Plants Suitability for Landslides Mitigation in the Giritengah Catchment Area, Indonesia

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Abstract. Changes in land use caused by human dependence on land to meet food, clothing, and settlement needs are in line with population growth. This triggers the destruction of watersheds and results in an increased of disasters such as landslides that lead to decrease land productivity and less water throughout the year. This study aims to determine the plant suitability for both annual plant species (forestry plants), and seasonal crops (agricultural crops) in the Giritengah catchment area. In addition, this study also aims to provide the proposed species that are suitable and at the same time allow for land improvement efforts. The results showed that the suitability classes for forestry plant species (teak, sengon, and mahogany) and annual plant species (chili, banana, and cassava) in Giritengah catchment were unsuitable/incompatible (N) with erosion hazard level as the heaviest limiting factor. There are two variable levels of erosion hazard, which are one of the reasons for the unsuitability of these plant species, namely the slope, which tends to be steep and the shallow soil solumn. To overcome this, it is necessary to apply soil and water conservation techniques both technically and vegetative.

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1 Introduction

In general, land use change usually is not followed by land degradation management techniques. Changes in land use are the result of human dependence on land to meet food, clothing, and shelter needs in line with population growth. The lack of balance between human activities in land use causes the watershed balance disrupted. This triggers the destruction of watersheds (DAS) and results in an increase in disasters such as landslides.

Land suitability is the suitability of a particular land type for a particular use. The process of land suitability classification is the assessment and grouping of certain areas of land in terms of their suitability for a specified use (FAO Framework, 1976). The prerequisite for land use planning is land suitability assessment (Akinci et al., 2013). Ahmadi et al. (2017) concluded that the findings of this study clearly show the suitability of land for industrial development, agriculture, tourism land use and can be the basis for planning the future development of the island based on ecological sustainability.

The topography of the Giritengah catchment is a hilly to mountainous area with relatively steep slopes. According to Paimin et al., (2009) landslides can occur under conditions of steep slopes, where there is a watertight sliding surface beneath the soil mass, and the soil mass became saturated with water. So that the condition of the land in the Giritengah catchment has the potential for landslides.

Tukiye, et.al, (2023) states that the impact of land use, especially agricultural productivity and climate change, requires a better solution for handling the movement of nutrients or nutrients and sediment in a land. Therefore, proper land use planning, such as afforestation, and water management strategies are climate resilience, such as water harvesting, will be very important to manage the risks associated with climate change and rapid land use change (Mengistu, et.al. 2023).

According to Nugroho et al. (2022) the landslide susceptibility factor can be analysed from the physical condition and management of the area concerned. Physical conditions include rainfall conditions, slopes, and geological conditions such as rocks or whether there are faults or faults. While management conditions include the type of land use or land use, settlements, and infrastructure. According to Aldrian et al., (2009) the form of handling landslides can be in the form of mitigation actions and early warning. One form of mitigation is by means of an ecological approach (vegetative/bioengineering). Mitigation by vegetative means is the use of plants to prevent landslides. Bioengineering has the same meaning but it combined with engineering techniques. The role of vegetation is to stabilize slopes (Riyanto, 2016). Plants with their typologies, namely crowns and roots, have an important role in preventing or eliminating landslides. We expect the vegetation with its wide distribution, diverse structure and composition to be able to provide great benefits and play a role in interception, evapotranspiration, infiltration, soil moisture, and others.

Selection of plant species is an important key in the success of vegetative control and handling of landslides. The selection of species based on the height where the tree grows. Selection of plant species needs to consider both the short and long term (Munawaroh, 2008). One of the weaknesses of agroforestry practices in various regions in Indonesia is that most of them are not land suitability based analysis, resulting in non-optimal production (Butarbutar, et al., 2017). So that the selection of species does not only pay attention to one ecological side, but also the economic side for the community.

Land evaluation is the process of estimating land suitability classes and land potency uses, both for agriculture and non-agriculture (Djaenudin et al., 2000 in Muhamad Yusuf Hidayat, 2006). Land evaluation is a process of assessing land resources to achieve for a specific purpose using a tested approach or method.

2 Method

2.1 Place and time of research

The location of this research was in the Giritengah Water Catchment Area (DTA), which is administratively located entirely in Giritengah Village, Borobudur District, and Magelang Regency in April - June 2022.

2.2 Tools and Research Material

The tools and materials used in the research include survey purposes, observation of land expanses and plant observation, and laboratory analysis. Tools and materials used for survey activities include Global Positioning System (GPS), Clinometer, Digital Camera, Pedological Hammer, Dodos, Pacul, Shovel, Boardlist, Plastic Clip, Meter, Hammer for Sample Ring, Sample Ring, Rope, Soil Drill, and Munsell Soil Color Chart (CC).

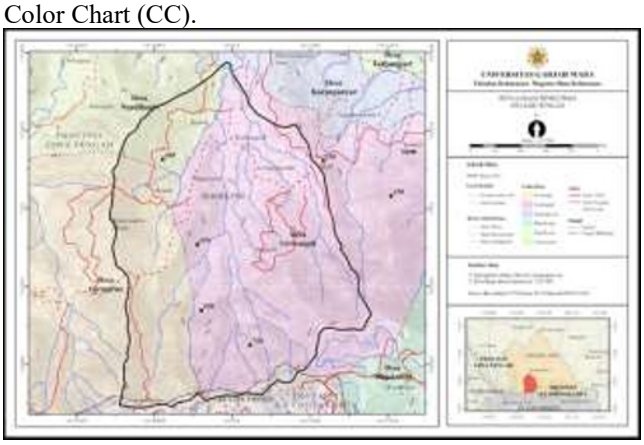

Fig. 1. Study area

2.3. Observation and Data Collection

Primary data obtained from survey data collection including soil sampling, data collection on plant species, interviews with local communities, actual land use, and laboratory results. Primary data collected during the survey included data and criteria for matching in land suitability assessments.

The secondary data collected is data on land maps, climate data and land use maps collected from the agencies holding each data guardian. We compiled the land suitability and table assessment for plants from various literatures.

2.4. Processing and analysis of data

The data analysis method used in this study utilizes the concept of evaluation and land suitability to assess the type of vegetation that is suitable for dealing with landslides that often occur in the study area. To analyse land suitability classification by referring to FAO framework (1976). The structure of land suitability classification distinguished according to its level, namely the level of Order, Class, Subclass, and Unit. The order itself is the state of global land suitability. At this level, land suitability is distinguished between land that is classified as suitable (S = Suitable) and land that is not suitable (N = Not Suitable).

The arrangement of land characteristics to evaluate suitability in this study grouped into three main factors to be able to present in detail the results of the formation of soil map units. The main factors in supporting the research process are topography, soil, and climate. After the data and information are obtained, the activities carried out are analysing and evaluating the land using different approaches such as multiplication of parameters, parameter sum systems, and matching systems between land quality and land characteristics with plant growth requirements.

Explanation Subclass is the state of the level in the land suitability class. Land suitability classes are divided into subclasses based on land quality and characteristics (soil properties and other physical environment) which are the heaviest limiting factors, for example Subclass S3rc, according to marginal suitability with limiting rooting conditions (rc = rooting condition). The level in the land suitability is in subclass and additional characteristics that affect its management based.

3 Result and discussion

3.1 Land characteristics

Land characteristics are a combination of several characteristics of the land and its environment. Land characteristics are described in each soil map unit (SPT) of the soil map, which includes the shape of the area or slope, soil drainage, soil depth, soil texture, soil pH, clay CEC, salinity, pyrite content, flood inundation and surface outcrops (rock outcrops)). The climate consists of rainfall and the number of dry months. The results of the arrangement of land characteristics are 27 land units Figure 3).

In accordance with the modification of Arsyad (2010) that the characteristics of the identifying land in the classification of land capability are inhibiting factors that are permanent or difficult to change. Soil texture in the Giritengah catchment area classified as fine with a slightly neutral pH, medium CEC and high KB in the karts hills and rather fine with slightly acidic pH, high CEC, and low KB in the volcanic hills. The fine-textured class consists of dusty clays and clays,

While the rather fine class includes clay loam, sandy clay loam. Some land units are also somewhat rough with a clay texture. In general, in all land units, the root media is well drained. An indication of good drainage is that the soil has good air circulation. The entire soil profile from the top to the bottom layer is a light color that has no manure.

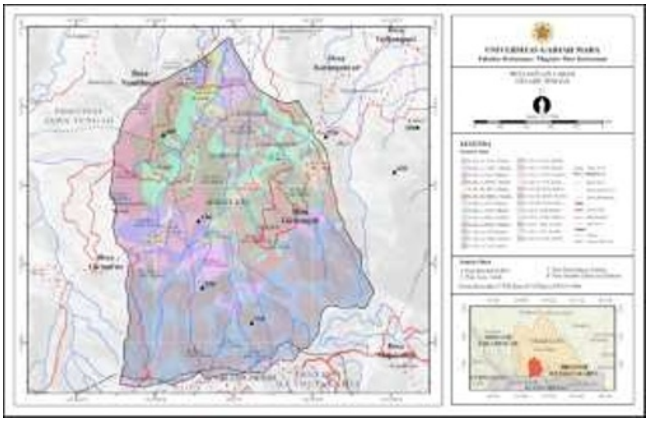

Fig 2. Map of Giri Tengah land unit.

3.2 Suitability of Forest Plant Type

The results of the assessment are in the form of land suitability classes and subclasses of the assessed plants determined by the heaviest limiting factor. These limiting factors may consist of one or more depending on the characteristics of the land. The types of forestry plants that dominate and spread over 27 land units are sengon, mahogany and teak. For all land units the three types are not suitable (N2) where for sengon and mahogany the limiting factors are rooting media, nutrient availability, and land slope. As for teak, the limiting factor is the availability of water.

The results of the matching analysis of sengon type plants in the Giritengah DTA show that for land units 1, 2, 3, 4, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, and 26 are N2 with a limiting factor heaviest, namely rooting media (r), nutrient availability (n) and erosion hazard level (e). Whereas for land units 5,6,7,8,19,20,21,22,23,24,25 and 27 the land suitability class is N2, namely the root medium (r), and nutrient availability (e).

The results of the suitability assessment of mahogany plants for all land units, the land suitability value is N2 with the limiting factors of root media (r), nutrient availability (n), and erosion hazard level (e). In terms of rooting media parameters, the main obstacle is the effective depth character (< 50 cm). In general,

mahogany plants grow well and optimally in fertile soil. Based on the rainfall characteristics, the suitability class is S1. In a sense, even though the rainfall is only 2393 mm per year, it turns out that mahogany is able to survive in arid land. The soil texture dominated by clayey clay so that it is included in the suitability class S1 and S2. There has never been a pool of water, so actually mahogany is still suitable for living on the land.

Teak growing in the Giritengah catchment has land suitability classes S3 to N2 with the heaviest limiting factor being the availability of slope water with a very severe erosion hazard. However, sometimes the limitations on water availability can change because every year high or low rainfall can change according to climate phenomena.

3.3. Land Suitability Analysis for Seasonal Plants

Chili plants in the Giritengah catchment are in the land suitability class S3 to N2 with the heaviest limiting factors being root conditions and the level of erosion hazard. Of the 27 land units, only land unit number 24 fits the S3 class (according to marginal). This land has large boundaries, but conditions improved to reduce the risk of erosion that results in loss of top soil so that the nutrients in the top soil are depleted thereby reducing production or profits.

Suitability class of banana plant species is not suitable (N1 and N2) with the weighting factors being the effective depth/solumn (r), and the level of erosion hazard (e). The suitability of sweet potato species was also in the non-conforming suitability class (N1 and N2). The weighting factors in the suitability class for sweet potato species in the Giritengah watershed are the effective depth (solumn) and the level of erosion hazard.

3.4. Constraints and Efforts to Develop Plant Cultivation in DTA Giritengah

Land use planning requires evaluation of land suitability to reduce the risk of failure and increase the economic value of the land. Land suitability needs to pay attention to the characteristics of plants because plants have different growing requirements and different characteristics to produce optimally (Saputra et al., 2021). From the results of the matching analysis on annual plant species (sengon, mahogany, and teak) and seasonal crops (chili, banana, sweet potato) there are various obstacles. To overcome the various limiting factors, it is necessary to do handling efforts. For the chat for the development of forestry plant cultivation and food crops served in the following table.

Table 3.1 Constraints solution for plants

Nu	Plants	Constraints	Land unit	Proposed penanganan
1	Sengon	- Root media system, - Nutrient availability, - Slopes or erosion hazards	1,2,3,4,9,10,11,12,13,14,15,16,17,18,26	- Intercropping planting pattern with crops - Implement the use of fertilizers, pesticides, herbicides, fungicides in doses that are balanced with nutrient losses - Planting in strips according to contour lines and/or field strips if the slope is irregular.
	Sengon	- Root media system, - Nutrient availability	5,6,7,8,19,20,21,22,23,24,25,27	- Intercropping planting patterns with crops - Implement the use of fertilizers, pesticides, herbicides, fungicides in doses that are balanced with nutrient losses.
2	Mahagony	- Root media system, - Nutrient availability, - Slopes or erosion hazards	1-27	- cropping in buffer strips (buffer strip cropping) consisting of grasses or Leguminosae made between staple crops - ground cover planting - application of compost, manure, and other organic materials. - Inter cropping with short rotation crops that have similar growing characteristics.
3	Teak	- Water availability - Slopes - Erosion hazard	1-27	- Inter-cropping with short rotationof crops that have similar growing characteristics.
4	Chilli	- Water availability - Root media system - Erosion hazard	1-27	- Inter-cropping with short rotation of crops that have similar growing characteristics.
5	Banana	- Root media system - slopes - Erosion hazard		- Addition of compost, manure, and other organic materials. - Making terraces or planting parallel to the contour
6	Sweet potatoes	- Water availability - Root media system - Slopes - Erosion hazard		Making ditches or waterways and adding organic matter

The matching results for woody plants and annuals show that the dominant limiting factor for suitability is the root media, especially the thickness of the solumn or the effective depth of the soil and the level of erosion hazard. The soil solumn in the Giritengah catchment is thin, if the level of erosion hazard tends to be severe, the loss of fertile soil in the topmost layer will also be higher. Naturally, the displacement of surface material is a result of the physical forces of water or wind or due to agricultural activities (Nugroho, et.al, 2022). The suitability class of each plant is largely determined by the limiting factor of the

level of erosion hazard. Based on the Universal Soil Loss Equation (USLE) formula (Wischmeier and Smith, 1978) the parameters used to obtain the amount of erosion per year are the rain erosivity factor (from rain intensity), soil erodibility factor, slope slope factor, crop factor (soil use) and soil conservation engineering factors. Land with a relatively flat level of erosion hazard is only moderate, so erosion reduced by constructing bench terraces to reduce the volume of surface runoff by up to 90% compared to land without bench terraces (Nugroho, et al, 2022).

3.5. Solutions

Landslide is a phenomenon of material movement down the slope due to the influence of slope destabilization due to the force of gravity and contact with water (Noviyanto, 2020). Landslides cause significant soil loss, deposition of landslide sedimentary material, changes in the morphological and physicochemical characteristics of the soil. Noviyanto also mentioned that landslides considered as one of the factors causing land damage, because they reduce soil fertility. Sparling et.al. (2003) explained that the decrease in c-organic soil and nutrients in landslide-affected material is due to mixing of soil material with parent material that is poor in c-organic and nutrients, presence of gravity and contact with water. At the research location in 2021 there are 9 location points (figure 3) of landslide events (BPBD, 2021).

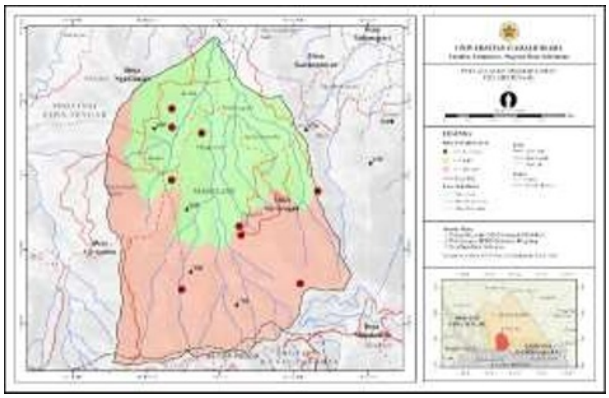

Figure 3. Map of landslide potential zoning and landslide occurrence points

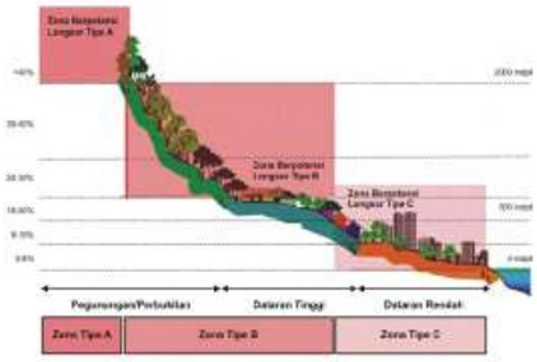

Figure 4. Zones of the watershed.

Based on Public Works Regulation No. 22 of 2007 there are 3 zones with the potential for landslides as shown in Figure 4. These zones are divided based on height above sea level and slope. Based on these zones, DTA Giritengah is in 2 (two zones), namely zones A and B. In selecting plant species based on Riyanto (2016), Zone A is at an altitude of 0-500 meters above sea level and Zone B at the research site is included in Zone B1. i.e. altitude 500-100 m above sea level. Then the proposed types of plants that matched are cloves, durian and *rambutan*.

Around the 90s the local government provided assistance with other plants, namely clove plants. For example, matching plants was carried out on one of the land units numbered 3, 10, 19, and 23. Apart from these types, the community also tried to plant durian plants in the hope of obtaining additional yields as a commodity. Types of durian and *rambutan* plants also have an unsuitable land suitability class (N). Of the three types, the slope zone is the heaviest limiting factor in developing plant species in the Giritengah catchment area.

The principle of landslide prevention is to prevent water from being concentrated in the sliding plane, binding the soil mass so it does not slide by seeping water into the deeper layers of the soil from the waterproof layer (gliding area) (Riyanto, 2016). Prevention of landslides and erosion done with plant-based interventions to strengthen slopes. Vegetation plays an important role in the prevention and mitigation of natural disasters and in the provision of various socio-ecological benefits (Olla uri, 2021).
Meanwhile, for mechanical handling on steep slopes, they plant clove, durian and *rambutan* planting with individual terraces as a solution. Individual terraces (figure 6) is a soil conservation technique that is suitable for staple crops planting.

4 Conclusion

1. In the Giritengah catchment area, Sengon, Mahogany and Teak plants, which are annual woody plants, are included in the land suitability class N (not suitable) with the heaviest limiting factor in the level of erosion hazard. Likewise for annual crops with the types of chili, banana and cassava the land suitability class is N (not suitable) with the heaviest limiting factor on the level of erosion hazard.
2. Variables that add to the level of erosion hazard are shallow solumn and steep slopes. To overcome this, several alternative and required soil and water conservation techniques that are appropriate to the field of tillage/agricultural land.
3. The types of plants proposed, namely clove, durian and *rambutan* according to land suitability class, are not suitable, but to anticipate that they can still grow these commodities, the efforts made are planting with agroforestry patterns accompanied by individual terrace techniques.

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this rearch can benefits in developing the vegetative methods for reduuucing the landslides.

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