Soil Erodibility Characteristics of Reclamation Area—A Case Study in Indonesian Coal Mining

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Soil Erodibility Characteristics of Reclamation Area—A Case Study in Indonesian Coal Mining

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Abstract: Soil erosion is one of the most important problems in Indonesia coal mining reclamation area because located in tropical areas which has high average of rainfall. Severe soil erosion leads to the unsuccessful reclamation progress in the post mine surface due to impact on steep slope and limit of seedling establishment. Considering the impact of soil erosion in mining activities, Indonesian government had issued several regulations related to erosion control. Soil erodibility is one of the main factors controlling soil erosion. It will determine amount of soil loss and total sediment. Estimation of soil erodibility aims to determine the susceptibility of soil to be eroded by water. The estimation considers soil texture, percentage of organic matter, soil structure and soil permeability. This study was integration between field work to collect soil sample, soil laboratory analysis, soil erodibility analysis using erodibility equation Wischmeier and Smith (1978) and analysis to predict soil erosion/ annual total soil loss. The results show that soil erodibility in study area was calculated to range from 0.091 to 0.142 tons ha h/ha/MJ/mm and soil erodibility of the study area was categorized as very low and low. There are strong relationships between soil erodibility and soil erosion but the correlation was not fully linier due to other factors controlling soil erosion / annual total soil loss.

Key words: Soil erodibility, erosion, coal mining, reclamation area.

1. Introduction

In Indonesia, soil erosion is one of important problem in coal mining reclamation area because Indonesia is located in tropical areas which has high average of rainfall. Soil erosion causing many negative impacts to the environment including top soil loss, destroy aquatic habitat, dam and pond siltation, clog river by deposition of sediment, water pollution, air pollution, increases water treatment cost, degrade water consumptive use, negative impact to public health [1, 2].

Considering the impact of soil erosion in mining activities, Indonesian government had issued several regulations related to erosion control. Director General of general mining, Ministry of Mining and Energy issued Decree No. 693.K/008/DDJP/1996 concerning technical guidance of erosion control in general mining. This guidance describes general principle of erosion and sedimentation control and methodology of erosion control in detail. The methods of erosion control are vegetative method, civil engineering method and the combination both of them [3].

Soil erosion is controlled by several factors both natural factors and human intervention factors including climate properties, soil properties, topographic properties, vegetation cover properties, and human intervention factor [2, 4, 5].

Soil plays an important role in reclamation activities including as medium for plant growth, medium for soil organism, nutrient provider and water provider. Besides, soil erodibility is an influential factor in soil erosion, land degradation and sedimentation.

Soil erodibility is degree of soil resistance from detachment and transport [6]. Several soil properties, soil texture, soil structure, aggregate stability, shear

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strength, hydraulic properties, water content, organic matter content and chemical content, control the soil erodibility [4, 6].

There are several methods for estimating soil erodibility such as estimation using equation/formula, estimation using nomograph and direct measurement in the field. Each method has own advantages, limitations and challenges to apply it. Direct measurement of the erodibility factor is both costly and time consuming and has been feasible only for a few major soil types. In 1961 study, the affect of soil properties to soil erodibility was conducted with utilization of field plot rainfall simulator, and reported several erodibility equations [5].

Estimation of soil erodibility aims to determine the susceptibility of soil to be eroded by water. The estimation considers soil texture, percentage of organic matter, soil structure and soil permeability.

Soil erodibility is one of the main factors controlling soil erosion. It will determine amount of soil loss and total sediment. Soil erodibility is also an important factor in determination of soil cultivation type, type and degree of conservation practice, erosion control structure, volume of sediment pond, period of sediment pond dredging, land suitability class and land capability class.

In this study, several investigations about soil erodibility were carried out in KPC (Kaltim Prima Coal) mine located in East Kalimantan. KPC mine is the biggest open cut coal mine in Indonesia and produces over 40 Mt of clean coal in 2010. The mine site belongs to tropical rainforest climate and the average annual rainfall shows 2,000-4,000 mm/year. From series of studies in this mine, the relationships between soil erodibility and soil erosion were discussed.

2. Soil Properties of Study Area

Based on soil laboratory analysis, soil texture in the study area range from clay, clay loam and silty clay loam. Clay is characterized by very small particle size (< 0.02 mm), low infiltration capacity causing high surface run off which is flowing over the soil and carrying soil particles. Clay loam contains 30.88%-34.88% of clay, 26.29%-44.29% of silt and 20.83%-42.83% of sand. Silty clay loam contains 38.53%-39.23% of clay, 42.83%-48.72% of silt and 12.05%-18.64% of sand.

The types of soil structure in the study area are columnar, prismatic, sub angular blocky, angular blocky and platy. Soil texture and soil structure determine porosity, infiltration, permeability, consistency, drainage, water and air movement, erodibility that are going to influence land cultivation and soil erosion control.

Soil pH is a degree of acidity or alkalinity of soil. Soil indicates as an acid soil if the pH below than 7.0 and indicates as an alkaline soil if the pH is greater than 7.0. The soil pH of the study area ranges from 4.16 to 4.98 which are categorized as acid soil. Soil pH influences the availability of nutrients, the availability of microorganism and soil toxicity. The salinity of the study area ranges from 0.03 mS to 0.20 mS.

CEC (cation exchange capacity) associated with percent of organic matter and indicates soil fertility. The CEC of the study area ranges from 6.95 to 16.42. The percent of organic matter ranges from 0.68 to 2.26. Percent of organic matter affects soil fertility which is influencing plant growth.

3. Methodology

This study was integration between field work to collect soil sample and to observe physical characteristics of land, soil laboratory analysis, soil erodibility analysis using erodibility equation Wischmeier and Smith [5] and analysis to predict soil erosion/ annual total soil loss. Research tools used in this study were personal computer, tools for soil sampling, GPS (global positioning system), clinometer, camera and observation form.

Field work was conducted to collect and observe soil properties and physical characteristics of land, to observe hazard characteristic (soil erosion) and also to collect soil sample. Field observation was conducted at 10 points of reclamation area that representing a variety age of plant from 2004 to 2011.

Soil laboratory analysis was conducted to characterize physical properties and chemical properties of soil for calculating soil erodibility. Soil properties analyzed in this study include soil texture (percent of sand, silt and clay), soil structure and percent of organic matter.

Soil erodibility values were calculated using the following formula of Wischmeier and Smith [5] :

$$100\,K = 2.1\,M^{1.14}\cdot(10^{-4})\cdot(12 - a) + 3.25(b - 2) + 2.5\,(c - 3)$$

where,

K = Soil erodibility;

M = (silt (%) + very fine sand (%)) (100 – clay (%));

a = organic matter (%);

b = Soil structure code;

c = Soil permeability code.

Tables 1 and 2 show soil structure code and soil permeability code used in the formula. The soil erodibility calculated by the fomula assessed accoding to Table 3 [7].

4. Results and Discussion

Soil erodibility indicates the susceptibility of soil to be eroded and transported by water. The higher value of soil erodibility indicates land more easily eroded. Soil properties that affect erodibility are soil texture, percent of organic matter, soil structure and soil permeability.

Soil textures in the study area are various including clay, clay loam, and silty clay loam. Those soil textures are generally found spread over Indonesia coal mining reclamation area.

Soil sample properties which were used for analyzing soil erodibility can be seen in Table 4, consist

Table 1 Soil structure code [7].

Soil structure class(diameter)	Code
Very fine granular (< 1 mm)	1
Fine granular (1-2 mm)	2
Medium to coarse granular (2-10 mm)	3
Block, blocky, platy, massif	4

Table 2 Soil permeability code [7].

Soil permeability class	Permeabilityrate (cm/h)	Code
Very slow	< 0.5	6
Slow	0.5-2	5
Moderate to slow	2-6.3	4
Moderate	6.3-12.7	3
Moderate to rapid	12.7-25.4	2
Rapid	> 25.4	1

Table 3 Classification of soil erodibility, USDA (1973 in Dangler and El-Swaify, 1976) [7].

Class	Soil erodibility	Description
1	Very low	0.00-0.10
2	Low	0.11-0.20
3	Moderate	0.21-0.32
4	Moderately high	0.33-0.43
5	High	0.44-0.56
6	Very high	0.56-0.64

Table 4 Soil sample properties.

Sample No.	Sand (%)	Silt (%)	Clay (%)	Soil structure	Organic matter (%)
1	14.51	39.07	46.43	Columnar	1.24
3	15.31	34.51	50.19	Columnar	1.38
5	1.04	29.07	69.89	Prismatic	2.26
7	16.35	39.92	43.73	Prismatic	1.11
9	12.05	48.72	39.23	Columnar	1.10
11	18.64	42.83	38.53	Columnar	2.24
13	20.83	44.29	34.88	Sub angular blocky	1.93
15	42.83	26.29	30.88	Columnar	0.68
17	10.43	56.56	33.01	Sub angular blocky	6.90

Source: Soil laboratory analysis

of soil texture (percent of sand, percent of silt, and percent of clay), soil structure, and percent of organic matter. Soil permeability was obtained from field observation. It varies from very slow to moderate to slow.

Results of soil erodibility analysis and prediction of total soil loss are presented in Table 5 and Fig. 1. The results shows that soil erodibility in study area is calculated to range from 0.091 to 0.142 tons ha h/ha/MJ/mm. According to Table 3 (classification of soil erodibility), soil erodibility of the study area are categorized as very low and low.

Correlation between soil erodibility and soil texture can be analyzed from this result. According to Table 4, clay contains > 40% clay (41.89%-69.89%), clay loam contains 30.88%-34.88% clay, silty clay loam contains 33.01%-39.23% clay. Thus, it can be said that the higher content of clay in soil, the higher soil erodibility, soil is easy to be eroded by water/run off. The highest erodibility was clay, followed by clay loam and silty clay loam as the lowest erodibility. Clay tends to have high erodibility and characterized by very small particle size (< 0.02 mm), low infiltration capacity causing high surface run off which is flowing over the soil and carrying soil particles. Clay loam contains 30% clay, 20%-40% sand and 25-45 silt, high infiltration capacity, high permeability, low surface run off result on low of soil erodibility. Silty clay loam is dominated by silt which has small particle size (0.002-0.05 mm), high content of clay (> 30%) as binding agent and 10%-18% of sand which is not easily eroded.

As discussed in introduction, soil erodibility is one of the main important factors controlling soil erosion.

Table 5 Soil erodibility and total soil loss.

Sample No.	Soil erodibility (tons ha h/ha/MJ/mm)	Total soil loss (ton/ha/year)
1	0.142	0.070
3	0.142	0.291
5	0.141	0.578
7	0.142	0.208
9	0.092	0.271
11	0.092	0.018
13	0.117	0.023
15	0.118	0.102
17	0.091	2.307

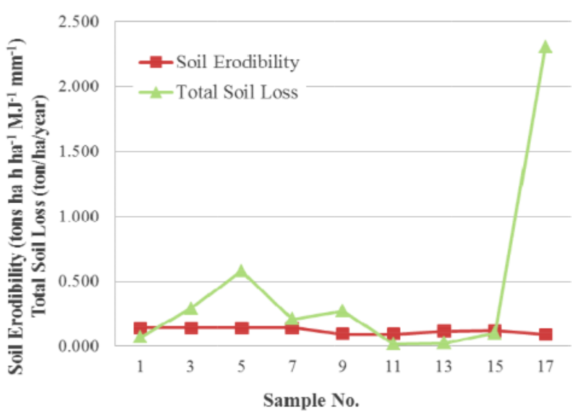

Fig. 1 Correlation between soil erodibility and total soil loss of the study area.

To investigate correlation between soil erodibility and soil erosion/soil loss, calculation of soil erosion/soil loss was performed considering other main factors includes rain erosivity, topographic factor, cover and management factor and support practice factor. Calculation of soil erosion/annual soil loss was applied USLE (universal soil loss equation) introduced by Wischmeier and Smith [5]. The input data was obtained from field observation and rainfall monitoring.

As can be seen in Table 5, almost all of the sampling point have total soil loss < 2 ton/ha/year. Sampling point which has lowest soil erodibility (0.091 tons ha h/ha/MJ/mm) has the highest soil loss (2.307 ton/ha/year). It indicates that there are other factors controlling soil loss. Investigation to the field data showed that sample No. 17 has steep slope (30%-60%), thus topography factor was the affecting factor to the high of soil loss.

Correlation between soil erodibility and soil erosion/annual total soil loss can be seen in Fig. 1. The chart shows that there are strong relationships between soil erodibility and soil erosion but the correlation was not fully linier due to other factors controlling soil erosion/annual total soil loss.

Results of this research are very important for making decision on soil erosion and sedimentation control, soil treatment, type of land cultivation and management, degree and type of conservation practice and other human intervention, continual improvement to achieve reclamation success and sustainable use of land.

5. Conclusions

Soil erodibility in study area range from 0.091 to 0.142 tons ha h/ha/MJ/mm and categorized as very low and low of soil erodibility. It indicates that based on soil erodibility, lands are not easily to be eroded. Correlation between soil erodibility and soil texture indicated that the highest erodibility was clay, followed by clay loam and silty clay loam. Clay is characterized by very small particle size and low infiltration capacity. Those characteristics were causing high surface run off carried soil particles. Correlation between soil erodibility and predicted soil erosion/annual total soil loss indicated strong relationships between soil erodibility and soil erosion but the correlation was not fully linier due to other factors controlling soil erosion/annual total soil loss. Results of the analysis of soil erodibility are needed to predict soil erosion and it is very important for making decision related to land management especially for soil erosion and sedimentation control.

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References

[1] Erosion and Sediment Control Surface Mining in the Eastern United States, Planning, Environmental Protection Agency, United States, 1976.

[2] A. Wild, Soil and the Environment: An Introduction, Cambridge University Press, New York, 1993.

[3] Decree of Director General of General Mining, Indonesia Ministry of Mining and Energy No. 693.K/008/DDJP/1996 Concerning Technical Guidance Erosion Control in General Mining Operation, Republic of Indonesia, Jakarta, 1996.

[4] H. Blanco, R. Lal, Principle of Soil Conservation and Management, Springer Science + Business Media B.V., USA, 2008.

[5] W.H. Wischmeier, D.D. Smith, Predicting Rainfall Erosion Losses—A Guide to Conservation Planning. Agricultural Handbook No. 537, United States Department of Agriculture, Washington D.C., 1978.

[6] R.P.C. Morgan, Soil Erosion and Conservation, 3rd ed., Blackwell Publishing Ltd., USA, 2005.

[7] S. Arsyad, Konservasi Tanah dan Air. EdisiKedua (Land and Water Conservation), 2nd ed., IPB (Institute Pertanian Bogor) Press, Bogor, 2010.

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