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Identification of the Overall Slope Pit Angle Value for Erosion Control in Disposal Land

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Abstract

Open-pit mining can cause changes in environmental conditions, especially in disposal land. The formation of gully erosion on disposal land tends to increase as the area of open land increases. The aim of this research is to calculate the amount of erosion and the geometry of the bench terrace as a form of recommendation for reducing the rate of erosion. The methodology used is the USLE (Universal Soil Loss Equation) method approach in predicting the amount of erosion and an empirical approach in providing recommendations to reduce the rate of erosion for conservation measures in the form of bench terraces. The results showed that the erosion formed on disposal land was 123.43 tons/ha/year with a range of 60-180 tons/ha/year in the category of moderate erosion hazard. While for the dimensions of bench terraces recommended on disposal land, the overall slope pit angle value was $46,6^0$ with a maximum single slope pit angle on the bench of 60^0 (16.6%). Bench dimensions in the form of bench terraces will have a major influence on the overall slope pit angle value formed. The smaller the width of the bench formed with the single slope pit angle, the greater the value of the overall slope pit angle formed. In addition to the width of the bench that affects the value of the overall slope pit angle is the height of the disposal slope. The height of the disposal slope will be directly proportional to the decrease in the overall pit angle slope, to the number of benches formed. With soil conservation measures in the form of traditional terraces in the form of bench terraces with a value factor of 0.4 in open land without vegetation, it can decrease from 123.43% (tons/ha/year) to 49.37 tons/ha/year ranging from 15-60 tons/ha/year with the category of low erosion hazard level, and or about 39% reduction in erosion that occurs.

1. Introduction

Indonesia is rich in natural resources, particularly coal. The presence of technology and techniques in the management and utilization of natural resources must pay attention to the changes in the environment that occur. Mining by open pit mining and causing changes in environmental conditions has a tendency to increase along with the increase in the area of open land due to land clearing land cover. The impact of open mining can have negative impacts in the form of changes in the landscape, air pollution, and impacts on biodiversity and soil surface erosion [1]. Mining activities at each stage can have a negative impact on the loss of habitat for flora, fauna, and other living creatures. Land clearing for mining activities can cause loss of vegetation or biodiversity on the land [2]. In addition, there may also be loss of soil nutrients due to overburden removal activities.

Open land can only occur in mining areas or in disposal land. Efforts to control the form of re-vegetation as soon as possible to do reclamation which can reduce the magnitude of the rate of erosion when there is rain of a sufficiently large intensity. The large impacts that occur on the disposal land area are known to be very vulnerable to decreased land productivity, such as the existence of surface erosion rate grooves on the soil, the absence of drains in the disposal land. A disposal is a place where the overburden is stockpiled and where the material/ soil comes from a mining pit [3]. Mining activities have a complex effect on change in morphology vegetation, soil structure and others [4]. High soil erodibility indicates that the soil in the area is very vulnerable to erosion, especially in the disposal land. Low organic matter content and a high percentage of dust and sand in the soil make it very difficult for the soil to form a stable structure, so if either of these is high it will be more sensitive to erosion [5]. The formation of trench erosion on disposal land indicates failure in erosion management, therefore the main objective of this research is to calculate the amount of erosion and calculate the geometry of bench terraces as a form of recommendation in reducing the rate of erosion.

Failure to anticipate erosion management will make the land critical and experience excessive degradation. Of course this cannot be allowed for mining companies to protect and control the environment so that it is not affected in the long term, especially coal mining [6]. Forms of control and management of the impact caused can be done by reclamation effort and continued with re-vegetation of land in the disposal program will later be adjusted to the reclamation plan that has been agreed and adjusted to its designation. Reclamation is an inseparable part and is intended to organize, restore and restore ex-mining land as it was intended. So that the land remains productive for a long time [7].

Reclamation and re-vegetation are 2 different words but have the same goal of restoring land use. This is also regulated in the Minister of Energy and Mineral Resources Regulation Number 1827K of 2018 concerning guidelines for the implementation of Good Mining Engineering Principles [8] and the Regulation of the Minister of Energy and Mineral Resources of the Republic of Indonesia Number 07 of 2014 concerning Implementation of reclamation and post mining in mineral and coal mining business activities[9]. Whereas the reclamation activities are carried out throughout the mining business stages to organize, restore and improve the quality of the environment and ecosystem so that they can function again according to their designation. Reclamation in the form of re-vegetation may include land use, re-vegetation, and maintenance activities. Land use stewardship activities, effort is made to control the amount of erosion and evaluate the dimension of the waterways in the disposal area.

The land arrangement is a form of realignment of ex-coal mining areas so that they can return to their designation. This structuring activity uses a bulldozer to cultivate the soil surface and is also used to spread the soil in the root zone as a source of nutrition for plants. Replanting known as land re-vegetation can be adjusted to the shape of the land that has been arranged. Land management activities cannot be separated from the use of heavy equipment, of course this can lead to high levels of density and the occurrence of closing of soil pores. A dense soil surface causes some plants to be limited in carrying out root penetration into the soil. In addition, another impact caused is the occurrence of erosion on the surface of the soil when there is heavy rain [10].

Paddock dumping method, or better known as bottom up dumping is a layer of overburden stacked by piling it on top of an embankment, followed by overlying by a bulldozer to form a relatively thin layer [11]. Paddock is far superior in terms of security and safety at the overburden embankment. Heap are made from the bottom up and terrace will form as an effort to reduce the rate of soil erosion [3]. The pit slope angle can be defined as the angle formed when connecting the lowest toe of bench (defined below) to the upper most crest of the horizontal hole.

Bench terraces are particularly suitable on land with a slope of 15% or more, with the aim of preventing loss of topsoil due to erosion. Bench terraces aim to improve the permeability of the soil [12]. Bench terraces can be made by cutting the slope and leveling the ground at the bottom. Bench terrace function to slow surface runoff, accommodate and drain runoff, and increase infiltration rates. The bench terrace model that is often used on ex coal mining land is the bench model tilted inwards. A bench terrace with an inward slope is a bench terrace that is designed with an inward slope opposite to the original slope, meaning that surface water flow from each slope area will flow into the terrace channel and continue to the water drainage system so that there is almost no delivery of surface runoff water from one terrace to the other terraces [13].

Erosion is the process of moving or transporting soil material from one place to another through a medium of water and/or wind which occurs naturally or by action. Change in soil and vegetation can cause sheet erosion (erosion of the soil surface) and rill erosion (groove erosion) which swells into gully erosion (erosion of trenches) [12]. The method used to predict the amount of erosion is the USLE (The Universal Soil Loss Equation) method which is influenced by rainfall, and runoff (rain erosion), soil erodibility, slope length, steepness, soil cover vegetation and crop management and the factor of special soil conservation measures that have been taken.

2. Methodology

This research was conducted in the PT. Tambulun Pangian Indah which is a former coal mining area is located in the Jujuhan District, Bungo Regency, Jambi Province. The methodology used is the USLE (Universal Soil Loss Equation) method approach in predicting the amount of erosion and an empirical approach in providing recommendations to reduce the rate of erosion for conservation measures in the form of bench terraces. According to Wishmeier and Smith (1978) in [14] Prediction of the amount of erosion on disposal land can be determined using the USLE (Universal Soil Loss Equation) method which consists of 5 parameters, namely rainfall resistivity, soil erodibility, slope length and slope, land cover and soil conservation measures. The formula used is a follows [14]:

$$A = R \times K \times LS \times C \times P$$

Where:

A : Value of the amount of soil erosion that occurs (ton/ha/year)
R : The erosivity factor of the rainfall
K : Factor of soil erodibility
LS : Slope length factor and slope gradient
C : Factor of land cover
P : Factor of soil conservation treatment

The steps in determining the amount of erosion are as follows:

1. Calculate the rainfall erosivity value. Rainfall data used for the last 10 years using the Lenvain (1975) and Bols (1978) formula.
2. Calculate the soil erodibility value.
   a. Laboratory tests (soil texture, soil organic C, and soil permeability)
   b. Soil texture properties using the USDA soil texture triangle diagram
3. Length and slope of the slope using mapping analysis using the surfer application.
4. Land cover values are adjusted to the table 1.

Management of soil cover on ex mining land in the disposal land needs attention to the protection of land cover types. The nature of this protection is generally very difficult to determine, but to give results an approach can be taken to the type of land cover, see table 1.

5. And land conservation measures are adjusted to the table 2.

Soil conservation techniques are not only carried out mechanically or physically, but also include various kinds of effort aimed at reducing soil erosion, soil conservation treatments are adjusted to the slope angle and its utilization, see table 2.

Table 1. Factor C Value [15]

No	Types of Use	Factor Value
1	Open Soil/No Plants	1,0
2	Shrubs / meadows	0,3
3	Grass	0,2
4	Farming	0,4
5	Settlement	1,0

Table 2. Factor P Value [15]

No	Special Measures for Soil Conservation	Factor Value
1	Fine Construction	0,04
2	Moderate construction	0,15
3	Less Well Construction	0,35
4	Traditional terraces	0,40
5	No Conservation Action	1,00

Table 3. Assesment of the Erosion Hazard Level [16]

Thickness of Solum(cm)	Maximum erosion (A) tons/ha/year				
	<15	15-60	60-180	180-480	>480
>90	SR	R	S	B	SB
60-90	R	B	B	SB	SB
30-60	S	SB	SB	SB	SB
<30	B	SB	SB	SB	SB

Information: SR = Very low, R = Low, S = Medium, B = Severe, SB = Very severe,

The result of calculation using the formula USLE, and the amount of soil erosion that occurs in a disposal land which is a former coal mining land, can be related to the thickness of the soil and the amount of maximum erosion obtained, see table 3.

If the predicted results of the magnitude of erosion on the disposal land are known, the final stage of this research is to provide recommendations for the geometry of the bench terraces as an effort to reduce the rate of erosion that occurs. The formula that can be used to calculate overall slope pit angle on disposal land is [11]:

$$(\theta) = tan^{-1} \frac{N_B \; x \; B_H}{\{(N_B - 1)B_W\} + \frac{N_B \; x B_H}{tan\;(B_A)} + (R_W)}$$

Where:

θ : overall pit slope angle; degree

N_B : number of benche

B_H : bench height; meter

B_W : bench width; meter

B_A : bench angle; meter

R_W : ramp width; meter

3. Results and discussions

In general, open pit mining and excavation methods using a backfilling system in mining operations are considered more economical and will reduce the area of open land. It can be ascertained that the disposal area is an area that does not contain mineral content with economic value and or an area of former coal mining.

The condition of the soil surface in the disposal area was found to have gully erosion, where this condition occurs indicating that the disposal area is partially covered by vegetation and is prone to the resulting amount of erosion, see figure 1 on the right. The disposal land that is inactive for a long time will have a wide impact on the possibility of loss of soil cover and the instability of the disposal condition due to erosion, besides that the disposal area has not received special action in erosion control. The form of gully erosion on the surface of the soil that occurs in the disposal area can reduce soil productivity if special handling is not carried out regarding the amount of erosion produced. Erosion that occurs at the research location is caused by the water medium in the process of moving or transporting soil material from one place to another.

The results of calculations using the USLE (Universal Soil Loss Equation) method, the amount of erosion that occurs on disposal land is 123.43 tons/ha/year, see table 4 with a medium erosion hazard category ranging from 60-180 tons/ha/year, see table 3 which shows the condition of disposal in the form of open land cover/without revegetation with a factor value of 1, see table 1.

Table 4. Magnitude of Erosion Before and After Soil Conservation Action

Parameter Prediction of erosion amount	Magnitude of Erosion before action	Magnitude of Erosion after action
R	144,29	144,29
K	0,29	0,29
LS	3.18	3.18
C	1	1
P	1	0.4
Erosion tons/ha/year	123.43	49.37
Category of Erosion Hazard Level	Medium	Low

The amount of erosion on disposal land is influenced by the erosivity of rainfall, soil erodibility, length and slope, land cover and soil conservation measures. The erosivitas of the rainfall is 144.29 cm/hour see table 4 and the erodibility of the soil resulting from the calculation will affect the amount of erosion and can be used as a measure of the ability of the soil to withstand erosion. The presence of organic matter content, texture and structure of the soil as well as permeability are part of the size of the erodibility produced. The higher the intensity of rainfall and the erodibility of the soil will make it easier for the material to be transported and carried away by the water media. The erodibility value of the soil is in the range of 0.17-0.29, which is included in the low to moderate class. with a resistivity of rainfall of 144.29 cm/hour, see table 4.

The land arrangement activity uses excavated soil from a former coal mine by forming bench terraces with an inward slope, the aim of which is to do so that the rainwater that falls does not flow directly to the next level. Bench terraces are a conservation technique and an appropriate measure to reduce erosion. The results showed that for the dimensions of bench terraces recommended on disposal land, the overall slope pit angle value was $46,6^0$, see table 5, with a maximum single slope pit angle on the bench of 60^0 (16.6%).

Bench dimensions in the form of bench terraces will have a major influence on the overall slope pit angle value formed. The smaller the width of the bench formed with the single slope pit angle, the greater the value of the overall slope pit angle formed. In addition to the width of the bench that affects the value of the overall slope pit angle is the height of the disposal slope. The height of the disposal slope will be directly proportional to the decrease in the overall pit angle slope, to the number of benches formed.

Application of bench terraces is expected to inhibit the rate of erosion and reduce the amount of lost soil cover. With soil conservation measures in the form of traditional terraces in the form of bench terraces with a factor value of 0.4, see table 1. Erosion that occurred on disposal land decreased 123.43% (tons/ha/year) to 49.37 tonnes/ha/year, see table 4, with a low erosion hazard category, see table 3 in the range between 15-60 tons/ha/year, and or about 39% reduction in erosion that occurs.

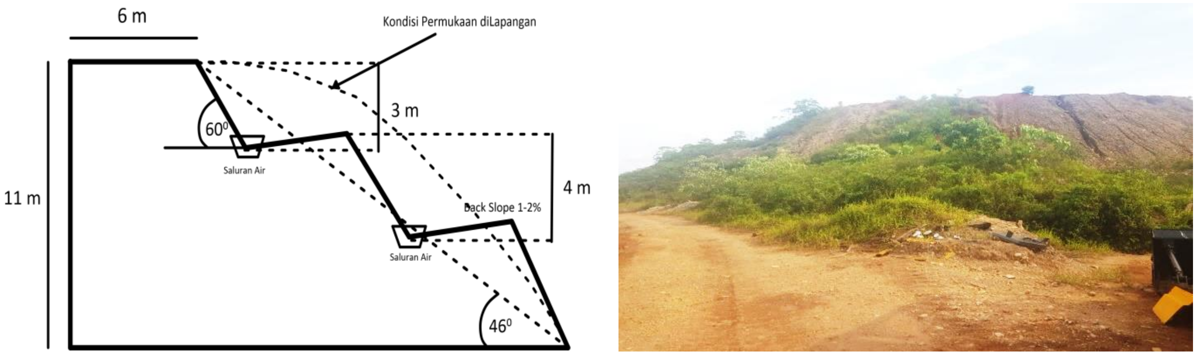

Figure 1. Recommended Bench Terrace (left), Disposal Land (right)

Table 5. Overall Slope Pit Angle Value

Slope Height (m)	Total Benches (n)	Overall Slope Pit Angle (^{0})	Overall Slope Pit Angle (%)
11	3	46.6	12.7
20	6	50.2	13.8
50	12	55.4	15.2

4. Conclusion

Open-pit mining can cause changes in environmental conditions, especially in disposal land. The formation of gully erosion on disposal land tends to increase as the area of open land increases. Disposal land that has been inactive for a long time will have a broad negative impact on the possibility of loss of soil cover due to erosion and the absence of soil conservation measures as an erosion control effort. The results showed that the erosion formed on disposal land was 123.43 tons/ha/year with a range of 60-180 tons/ha/year in the category of moderate erosion hazard. While for the dimensions of bench terraces recommended on disposal land, the overall slope pit angle value was 46^0 with a maximum single slope pit angle on the bench of 60^0 (16.6%). Bench dimensions in the form of bench terraces will have a major influence on the overall slope pit angle value formed. The smaller the width of the bench formed with the single slope pit angle, the greater the value of the overall slope pit angle formed. In addition to the width of the bench that affects the value of the overall slope pit angle is the height of the disposal slope. The height of the disposal slope will be directly proportional to the decrease in the overall pit angle slope, to the number of benches formed. With soil conservation measures in the form of traditional terraces in the form of bench terraces with a value factor of 0.4 in open land without vegetation, it can decrease from 123.43% (tons/ha/year) to 49.37 tons/ha/year ranging from 15-60 tons/ha/year with the category of low erosion hazard level, and or about 39% reduction in erosion that occurs.

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