Organized By:

Departement of Agricultural Engineering
Faculty of Agricultural Technology
Universitas Gadjah Mada

Perhimpunan Teknik Pertanian
PERTETA
Cabang Yogyakarta

isabe
Yogyakarta, August 28-29 2013

The International Symposium on Agricultural and Biosystem Engineering

Proceedings

Supported by:

한국농업기계학회

Sponsored by:

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Yogyakarta, 28-29 August 2013
Departement of Agricultural Engineering, Faculty of Agricultural Technology, Universitas Gadjah Mada
Jalan Socio Justicia No.1 Bulaksumur
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Analysis of Soil Erosion on The Catchment Area of Musi Hydro-Power Plant, Bengkulu Province

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Abstract

This research aims to determine the soil erosion that occurs in the Musi catchment Hydro-Power Plant Bengkulu. The study was conducted from October to December 2012 in the catchment area of 60.357.21 ha. This area is located at 102 ° 22'18 .98 "-102 ° 38'38 .93" Lat., And 3 ° 16'28 .873 "-3 ° 33'57 .441" long. The potential for soil erosion that occurs in hydropower Musi river basin using USLE method to determine the index of rainfall erosivity, soil erodibility, and slope length, crop management, and soil management. In addition, this study also calculates Sediment Delivery Ratio (SDR), the ratio analysis method to estimate the amount of sediment is calculated based on the calculation of the amount of total sediment erosion in the watershed area. The results showed that the total amount of erosion that occurs in the Musi Hydro-Power Plant, Bengkulu Province reached 1.737.884,27 tons / year which is twice the value of soil erosion tolerance of 811.804,475 tons / year. The amount of sediment released into the Musi river in the catchment, further, is of 137.292,857 tons / year is twice the value of tolerance sediments of 64.132,55 tons / year, unfortunately.

Keywords: Musi Catchment Hydropower,Soil Erosion, Rainfall erosivity and Sedimentation

Introduction

Musi Hulu sub-watershed had been functioned as a water catchment area for Hydroelectric Power Plant (HEPP) Musi and conservation value is very important especially as life support communities in the District Rejang Lebong and the District Kepahiang. Along with the increased activity in the upstream population led to the need for greater land so the impact on land use changes in the watershed Musi Upstream. Based on data from watershed land use MusiUpstream in 2003 by the Ministry of Public Works Central River Region VIII Sumatra, an area of 30% primary forest, secondary forest (dry) 7%, 23.5% field, open land 0%, 6% plantation, settlement of 1%, rice 0%, and 33.5% shrubs. Whereas in 2007 to change the use of land, the area of 8% of primary forest, secondary forest (dry) 19%, 46% field, open land 3%, 5% plantations, settlements 2.5%, 3% rice, and shrubs 13.5%-bush.

Changes in land use in the watershed is particularly Musi Hulu from forest to other uses, resulting in the ability of the area of land upstream as water infiltration is reduced so that most of the rain water to run off. The amount of rain water runoff can cause erosion and sedimentation in the catchment area is increasing, and the flood discharge will occur rainy season and then will be followed by drought in the dry season. This is because all the water in the rainy season rapidly flows downstream due to high surface runoff, so the stored water in the upstream becomes greatly reduced (Sumarto, 1987).

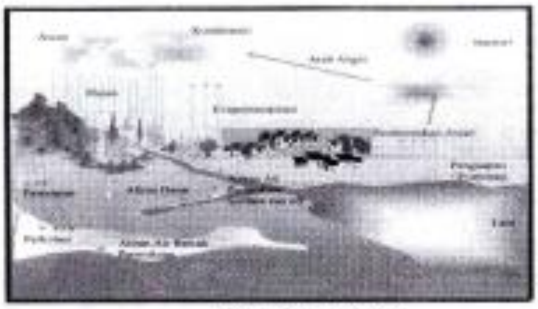
Herefore, to solve these problems, we need to study how mucherosion, and sedimentation in the Musi catchment upstream so that they can provide additional information for the public and relevant agencies in the context of river basin management more effective and efficient.

Basic Theory

Hydrological Cycle

Hydrological cycle is the process of drainage and conversion into water vapor condenses back into water continues unceasingly. Hydrological cycle is the journey of water from the sea surface to the atmosphere and then to the ground and back again to the sea and that is never exhausted. The water will be detained temporarily in rivers, lakes / reservoirs, in the soil so that it can be used by humans or other creatures. In the hydrologic cycle,thermal energy causes evaporation (Asdak, 2007).

Processes on hydrological cycle can be seen in Figure 1.



Sources: Anonymous II, 2009

Figure 1. Hydrological Cycle

Watershed

Watershed is an area of land which is an integral part of the river and its tributaries, which serves to accommodate, store, and drain water fróm rainfall to the lake or to the sea naturally, which is the limit on land is the separator topographic and boundary in the sea until the water area is still affected by land activities. Sub-watershed is part of the watershed that receives rainwater and releases it through tributaries to the main river. Each watershed is divided into sub-watershed runs - Sub-watershed (Anonymous II, 2009).

There is a small watershed and there is also very broad. Large watershed may consist of several sub-watersheds and sub-watersheds may be composed of several sub-sub-basin, depending on the number of branch tributary rivers, which are part of a major river system. The condition of a watershed is deemed impaired if the coefficient of runoff water tends to rise from year to year, the ratio of the maximum and minimum water level tends to rise from year to year, and the ground water level fluctuates in the extreme (Asdak, 2007).

Erosion and Sedimentation

Erosion and Sedimentation is the process of soil particle detachment from its parent in a place, and the material terangkutnya by the movement of water or wind, followed by deposition of material contained elsewhere (Sucipto, 2008).

Sediments can be divided into two groups based on the mechanism of the movement as follows :

1. Suspended Load, which moves sediment particles suspended in a stream of water.
2. Bed Load, which moves sediment particles rolling and jumping.

According to the original condition (White, 1987 in Sucipto, 2008), the sediment can be divided into:

1. Bed Material Transport, dimana material berasal dari saluran itu sendiri.
2. Wash Load, dimana material tidak sama dengan sedimen Bed Load dan ditambah oleh material luar saluran.

Types of Water Erosion

AccordingHardjowigeno.S(2007), the types ofwater erosionis dividedinto seven, that is, Dissolving, SplashErosion, SheetErosion, RillErosion, GullyErosion, ChannelErosion, Avalanche.

USLE Erosion Analysis Methods

According Asdak (2007), to estimate the amount of erosion that occurs in a watershed is USLE method can be used, with the formula:

E = R.K.L.S.C.P....................(1)

Where :

E = Estimated total amount of erosion (ton / ha / year).
R = Rainfall erosivity factor.
K = Soil erodibility factor.
L.S = Length-slope factor.
C = Factor land cover crops or crop management.
P =Factor land conservationmeasures.

Rainfall erosivity index (R) is calculated using the formula Bols: Rm = 6.119 x (Rain) x 1.21 m (Days) x 0.47 m (Max P) 0.53 m ....(2)with:

- Rm is the monthly rainfall erosivity average (EI30).
-(Rain) m is the number of monthly rainfall average in cm
-(Days) m is the number of days the average monthly rainfall in a given month
-(Max P) m is the rainfall average daily maximum for a particular month in cm.

Sediment analysis methods SDR

The amount of sediment yield estimates by Asdak (2007) may be determined by the following equation :

Y = E (SDR) Ws.........................(6)

Where :

Y = The result of sediment per unit area.
E = Erosion total.
Ws = Area of the river drainage area.
SDR = Sediment discharge ratio.

Materials and method

Research Sites

The research was conducted in the watershed upstream Musi, Kepahiang District and District Rejang Lebong. Site review of research can be seen in Figure 2.

Sources : Amri K, et al(2010)

Figure 2. Hulu Musi Catchment Map

Data Collection

Primary Data

Primary data collection method used in this study were performed with a descriptive survey approach, namely in the field of soil sampling for calculation of erosion and sedimentation. Sampling was done at some point which is located in the Upper Musi catchment based land unit map of the area.

Secondary Data

The data used in this study include :

1. Daily rainfall data for the last 25 years.
2. Map unit watershed land Musi Hulu.
3. Hulu Musi catchment map.
4. Data on land use and watershed characteristics Musi Hulu.
5. Data Musi river basin topography and geology Hulu.

Data Processing

Stages of processing data in this study include:

To determine the statistical parameters of maximum rainfall data.

procedure :

1. Determination of the monthly rainfall erosivity average (EI30) (Rain) m is the number of monthly rainfall average in cm -
2. Dermination of the number of days the average monthly rainfall in a given month
3. Determination of the rainfall average daily maximum for a particular month in cm.
4. Determination of the total erosion
   E = R.K.L.S.C.P
5. Determination of the sediment
   Y = E.(SDR).Ws

Result and discussion

Overview Of The Musi Catchment Upstream

DAS Musi Hulu is catchments which serves to accommodate, store, and drain rainwater to the Musi hydropower dam located in District Ujan Mas, Kepahiang District. Watershed Upstream Mushi administratively located in the District Kepahiang and Rejang Lebong District, Bengkulu Province.

Hulu Musi catchment geographically located at 102 ° 22'25 "- 102 ° 38'39" east longitude and at 3 ° 16'28 "- 3 ° 33'59" south latitude. This watershed has an area of 60.357,21 ha. Limitation of Musi catchment area of the Upper namely: east borders the river water Kelingi and South Sumatra province, north bordering Lebong regency, west bordered by Sub-watershed Lemau and North Bengkulu, and the south by the District Kepahiang.

Hydrological characteristics of the Musi catchment upstream topography Conditions

According BPDAS Ketahun (2012), topographic profiles Musi catchment upstream region is dominated by hills were choppy with pungguk rather steep hill, ramps, up the slope of the flat.

Rainfall and Climate Conditions

The amount of annual rainfall in the upstream watershed Musi last 25 years mostly at the level of 2000-3000 mm / year, the highest amount of rainfall occurred in 2005, namely at the level of 5000 mm / year, and the lowest occurred in 2011, ie below 500 mm / years.

Watershed Upstream Musi has wet months (rainfall more than 100 mm) in all year round. Lowest rainfall occurs in June, July, and August in the amount ranging between 132-170 mm / month. Based on the determination of rainfall patterns according Tjasyono (2008) in Sirait Hansen (2010), contained in the precipitation Musi river basin upstream rainfall patterns are grouped into type A or pattern Monsun.

According to Suharto (2009), the climate in the Musi catchment upstream including climate and wet tropical climate classification according to Smith-Ferguson including zones A, due to the higher number of wet months than dry months in each year.

Land Use Conditions

Land use Hulu Musi catchment area is dominated by a young shrub land cover types and mixed garden of 40.69%, and 26.39% of the forest.

Distribution of Soil Types

Broadly speaking there are watershed land Upstream Musi consists of alluvial soil and soil mineral acid such as land inseptisol, entisols, histosols and ultisol.

Analysis of Rainfall

Maximum Daily Rainfall

Rainfall data obtained were analyzed in advance to get the maximum daily rainfall data. After analysis by the method of partial series (sort of data from large to small or vice versa), obtained by the maximum daily rainfall data for 25 years in sequence.

Erosion Analysis

By using models of calculating soil loss or Universal Soil Loss Equation (USLE), so we can determine the amount of erosion that occurs.

E = R.K.L.S.C.P

Description :

E = Estimated total amount of erosion (ton / ha / year)

R = Rainfall erosivity factor

K = Soil erodibility factor

L.S = Length-slope factor

C = Factor crop land cover

P = Factor land conservation measures

Rain Erosivity Factor (R)

Table 9. Value Calculation Erosivity

No	Month	Rain (cm)	Days	Max P (cm)	EI_{30}
1	January	23,41	17,96	4,50	158,54
2	February	20,95	15,42	4,57	150,21
3	March	26,01	19,56	4,84	179,94
4	April	21,56	17,25	4,71	149,88
5	May	20,13	15,08	5,03	152,12
6	June	13,26	12,32	3,41	82,14
7	July	13,95	13,04	3,46	85,80
8	August	17,08	13,28	3,84	114,73
9	September	20,78	14,44	4,53	152,61
10	October	22,25	16,84	4,53	154,24
11	November	24,44	18,68	4,26	159,26
12	December	32,19	19,63	5,34	244,80
Value of R = Total EI_{30}					1784,27

Sources:Calculation Results

Factors Erodibility Land (K)

Once the value of Texture Soil Ingredients Organic, Soil Structure and Permeability Soil is known, it can be determined the value Erodibility Soil (K) using Nomogaf based on each land unit, then taken K values averaged to obtain the value of K at 0.088.

Length-Slope factor (L.S)

Table 10. Analysis of Slope (slope)

No	Slope Class	Area (ha)	Area	S %	S Factor
1	Flat (0-8%)	14.325,62	0,24	4,0	0,0095
2	Ramp (8-15%)	25.760,40	0,43	11,5	0,0491
3	Rather Steep(15-25%)	14.282,75	0,24-	20,0	0,0473
4	Steep (25-45%)	3.069,67	0,05 •	35,0	0,0178
5	Very Steep(>45%)	2.931,53	0,05	72,5	0,0352
	Total	60.369,97			0,16

Sources: BPDAS Ketahun, 2012 and Calculation Results

Land Cover Crop Factor (C)

Land cover crop factor determined from land use multiplied by the index of crop management.

Table 11. Determine the average value C

No	Land Cover	Total	%Area	C	C x %Area
1	Young Thicket	514,35	0,009	0,001	0,000009
2	Old Thicket	2247,98	0,037	0,001	0,000037
3	Open Land	4632,29	0,077	1,000	0,077000
4	Mixed Garden	4448,04	0,074	0,200	0,014800
5	Young and Mixed Garden Grove	24564,92	0,407	0,100	0,040700
6	Forest	15931,45	0,264	0,001	0,000264
7	Field	4052,82	0,067	0,400	0,026800
8	Settlement	2893,05	0,048	1,000	0,048000
9	Rice Fields	912,79	0,015	0,010	0,000150
10	Rubber Society	85,32	0,001	0,200	0,000200
11	Young Shrub and Rubber	86,95	0,001	0,100	0,000100
	Total	60369,97			0,208060

Sources: BPDAS Ketahun, 2012 and Calculation Results

Factors Soil Conservation Measures (P)

Land conservation measures factors determined from soil conservation index is determined from the interpretation of the types of crop land are evaluated with slope.

Table 12. Determine the average P value

No	Slope Class	Area (ha)	%Area	P	P x %Area
1	Flat (0-8%)	14.325,62	23,73	0,50	0,1186
2	Ramp (8-15%)	25.760,40	42,67	0,75	0,3200
3	Rather Steep(15-25%)	14.282,75	23,66	0,75	0,1774
4	Steep (25-45%)	3.069,67	5,08	0,90	0,0458
5	Very Steep(>45%)	2.931,53	4,86	0,90	0,0437
	Total	60.369,97			0,7056

Sources: BPDAS Ketahun, 2012 and Calculation Results

Erosion hazard rate is the ratio of the erosion that occurs with tolerance erosion (erosion are still allowed). Based on an approximate calculation of the amount of erosion that occurs at catchment Musi hydropower is x same amount of total erosion area Musi hydropower catchment, namely is 13.45 tonnes / ha / year. The all total = 1.737.884,27 tons / year.

The amount of erosion tolerance obtained by Table 2.2 Tolerance of Soil Erosion To Size (Thompson, 1957) in Sucipto (2008), where soil conditions hydropower catchment area Musi including soil conditions with lower permeability layer rather quickly in the unconsolidated materials have value erosion tolerance of 13.45 tonnes / ha / year with a catchment area of Musi hydropower 60.357,21 ha, the total erosion tolerance for hydropower Musi catchment area is 811.804,475 tons / year. Therefore the magnitude of erosion index was at is 2,14.

Sedimentation Analysis

Based on estimates of sediment by Asdak. C 2007 The amount of sediment can be determined as follows :

$$Y = E\,(SDR)\,Ws$$

Where :

Y = The result of sediment per unit area

E = Erosion total

SDR = Ratio Sediment Discharge

Ws = Area Watershed

Based on the estimated USLE method, total erosion values obtained (E) in the Musi catchment hydropower that is equal to 13,45 tonnes / ha / year with a catchment area 60.357,21 ha, then the value obtained from Table 2.1 Sediment Discharge Ratio (SDR) of 0.079 , so that the flow of sediment that occurs in the catchment area are as follows Musi hydropower.

Based on calculations, the value of the sedimentation in the catchment area Musi hydropower amounted to 137.252,857 tonnes / year, while the value of tolerance is the product of the sediment erosion tolerance values and the SDR rate. For flow in hydropower Musi catchment erosion tolerance value is 811.804,475 tons / year and the SDR rate is 0.079, so the value of tolerance sediment is 811.804,475 tons / year x 0.079 = 64.132,55 tons / year. Of values can be seen that the sedimentation rate in the Musi catchment hydropower already passed the maximum tolerance limit.

Conclusions And Suggestions

Conclusion

The magnitude of the erosion in the catchment area Musi hydropower reached 13,45 tons / ha / year or at 1.737.884,27 tons / year which exceeds the tolerance limit erosion in the amount of 811,804,475 tons / year. So the index erosion in the catchment area including grade Musi hydropower ugly or exceeds the maximum tolerance. The amount of sedimentation in the catchment area Musi hydropower amounted to 137.252,857 tons / year which exceeds the tolerance limit sedimentation in the amount of 64.132,55 tons / year.

Suggestion

Rainfall data should be used in the calculations obtained from the rain at least 3 stations located in the catchment area for the results to be more accurate calculation. Maintain the availability of water for hydroelectric energy sources Musi, the manager should evaluate the capacity of hydroelectric dams in order to accommodate the maximum discharge (excess water) that occurs during the rainy season, so that during the dry season (low rainfall) water being stored is expected to meet the needs of discharge electrical energy. Reduce the rate of erosion and sedimentation, high erosion areas should be carried out replanting with plant density is high enough and the plantation areas are sloping land conservation efforts should be made by way of the creation of soil conservation terraces.

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