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Design of soil and water conservation techniques to minimize soil erosion on degraded land in Samarinda Tenggarong Axis Road

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Abstract. Soil conservation activities are aimed at tackling land degradation, especially soil erosion, which occurs rapidly. If there is human intervention, land will become more sensitive to the influence of water (rainfall) and gravitational forces. This study aimed to identify the types of erosion that occur on degraded land and design appropriate soil and water conservation techniques based on vegetative and physically degraded land conditions on the Samarinda-Tenggarong Axis road. The results of the documentation collected from each research site identified the type of erosion, and designed soil and water conservation techniques. This research is focused on the design referring to Permenhut P.04/Menhut-11/2011 and UU RI/37/2014. The results of this study showed that location 1 of the recommended technique is the vegetative technique and the manufacture of Water Sewerage, location 2 is the bench terrace technique, location 3 is the retaining wall technique, location 4 is the individual terrace technique, location 5 is the stone terrace/wall technique, location 6 is the stone terrace/wall technique, and location 7 is the garden terrace technique. The design of the soil and water conservation techniques recommended in this study is expected to have a positive effect on minimizing soil erosion on degraded land.

1. Introduction

Increasing population growth in each region also increases the need for land because land is a very important resource in meeting the needs of human life, so much of the land is used for shelter, planting, and carrying capacity of economic activities. Unwise land use can result in environmental destruction such as deforestation or illegal logging activities, mining activities, C excavations, industrial activities, and improper agricultural practices (agrochemical pollution). Agricultural development and the reduction of woody species in the region are influenced by various factors, such as deforestation, cutting down trees for animal feed, excessive grazing, a deficient afforestation strategy, and efforts to alleviate poverty, among other contributing elements [1]. The fundamental reason driving ecological disasters that have occurred is that they will continue to occur in land use that continues to rise without consideration for the principle of sustainability, notably in the administration of land and water conservation policies.

In low/lower-middle income countries, land and forest management methods have resulted in millions of hectares of degraded land [2]. Land degradation, characterized by the gradual decline or loss in a land's capacity to provide essential ecosystem services, poses a significant threat to the safety of global food supplies, the progress of economies, and the overall quality of life of billions of individuals [3]. Agricultural production faces substantial challenges due to land degradation [4]. Target 15.3 of the Sustainable Development Goals (SDGs) requires countries to achieve land degradation neutrality by 2030. The pressing issue of land degradation impacts both human progress and the natural surroundings. The Sustainable Development Goals (SDGs) introduced a fresh strategy for tackling land degradation, drawing upon recommendations put forth during the United Nations Rio+20 conference that recognized the importance of working towards achieving "zero net land degradation." [5].

Erosion is influenced by a variety of environmental elements; however, land utilization and supervision are the most crucial factors capable of swift transformation over time and are directly influenced by human activities [6]. The effects of climate change and variability on land use take time to manifest, whereas the effects of human land modification manifest quickly in terms of soil loss [7]. Soil erosion is a major issue; however, there are feed shortages, water shortages, road closures, firewood shortages, land shortages, and off-farm and non-farm jobs [8]. Soil erosion and land degradation are serious concerns in arid and semi-arid regions worldwide. Owing to an increase in landslides, floods, and drought, the strength of soil erosion has increased [9].

The fundamental reason driving ecological disasters that have occurred and will continue to occur is that their use continues to rise without consideration of the principle of sustainability, notably in the administration of land and water conservation policies. Current land-use dynamics tend to overlook the influence of diminishing land quality's ability to support specific uses, which eventually reduces carrying capacity. According to [10], soil erosion caused by inadequate land management has emerged as a significant obstacle affecting agricultural output and food supply security. To mitigate soil erosion, strategies for soil and water conservation (SWC), such as the implementation of soil and stone bunds, have been devised and implemented.

Soil conservation refers to structuring each plot of land in a way that is based on the ability of the soil to treat it wisely, so that the soil is not harmed. Soil conservation techniques such as reforestation, neglect of farmland, and soil conservation practices can fully offset the influence of climate change on soil erosion [11]. The ability of ecosystems to manage erosion and preserve soil. is known as the soil conservation service (SCS). Despite decades of notice and some work to improve soil conservation and repair areas, significant problems remain in topographic circumstances that necessitate cautious management to avoid deviating from soil and water conservation standards [12].

However, using soil and water conservation strategies is the most effective way to protect and use the environment and natural resources while also reducing surface runoff and erosion. Various attempts have been made to improve soil stability so that land can support the activities of living organisms, including vegetative, mechanical, and chemical soil conservation approaches. Soil and water conservation strategies can help to avoid erosion, heal damaged soil, avoid erosion, heal damaged soil, and maintain and increase soil productivity to contribute to the failure of land rehabilitation and soil conservation, including the technology's weakness and/or inaccuracy, and restricted funds.

The condition of the land on the left-right side of the Samarinda–Tenggarong Axis Road based on field observations shows that the land is degraded due to the activity of former excavations, land clearing, and lack of vegetation in the form of trees, which makes the land critical. Based on this description, research was conducted to identify the types of erosion that occur on degraded land directly in the field and to design techniques for conserving soil and water, vegetatively degraded land, and mechanical physical to increase land productivity. This study aimed to identify the types of erosion that occur on degraded land and design appropriate soil and water conservation techniques based on vegetative and physical-mechanical degraded land conditions on the right-left side of the Samarinda-Tenggarong Axis road.

2. Material and method

2.1. Research site

This study was carried out on degraded land located on the left-right side of the Samarinda-Tenggarong Axis Road, East Kalimantan Province. Locations 1 and 2 were in Bukit Pinang Village, Samarinda Ulu District. Locations 3 and 4 were in Bukit Raya Village, Tenggarong Seberang District. Locations 5, 6, and 7 were located in Teluk Dalam Village in Tenggarong Seberang District. A map of the study locations is shown in Figure 1.

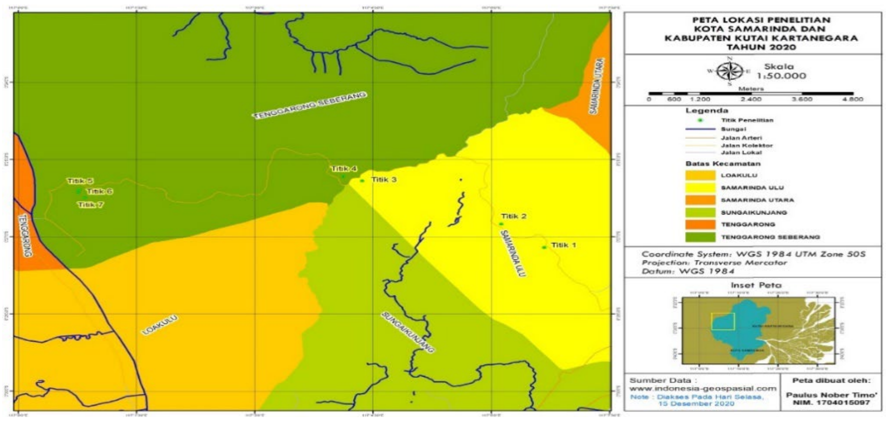

Figure 1. Research Location Map.

2.2. Research procedure

Primary data were directly collected or obtained from the results of measurements in the field, as follows: the determination of coordinate points was carried out to retrieve seven locations that had the potential to experience degraded land, which had different levels of topography using GPS, identification of the type of vegetation of land cover, and the type of erosion that occurs was carried out directly in the field, documenting the condition of degraded land on the right and left of the Samarinda-Tenggarong Axis Road.

2.3. Analysis of soil properties

The analysis of soil properties (soil texture: sand, silt, and clay; Cation Exchange Capacity) was conducted at the Laboratory of Soil Science and Forest Nutrition Faculty of Forestry Mulawarman University.

2.4. Data analysis

Field data in the form of types of erosion that occurred and laboratories in the form of physical properties of the soil were processed and analyzed in qualitative descriptions and presented in the form of tabulations and images, then interpreted in the form of narratives, as well as making appropriate soil and water conservation techniques.

3. Results and discussion

3.1. Geographical conditions

The research location was geographically between 0º27'12" LS and 117º06'42" BT °0º26'15″ LS and 117º00'51" BT. In general, the Samarinda-Tenggarong area is directly adjacent to other regions, including the north: Tenggarong Seberang District, south: Sunai Kunjng District, west: Tenggarong District, and east: Samarinda Ulu District. The research location is another use area, such as settlements, plantations, and ex-excavation areas.

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3.2. Climatic conditions

Samarinda City has the highest rainfall of 243.41 mm/month in April and the lowest rainfall of 116.83 mm/month in August, average air temperature of 26.11ºC and average humidity of 76.45% [13]. Based on the results of the analysis of precipitation data for 10 years (2011 – 2020), the climate type according to the Schmidt-Ferguson (1951) Climate Classification System at the study site obtained a value of Quotient (Q) = 7.45%; namely, climate type A was very wet areas with tropical rainforest vegetation [13].

3.3. The topographic, soil type, and Cation Exchange Capacity (CEC) in the research location

The topographic class at the research location was categorized as steep (25 – 40%) and very steep (> 40%). Based on the land map made by the Center for Agricultural Land Resources Samarinda (2016) scale 1:50,000, that the type of soil contained at 7 (seven) locations measurement was eutric cambisol and haplic mediteran was found at locations 1 and 2, while eutrik cambisol and haplic podzolic soil types were found at locations 3, 4,5,6 and 7 [14].

Some of these soil types have different characteristics from each Land Map Unit, namely eutric cambisol and haplic mediteran soil types made from calcareous clay parent with undulating tectonic plain landform, whereas for district cambisol soil types and haplic podzolic made from sandstone parents with single-fold anticline ridge landform. Cambisol soil results in flandform weathering of parent rocks and has a low organic matter content. Basedon after assessing the proportions of sand, clay, and silt, the cambisol's texture that was examined was categorized as clay-rich [15]. Podzolic soils are a type of soil formed by high rainfall and are also a type of old mineral soil. Podzolic soil types are generally yellowish and reddish because of oxidized iron and aluminum, and podzolic soil color indicates relatively low soil fertility.

The results of the cation exchange capacity analysis at the Soil Science and Forest Nutrition Laboratory, Faculty of Forestry, Mulawarman University are presented in Table 1. Cation Exchange Capacity (CEC) is a chemical attribute of soil that is intricately tied to the accessibility of nutrients for plants and signifies soil richness. This situation presents a notable threat of polluting groundwater, making it imperative for this issue to be treated with utmost seriousness [16]. Based on the table above, the value of land CEC at all points in the study location has a low category of soil CEC. Soils with low cation exchange capacity are less able to absorb and provide nutrients. The high and low CEC of the soil are greatly influenced by the properties and characteristics of the soil, such as organic matter, texture or amount of clay, type of clay minerals, and soil pH [17]. topography, soil type, and Cation Exchange Capacity (CEC) at the research location are shown in Table 1.

3.4. Texture and soil erodibility (K) value of each type of soil at the research site

The soil texture at 7 (seven) locations sites were dominated by rather fine soil criteria. Soils with a loamy texture have a moderate infiltration rate and are better able to support water for plants than coarse loamy textures, besides that they are also more supportive of the development of plant roots. Therefore, of had an important effect on determining the appropriate type of vegetation. In the soil map data, it can be seen that the study area was divided into 3 (three) types of soil namely cambisol, mediteran, and podzolic red-yellow. The soil erodibility value of each soil type at the study site is presented in Table 2.

From the three types of soil at the study site, the value of soil erodibility has a moderate dignity, this showed that the soil type is still relatively sensitive to the process of erosion and landslide events. The influence of silt fraction on susceptibility to erosion is generally well known, soils showed higher erodibility if the silt content is high, regardless of both other factions share [18]. While erosion is influenced by a multitude of elements, the type and texture of the soil, the incline of the slope, and the existence or absence of ground cover appear to have crucial significance in shaping the potential for soil erosion [19].

Table 1. Topographic, soil type, and Cation Exchange Capacity (CEC) in the research site

Location of Measure ment	Kilo metre (Km)	Topo graphic (%)	Soil Unit	Parent Material	Landfrom	pH	CEC (Cmol/ kg)
1	6	55 (very steep)	Eutric Cambisol, Haplic Mediteran	Calcareous clay	Undulating tectonic plains	Neutral	11.28 (Low)
2	7	31 (steep)	Eutric Cambisol, Haplic Mediteran	Calcareous clay	Undulating tectonic plains	Neutral	12.44 (Low)
3	10	37 (steep)	Eutrik Cambisol, Haplic Podzolic	Sandstone	Single-fold anticline ridge	(4-6) Acid	9.08 (Low)
4	9	53 (very steep)	Eutrik Cambisol, Haplic Podzolic	Sandstone	Single-fold anticline ridge	(4-6) Acid	7.00 (Low)
5	1	34 (steep)	Eutrik Cambisol, Haplic Podzolic	Sandstone	Single-fold anticline ridge	(4-6) Acid	6.84 (Low)
6	1	32 (steep)	Eutrik Cambisol, Haplic Podzolic	Sandstone	Single-fold anticline ridge	(4-6) Acid	7.40 (Low)
7	1	56 (very steep)	Eutrik Cambisol, Haplic Podzolic	Sandstone	Single-fold anticline ridge	(4-6) Acid	6.12 (Low)

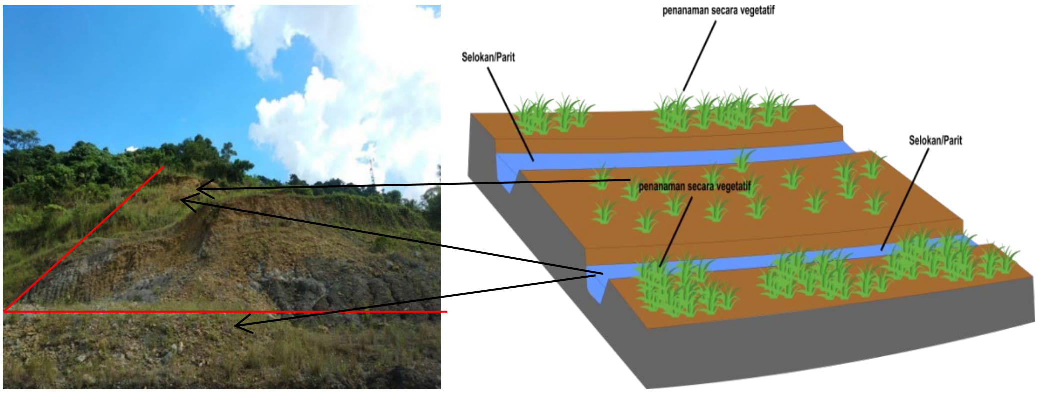
Table 2. Texture and Soil erodibility (K) value of each type of soil in the research site

Location of Measurement	Kilometre	% Fraction			Texture	Type of soil	K value
	(Km)	Sand	Silt	Clay			
1	6	17.41	46.68	35.91	silty clay loam	Cambisol	0.30 (middle)
2	7	22.26	28.27	49.47	clay	Mediteran	0.22 (middle)
3	10	60.07	18.15	21.78	sandy clay loam	Cambisol	0.30 (middle)
4	9	37.72	24.22	38.06	clay loam	Cambisol	0.30 (middle)
5	1	48.86	14.61	36.53	Sandy clay	Cambisol	0.30 (middle)
6	1	53.36	17.94	28.70	sandy clay loam	Podzolic of Red Yellow	0.32 (middle)
7	1	5.84	27.90	66.26	clay	Podzolic of Red Yellow	0.32 (middle)

3.5. Design appropriate soil and water conservation techniques according to vegetative and physically mechanically degraded land conditions on the Samarinda-Tenggarong Axis Road.

Vegetative and mechanical soil and water conservation techniques aim to control erosion and surface runoff, repair damaged soil and increase soil productivity. The design of soil and water conservation techniques for the 7 locations of research on the right and left of the Samarinda-Tenggarong Axis road was designed based on several considerations related to land slope conditions, land cover, soil texture, soil erodibility and the type of soil erosion that occurs. Figure 2 to 8 describe the recommended soil and water conservation design based on field conditions and then a soil and water conservation design is made in an effort to minimize erosion that occurs.

Research location 1



(a) (b)

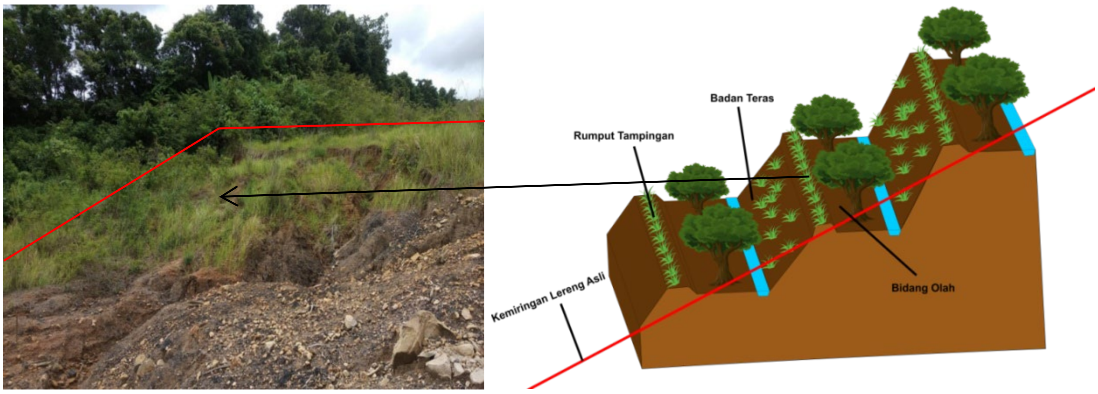
Figure 2. (a) The condition of the land of former excavation activities C; (b) Water Storage Channels and vegetative engineering.

Location 1 has a slope of 55% (very steep). This land is one of the former C excavations (sand and stone excavations) that lacks further treatment, so the land becomes critical and there is a channel. Many fragments of rock and soil have hardened, which makes it difficult for vegetation to grow and develop. Most of this land is open, but in certain places reeds *(Imperata cylindrica)*, karamunting *(Melastoma malabathricum)*, waru (*Hibiscus tilliaceus*), and pakutn asur *(Nephrolepis falcata)* are found. The soil texture at this location is silty clay loam with moderate soil erodibility, but the soil is still relatively sensitive to erosion.

Considering the state of the first location, utilizing mechanical methods is discouraged due to the abundance of rocky debris and compacted soil. A suitable method to be carried out at the first location is through vegetative techniques and the creation of a water sewer. The initial stage of planting is planting *cover crop legume* types such as *Pueraria javanica*, *Centrosema pubescens*, *Calopogonium mucunoides*, and *Mucuna bracteata* to prevent the direct impact of rainwater on the ground surface, drainage channels are made to adjust the flow of water where erosion occurs. The final stage of activities is to plant fast-growing plants such as jabon, pepper, and Multy Purpose Tree Species (MPTS) plants

This second location has a slope of 31% and is one of the local community lands that is left without treatment so that the flow of water flowing to the ground surface occurs quickly, which makes the land experience ditch erosion and landslides. Most of the land is overgrown with reeds (*Imperata cylindrica)*, karamunting (*Melastoma malabathricum*), and pakutn asur (*Nephrolepis falcata*). This land has a clay texture (smooth) and has medium soil erodibility and is classified as sensitive to erosion.

Research location 2

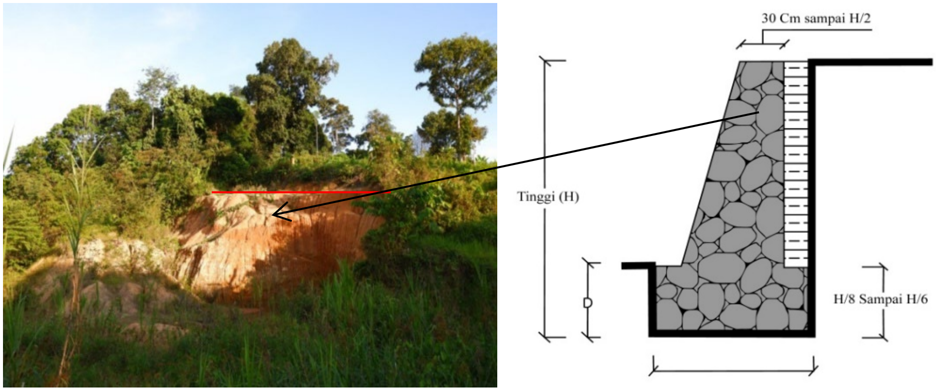


(a) (b)

Figure 3. (a) The condition of degraded reed land; (b) Bench terrace.

To anticipate the above land problems, it is necessary to apply mechanical and vegetative techniques. The mechanical technique carried out is the manufacture of bench terraces, because the manufacture of bench terraces refers to the state of the slope of the land, which ranges from 25 to 40%. Making a bench terrace involves cutting the slope and leveling the ground at the bottom so that a row of stairs or benches occurs. At the end of the outer terrace (lip of the terrace), a guludan is made 20 cm high by 20 cm wide, and the inside of the terrace is a water sewer with a size of 20 cm wide and 15 cm depth. By making a bench terrace accompanied by vegetative techniques, namely by planting *a legume cover crop* type terrace strengthening plant and also the lamtoro (*Leucaena leucocephala*). The benefits of bench terraces on degraded, sloping land can protect the land from erosion and landslides when it rains.

Research location 3

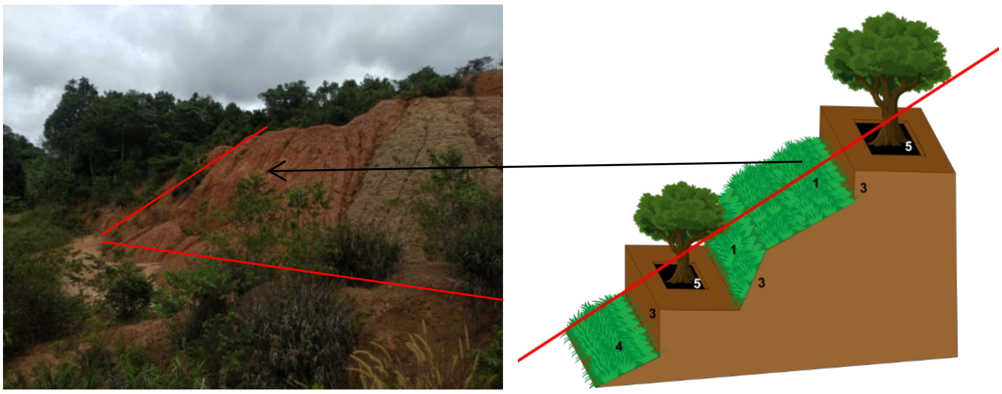


(a) (b)

Figure 4. (a) The condition of the excavated land; (b) Retaining wall.

This third location has a slope of 37%, which is one of the former soil excavations that is left unattended without further treatment of the land, so that the soil at the top begins to be eroded by rainwater flow, which causes the field erosion of the groove. Mostly in certain places, land cover is overgrown with reeds (*Imperata cylindrica*), karamunting (*Melastoma malabathricum*), and waru (*Hibiscus tilliaceus*). The soil texture of this field is sandy clay (rather fine), with an erodibility of the soil that is sensitive to erosion. This land is easy to be eroded by rainwater. Based on the condition of the third location, the recommended technique is the Retaining Wall technique. The main benefit of soil retaining walls is that they support loose or unstable natural soil, preventing the soil from the dangers of cladding and protecting the natural vegetation on it.

Research location 4



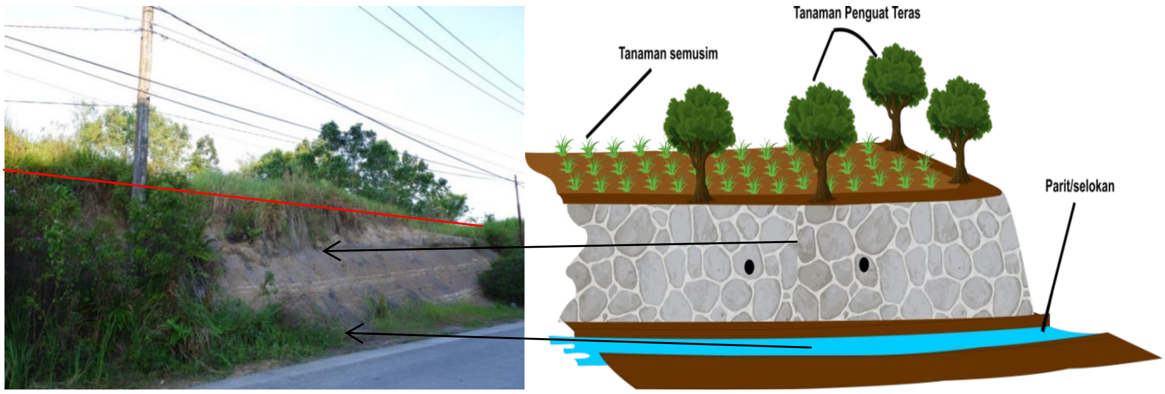
(a) (b)

Figure 5. (a) The condition of the cliff land of the former excavation activity C; (b) Individual terraces.

This 4th location is a former C excavation activity (soil excavation) without any further treatment, so the land is critical and there is erosion and a lack of vegetation of land cover growing on it. The slope of the land is 53% (very steep). In certain places, land cover is dominated by reeds (*Imperata cylindrica*), acacia (*Acacia mangium*), and mahang (*Macaranga gigantea*). The soil texture is clay loam, with a value of soil erodibility that is still sensitive to the occurrence of erosion.

The mechanical engineering treatment carried out is an individual terrace that, by looking at the slopes, can be made with a slope of the field ranging from 0 to 60%. Individual terraces are soil conservation techniques in the form of terraces made by cultivating a small amount of land and other remaining land allowed to grow natural vegetation. This method focuses on one terrace where rainwater is collected. The benefits of individual terraces are erosion control and surface flow reduction. The plants planted on these fields, such as lamtoro (*Leucaena leucocephala*), sengon (*Paraserianthes falcataria),* and legume *cover crop* types of ground cover between terraces, such as *Pueraria javanica* and *Centrosema pubescens,* The vegetation serves to help reduce erosion, strengthen cliffs and terraces, and fertilize the soil.

Research location 5



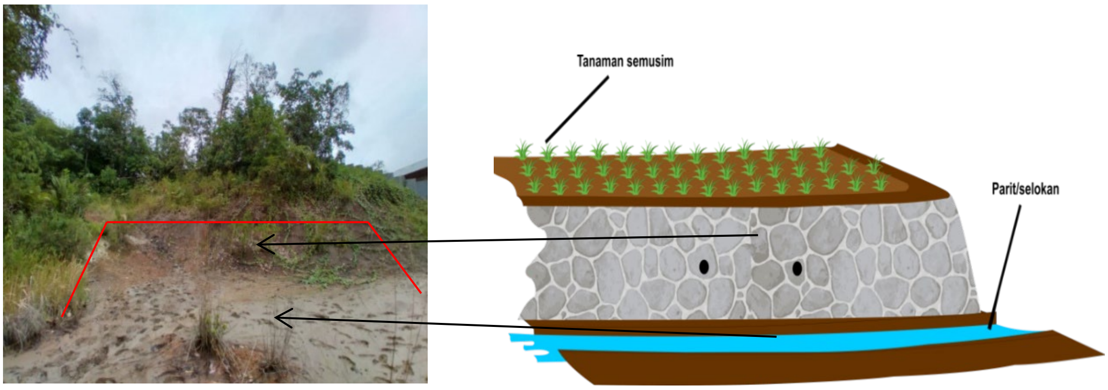
(a) (b)

Figure 6. (a) Degraded cliff conditions ; (b) Stone terrace/wall.

Land with a slope of 34% is former excavated land to widen the road area. This land surface is likely to be managed by the surrounding community for plantations. The land surface is overgrown with reeds (*Imperata cylindrica*), karamunting (*Melastoma malabathricum*), and pakutn asur (*Nephrolepis falcata),* and there are several commercial plants that have a sandy (fine) clay texture and a moderate erodibility value.

At the 5th location, conservation treatments that are suitable for land conditions are mechanical techniques and vegetative techniques. Mechanical techniques in the form of stone terraces and the manufacture of sewerage and ditches. The manufacture of stone terraces refers to the sewerage or ditching of the land, which ranges from 25% to 45%. A stone terrace is a method of making a soil- and water-retaining terrace where the walls are made at a distance corresponding to the length of the contour on the inclined land. The benefit of the rock terrace technique is to protect and maintain the condition of the soil and vegetation on it from soil erosion by rainwater and to avoid erosion and landslides of small sizes. Vegetation that is suitable for planting on the land is legume *cover crop* types such as *Pueraria javanica*, Centrosema *pubescens,* and lamtoro species (*Leucaena leucocephala*), rubber (*Hevea brasiliensis*), as well as terrace-strengthening plants.

Research location 6



(a) (b)

Figure 7. (a) The condition of the land that has been degraded; (b) Stone terrace/wall.

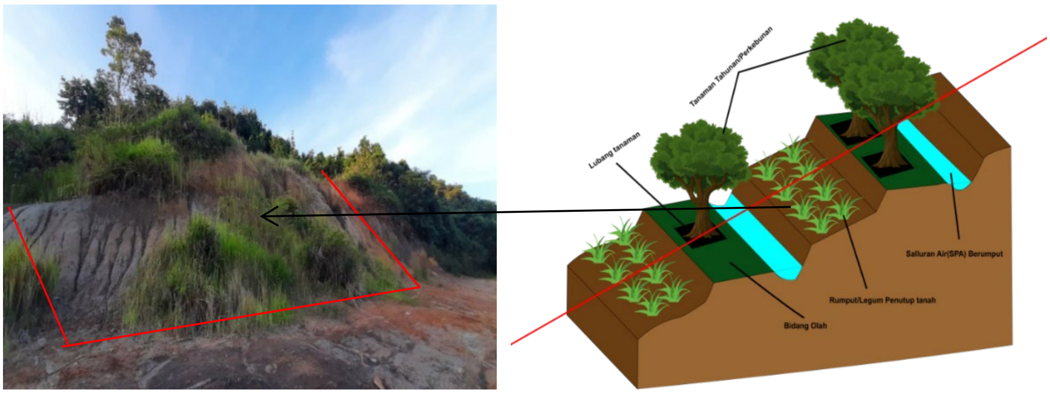
The 6th location, with a 32% slope, is a former sand excavation area that is left unattended without further treatment so that when it rains, there is erosion of the groove. Damaged land that is left interferes with vegetation growth and damages ecosystems. Location 6 was dominated by reeds (*Imperata cylindrica*), karamunting (*Melastoma malabathricum*), pakutn asur (*Nephrolepis falcata*), and rubber (*Hevea brasiliensis*). This land has a sandy clay soil texture (rather fine) and also has soil erodibility that is still sensitive to erosion.

The suitable solution in the 6th location above is with mechanical engineering treatment, namely by making stone terraces and water storage channels. A stone terrace is a method of making a soil- and water-retaining terrace where the walls are made at a distance corresponding to the length of the contour on the inclined land. The water sewer used in this method is an automatic water sewer. The benefit of making a stone terrace at the 6th location is to protect the vegetation that grows around the field so that it can develop according to its function and anticipate land damage from the danger of erosion. The land that is left without conservation measures will cause its function to decline. The recommended type of land surface cover vegetation is in the form of *legume cover crop* such as *Pueraria javanica*, and *Mucuna bracteata*.

Research location 7

The 7th location, with a slope of 56% (very steep), is a former excavation or cut land to make way to the former mining site, which causes channel erosion. Most of the 7th location was dominated by reeds (*Imperata cylindrica)* and karamunting (*Melastoma malabathricum*). The soil texture in this field is clay (smooth), with soil erodibility that is sensitive to erosion. This land is easy to be eroded by rainwater.

Mechanical techniques are made by the method of garden terraces that refer to marbles and slopes of 10–60%. The garden terrace method is a contour-directional soil conservation treatment in the form of a terrace that is only made on the plot of land to be planted. The benefits of the garden terrace method are soil erosion control, increasing infiltration water, and reducing surface flow. The garden terrace is suitable for planting plantations or annual plants such as rubber (*Hevea brasiliensis*), mango (*Mangifera indica*), and other plantations such as *legume cover crops* or shrubs that function as terrace reinforcement.



(a) (b)

Figure 8. (a) Degraded cliff conditions; (b) Garden terrace.

4. Conclusion

Based on the results of the study, it was shown that the types of erosion that occurred at the seven locations of the study site were groove erosion, trench erosion, and landslides. Application of soil and water conservation techniques at the 7 locations of research, namely: at location 1 with vegetative techniques, namely planting and making water storage channels; location 2 with bench terrace mechanical techniques; location 3 with soil retaining wall mechanical techniques (retaining wall); location 4 with individual terrace mechanical techniques; location 5 with stone terrace/wall mechanical techniques; location 6 with stone terrace/wall mechanical engineering; and location 7 with garden terrace mechanical technique. The design of soil and water conservation techniques recommended in this study is expected to have a positive impact on minimizing soil erosion on degraded lands and can be applied to degraded lands.

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