steep, 8% until > 45%, such as bananas and teak. High ground cover crops are usually used in regular cropping patterns between main crop rows, planted in rows, and used for cliff protection and reforestation.

The low landslide-prone level in 1999 which was in the southern part of the study area, where in 2019 after conservation in the form of agroforestry did not change the level of landslide prone on slopes > 65% with land use in the form of Yellowish Brown Latosol. This type of soil is a type of soil that is generally located in wavy to mountainous landforms, has a crumb texture to weak lumps, and a moderate to fast permeability level. This type of soil is not very sensitive to soil movements, but if it is triggered by high intensity rainfall, it can trigger soil movements that cause landslides. The danger of landslides will increase if the mountainous land which was originally covered by forest is cleared to become a seasonal crop farming area which does not apply soil conservation that is not in accordance with its purpose.

In areas prone to landslides with a high level of vulnerability, where in 1999 and 2019 the western part of the study area was included in areas that implemented vegetative conservation with agroforestry systems. Conservation that has been carried out in 2019 does not show changes in areas with high landslide-prone areas in the western part of the Cidadap sub-district. This is because the land use that are still widely found are moor/fields, rice fields, and settlements. The area is located on a fairly steep slope (8% until < 45%) with rainfall > 3,000 mm/year and soil types in the form of the Reddish Brown Mediterranean Complex and Litosol. This type of soil has a high enough infiltration, this can reduce the surface flow rate which will erode soil particles [25]. The absorption of water into the soil results in a high water content and can cause the soil to become saturated and stretch the particles between the soil, which can trigger the soil to move outward and cause landslides [7].

4. Conclusion
Based on the Storie Index method, landslide prone areas in the Cidadap watershed produce three levels of landslide-prone, namely low, medium and high. Landslide mitigation was carried out by the vegetative method in the Cidadap watershed, which was divided into three categories, namely crop rotation, crop and agroforestry and agroforestry rotation. On forest lands that are prone to low to high landslides, agroforestry conservation methods are used. On plantation lands that are prone to low to moderate landslides, a crop rotation conservation method is used. Then, for medium to high plantation land, two combinations of conservation methods were carried out, namely crop rotation and agroforestry. The type of use of dry land, rice fields, and plantations affects the level of landslide prone in the Cidadap watershed.

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