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Spatial Distribution Level of Land Erosion Disposition Base on The Analysis of Slope on Central Lematang Sub Basin

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Abstract. Soil erosion is a natural process that is influenced by the magnitude of rainfall intensity, land cover, slope, soil type and soil processing system. However, it is often accelerated by human activities, such as improper cultivation of agricultural land, clearing of forest land for mining activities, and changes in topographic area due to use for other purposes such as pile materials, mined pits and so on. The Central Lematang sub-basin is part of the Lematang sub basin, at the Musi River Region Unit, South Sumatra Province, in Indonesia, which has a topographic shape with varying types of slope and altitude. The critical condition of Central Lematang sub basin has been at an alarming rate, as more than 47.5% of topographic and land use changes are dominated by coal mining activities and forest encroachment by communities. The method used in predicting erosion is by USPED (Unit Stream Power Erosion and Disposition). This is because the USPED[1] method can predict not only sediment transport but also the value of peeling (detachment) and sediment deposition. From slope analysis result, it is found that the highest erosion potential value is found on slope (8-15%) and the sediment is carried on a steep slope (15-25%). Meanwhile, the high sediment deposition area is found in the waters of 5.226 tons / ha / year, the steeper area of 2.12 tons / ha / year.

INTRODUCTION

Erosion is the displacement of soil or rock particles by a natural medium such as water or wind, and would interfere with human activities. The main factor of soil erosivitas are rainfall, which will remove soil particles by two main processes: exfoliation of topsoil caused by raindrops that hit the ground and the occurrence of runoff. Pressure on land resources through human activities, such as illegal logging and farming land that is not suitable, coupled with the influence of climate change on the period and the amount of rainfall is intensive, will result in the degradation of the land caused by rainfall is over the normal rainfall that will increase the occurrence of runoff and soil erosion. The process of soil erosion has caused huge losses in the environmental field, because it has led to loss of land, destruction of soil aggregates, and the reduction of organic materials that will reduce soil fertility. Soil erosion impacts include downstream sedimentation that could reduce the flow capacity of the river, increasing the risk of flooding, and reduce the capacity of the reservoir[2]. Flooding often occurs today, due to the silting of the river which is one of the main sources of pollution of the river basin of Musi[3]. In addition, the sediment load that enters the rivers and lakes can contaminate the waters with increased turbidity, reducing sunlight penetration and affect the temperature of the water. Contribution to the decline in water quality through nutrient-laden heavy metals or other toxins and absorbed through the fine particles, which would lead to eutrophication, or water quality[4].

Distribution patterns of erosion and sedimentation deposition direction can be estimated by analyzing the slope, soil type, vegetation cover and the amount of rainfall that occurred in the region. The essence of modelling is to combine erosion sediment production processes that occur because peeled off topsoil (scour the land) by rainfall and water flow through the sediment transport processes. Putranto, et al (2014-2016)[5] to evaluate the magnitude of the critical sub watershed land Musi upstream to the middle section, using rainfall-runoff modelling spatial and found that the amount of soil erosion is found in areas with a slope > 37%, mixed land use and soil type alluvial.

METHODOLOGY

The purpose of this study was to assess the impact erosivity on water quality in the middle of upstream sub-basins Lematang are widely used for agriculture. This paper discusses ways to obtain quantitative estimates of soil erosion to better understand the overall connectivity between the slope and channel system which is the source of irrigation for agricultural activities. The focus is on the relationship between the supply of sediment that flowed into the river, and analyzed using modelling soil erosion and sediment transport which is implemented using GIS (Geographic Information Systems). By analyzing the degree of slope erosion using models of soil erosion, and predict patterns of sediment supply to the river, the model can predict parts of a landscape that shows which parts are more likely to contribute to sediment in larger quantities to the network channel and at which areas, a large amount of sediment will tend deposited on the channel. This prediction was tested by taking a sampling of fine sediment from the riverbed at key locations along the channel network and comparing the observed pattern with that predicted by models of soil erosion. Thus, the model focuses on the complex interaction between topography, soil and land use in influencing the potential for soil erosion and how the spatial distribution of these factors that cause variations in the distribution of erosion and deposition in the watershed. However, most applications are made not to focus on the delivery of sediment to the river segment or make suggestions clear management for soil and water conservation program, which is the main focus of this paper.

Study Area

The study was conducted on the territory of Central Lematang sub watershed, which is part of the watershed of Lematang, and part of the Regional Unit of the Musi River (Fig. 1). In administration, location of the region lies in District of West Merapi, Lahat, South Sumatra Province. Geographically, the study area located at coordinates 103° 29' 27.24"- 103° 43' 55.03" East and between 3° 56' 23.64" - 3° 42' 9.47" South hemisphare.

The area of research sub-catchment middle Lematang is 437.259 km2 with slope watershed middle Lematang ranged from 0% to 73.31%, spread in nine major river sub-basins. The distribution of land use in the area of research, the most widespread is the rubber plantation with an area of 110,490.03 hectares, and forest area of 34,608.650 hectares. While covering an area of 2,941.69 ha agricultural areas and open land area of 2,606.28 Ha. Soil type is dominated by podsolic brown red with rainfall intensity for 30 minutes (I_{30}) with a return period of 5 years, amounting to 79.57 mm/hours.

The USPED model employs a stream power-based sediment transport model with an expression of mass conservation to simulate soil erosion and deposition. The model departs from the RUSLE annual average soil loss equation expressed by E (tons/acre/year)[6] :

$$E = R.\ K.\ LS.\ C.\ P \qquad (1)$$

Where R represents the rainfall erosivity index, K the soil erodibility factor, LS - the slope length and steepness, C the land cover management factor, and P represents the support practices factor. The R, K, C, and P factors have fixed values and can be determined empirically[7][8].

The LS factor accounts for the strength/erosivity of the surface runoff and is expressed as the ratio of soil loss under a given slope steepness and length to the soil loss from the standard condition of a 5° (9%) slope, and 22.13 m length[8] :

$$LS = (\lambda/22.13)^t\ (65.4 \sin 2\beta + 4.56 \sin\beta + 0.0654) \qquad (2)$$

where λ is the slope length in meters (horizontal projection of the slope length in meters), β is the slope angle (degrees), and t is the length exponent that depends on slope steepness, with values of 0.5 for slopes exceeding 5%, 0.4 for 3-5% slopes, and 0.3 for slopes less than 3% slopes. This expression assumes standard slope parameters failing to take into account the topographic complexity of the upslope contributing area and is thus inappropriate for sediment delivery estimations. For example, argues that "the use of sediment delivery ratios owes its origin to the observation that using erosion predicted by the USLE overestimates the amount of sediment delivered from hillslopes, because sediment deposition often occurs on hillslopes and the USLE does not account for deposition"[9].

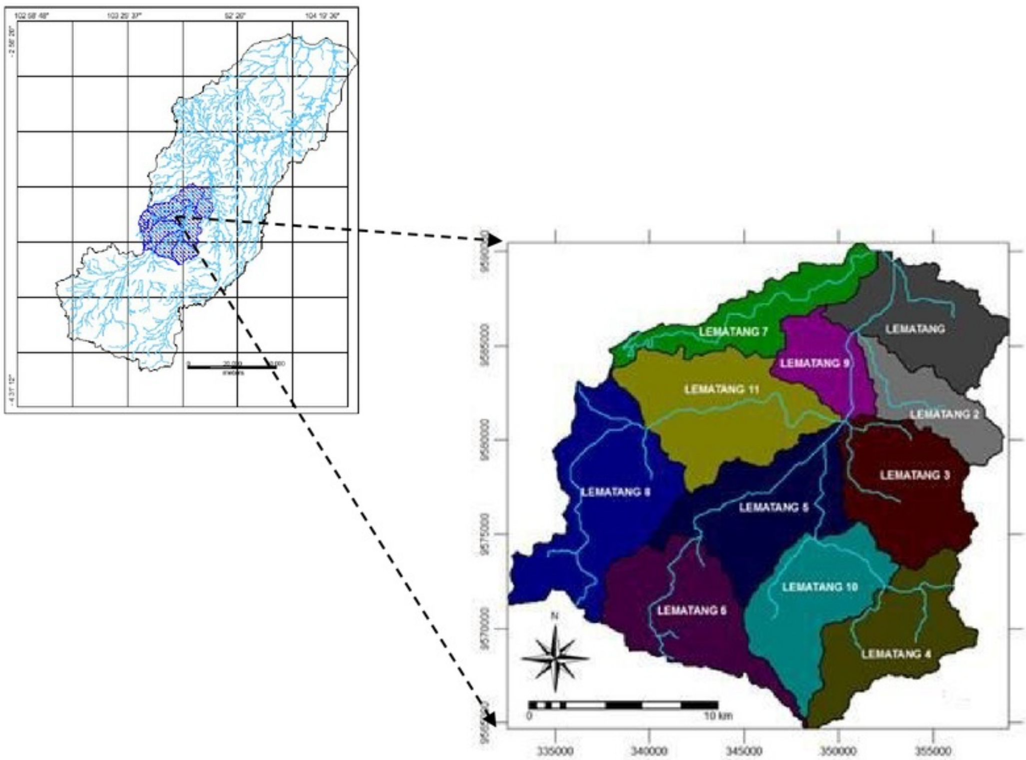


FIGURE 1. Location of research area

The value of sediment transport capacity used equation as follows [10]:

$$qs = K_t \, q^m \, sin^n \, b \tag{3}$$

where b represents the local surface slope (degrees), q is the unit water flow rate (m2/sec.), K_t is the soil transportability coefficient (dependent on soil properties and vegetation cover), and m and n are constants depending on the type of flow and soil properties. equation 3 provides the sediment flux (volume per unit width, m2/s) in the direction of the maximum hillslope gradient

$$q_s = R \, exp(-Rc/Ro) \tag{4}$$

where

$$R_c = 1000*MS*BD*RD*(Et/Eo)*0.5 \tag{5}$$

$$Ro = R / Rn \tag{6}$$

R_e is dependent on the moisture storage capacity (MS) of surface soil which can be derived from field capacity. It is also dependent on the soil bulk density (BD). Moreover it is dependent on rooting depth (RD) of various cover types, the ratio of actual to potential evapotranspiration (Et/Eo), the amount of annual rain (R) and the number of rainy days (Rn).

The results of the USPED model represent relative magnitudes of the soil erosion and deposition rates rather specific soil loss values traditionally expressed in tons/acre/year. This issue of dimensionless units were addressed by standardizing the model results in order to make comparisons meaningful at the sub-basin scale.

The net erosion/deposition ED is then computed as a divergence of sediment flow (change in a 2D field representing sediment flow in the direction of elevation surface gradient)[11] :

$$ED = \text{div}\ (q_s) = \partial(q_s \cos \alpha)/\partial x + \partial(q_s \sin \alpha)/\partial y \qquad (7)$$

where α in degrees is the aspect of the terrain surface (direction of flow). We get D in [kg/(m2.s)] by dividing T [kg/(ms)]/dx[m] or T [ton/10000m.year]/dx[m] = D[ton/(10,000m2.year)] = D[(ton/ha.year)]

RESULTS AND DISCUSSION

Model Implementation

In USPED (Unit Stream Power Erosion and Deposition) modeling, slope factor considered comparable to topographic index. Topography index results with parameter values K (soil erodibility), the value of C (land use), and P (land management), in order to obtain sediment transport. Elevation, soil, landcover, and hydrographic data for the central Lematang sub basin were acquired from a number of sources and processed by using GIS technique : (a) SRTM, to obtain slope, flow direction and 11 boundary pattern of river flow on central Lematang sub basin with 25 m resolution DEM; (b) Satellite TM + 8 image data on 5-4-2 combination band for land cover classification and management factor (C), and Root depht (Rd); (c) Soil information from Soil map from Bogor Agricultural Institute, to classify Bulk Density (Bd), Erodibility factor (K) and Moisture factor (Ms).

TABLE 1. Soil value parameter

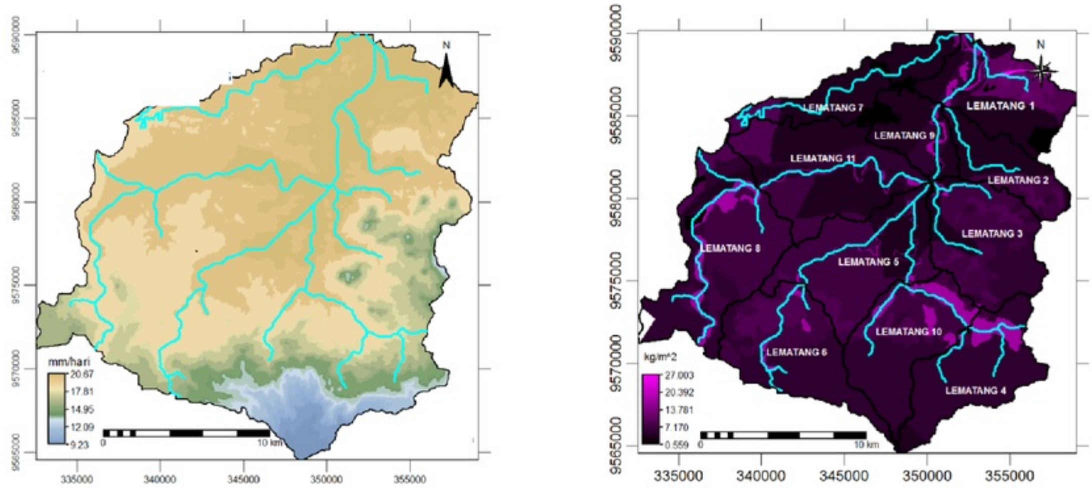
Soil Type	Texture	Area (Ha)	K	Bd	Ms
Brown Aluvial	Dust Clay	4,076	0.15	0.9	0.13
Brown Podsolic & Litosol	Clay loam	14,39	0,166	0.9	0.18
Brown Podsolic & Podsolic	Clay	1,474	0.166	1.04	0.1
Yellow Podsolic & Hydro	Clay	2,802	0.249	1.04	0.1
Yellow Podsolic & Podsolic	Clay	6,787	0.107	1.04	0.1
Red Yellow Podsolic & Podsolic	Clay	803.9	0.166	1.04	0.1
Podsolic reddish brown	Clay loam	5,473	0.166	0.9	0.18
Yellow Podsolic	Clay	4,814	0.107	1.04	0.1
Podsolic yellowish	Clay	3,101	0.166	1.04	0.1

Rainfall data used is daily and yearly for 10 years, from 2006 to 2015 th. The rainfall data is obtained from 3 rain gauge stations, West Merapi at UTM coordinats (352,300.800; 9,594,559.720; 75 m), UPPT-Lahat (340,312.859 9; 581,864.710; 100 m) and Pulau Pinang (334,865.110; 9,567,180.129; 325 m).

Sediment Transport Analysis

The soil loss equation parameters have been derived as follows:

1. Erosivity factor (R) - for the study area, the greatest level of R release rate in central Lematang watershed is 27.003 kg/m^2. While the value of release rate the smallest soil is 0.559 kg / m^2.
2. The results of the analysis of sediment transport in the catchment area classified according to each sub basin



(a) (b)

FIGURE 2. Rainfall map per number of average annual rain days (a) and result of erosivitas factor at study area (b)

The geometric properties of topography (slope, terrain curvatures) are the determining factor in the spatial distribution of the sediment transport capacity of a particular watershed. Normally characteristic for areas with good vegetation cover, but it can also occur on severely compacted soils on which soil detachment and rill formation are prevented by compaction. Increasing upslope contributing area combined with a high value of the local slope is translated into a high sediment transport rate. The areas of high transport rate are also associated with concave slope profiles and valleys because these are areas of convergent accelerated flow.

TABLE 2. Value of sediment transport per sub basin

Name of Sub Basin	Area (Ha)	Transport Sediment (ton/ha/year)
Sub Lematang 1	3,808.3	1.794
Sub Lematang 2	2,241.4	1.176
Sub Lematang 3	4,228.6	2.889
Sub Lematang 4	3,948.9	0.166
Sub Lematang 5	4,773.8	5.953
Sub Lematang 6	4,423.1	2.832
Sub Lematang 7	2,975.7	0.243
Sub Lematang 8	5,914.0	0.161
Sub Lematang 9	2,014.0	0.175
Sub Lematang 10	4,133.0	0.483
Sub Lematang 11	5,266.2	0.281

Analysis of Sediment Transport and Deposition

The level of erosion and sedimentation are classified by catchment area of each sub basin, in order to get the value of ED according to the catchment area boundaries were analyzed previously. Results limitation ED values can be seen in table 3. Based on table 3 found that the sub-Lematang 1 has a high degree of sediment deposition enough of 2.3035 ton/ha/ year. While the sub-Lematang 5 is a region of sediment deposition maximum of 1.417 ton/ha/year.

TABLE 3. Value of ED per sub basin

Name of Sub Basin	Area (ha)	Average of ED (ton/ha/year)
Sub Lematang 1	3,808.3	- 2.303
Sub Lematang 2	2,241.4	1.265
Sub Lematang 3	4,228.6	- 1.651
Sub Lematang 4	3,948.9	- 0.456
Sub Lematang 5	4,773.8	1.417
Sub Lematang 6	4,423.1	- 0.528
Sub Lematang 7	2,975.7	- 1.193
Sub Lematang 8	5,914.0	0.001
Sub Lematang 9	2,014.0	- 0.037
Sub Lematang 10	4,133.0	- 0.380
Sub Lematang 11	5,266.2	- 0.179

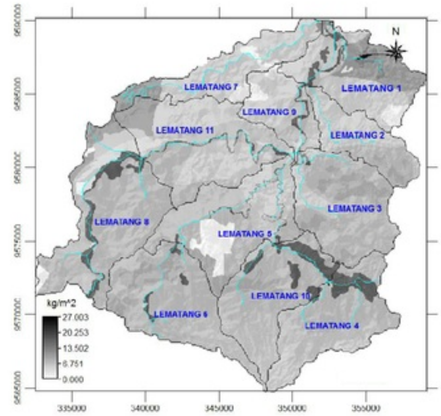


FIGURE 4. Central Lematang sub basin sediment transport rate included overland flow

The resulting erosion/deposition map (based solely on topography) shows that estimated high risk erosion areas are located on upper convex parts of hillslopes, in hollows and centers of valleys with concentrated flow. Areas of deposition usually occur on lower concave parts of hillslopes and in concave valleys. This situation is consistent with previous results suggesting that the highest erosion rates correlate with divergent shoulder elements and deposition with convergent footslope elements[12] or that the maximum soil loss occurs on slope convexities and maximum soil gain in both the slope concavities and the main thalwegs.[13].

If the spread of sedimentation analyzed based on various factors such as land use and land slope, the results can be seen on the following image.

Sediment transport rate and the spatial distribution of erosion and deposition as a function of topography

Based on the results of exfoliation ground level at grade slope, soil exfoliation results obtained for each grade level slope. The average yield and the maximum value exfoliation and a buildup of sediment in Table 4 and Figure 5.

TABLE 4. Value of ED each slope classification

Slope Class	Renge of slope	Area (Ha)	Average ED (Ton/Ha)
Class 1	< 8%	26,088.3 12	-0.3297
Class 2	8% – 15%	.7,390.375	-1.8239
Class 3	16% – 25%	.5,448.375	2.1207
Class 4	26% – 45%	.3,167.813	-0.3282
Class 5	> 45%	.1,416.063	0.1467

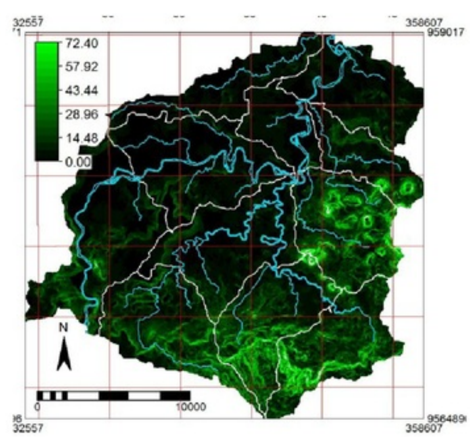


FIGURE 5. Sediment transport rate and the spatial distribution of erosion and deposition as a function of topography

When analyzed with slope, sloping area (8-15%) have a high degree of exfoliation which amounted to 1.8239 ton /ha and high precipitation in the region is rather steep (16-25%) of 2.1207 ton/ha.

Sediment transport rate and the spatial distribution of erosion and deposition as a function of topography and soil erodibility

Overall, introducing the K-factor in the analysis, the spatial pattern of the sediment transport capacity reflects the influence of areas of high erodibility, and thus sediment flow will have lower values on larger areas across the landscape rather than having very high values concentrated in concave areas of high slope. However, since the distribution of soil types is strongly correlated with topography, the pattern is also strongly dominated by topography.

The spread of sedimentation were also analyzed based on various factors soil types with the following results

TABLE 5. Value of ED per Soil Type

Soil Type	Teksture	Area (Ha)	Average of ED (ton/Ha)
Assosiation of Brown Alluvial	Dust Clay	4.076	1.9201
Assosiation of Brown Podsolic	Lom Clay	14.390	- 0.3372
Assosiation of Brown Podsolic	Clay	1.474	2.0519
Assosiation Yelow Podsolic & Hydromorf	Clay	2.802	- 2.2859
Assosiation of Yellow Podsolic & Podsolic	Clay	6.787	- 1.4316

The spatial distribution of erosion and deposition is also modified by the inclusion of the pattern of soil erodibility in the sense that it increases the areal extent of areas of high erosion risk.

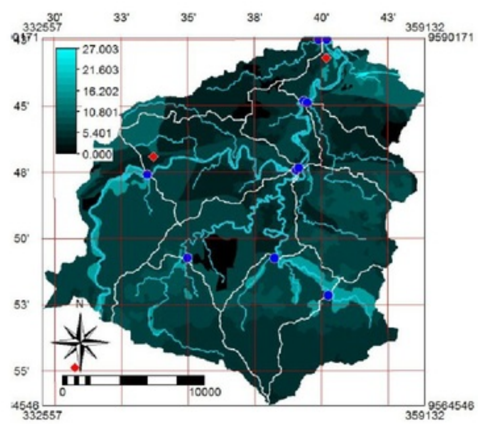


FIGURE 6. Sediment transport rate and the spatial distribution of erosion and deposition as a function of topography and soil erodibility

The influence of land cover on the sediment transport rate and spatial distribution of erosion and deposition

Based on the results overlay flaking level ground with the value of land use, land exfoliation results obtained for each land use, and the average value of peeling and the buildup of sedimentation as shown in Table 6.

Results of the classification ED (exfoliation of the upper soil) based on land use, it appears that the greatest exfoliation contained in the irrigation area of 2.139 tons / ha and sediments present in the territorial waters of 5.226 tons / ha.

Low C values indicating that they are naturally better protected from erosion by overland flow as opposed t_o gardens and irigation lands that are less resistant t_o erosion and have the highest C values, thus less resistant to erosion. The effect of this factor on the sediment transport capacity is to decrease the flux in areas that are well-protected by the vegetation cover and to increase it in areas that are poorly protected by a deeper root system. The inclusion of the C factor significantly alters the distribution of the areas of high sediment transport rate, making the topographic influence less pronounced and highlighting those areas of low protective vegetation cover, such as the regions at the confluence of the main stem with forest, plantation, and Embung and reservoir

TABLE 6. Sediment transport rate and spatial distribution of Erotion and deposition as a function of topography and land use clasification

Land Use	Area (Ha)	Average Value of ED
Village	9,191.875	0.8045
Irigation	1,640.8125	-2.1390
Dryland Farming	5,448.3750	2.1207
Garden	4,004.8125	-0.3282
Plantation	2,0581.1250	0.1467
Open Field	3,421.8125	-0.1521
Forest	10,753.7500	0.4978
Water	800.4375	5.2258
Open Land Use	36.5625	-0.0526

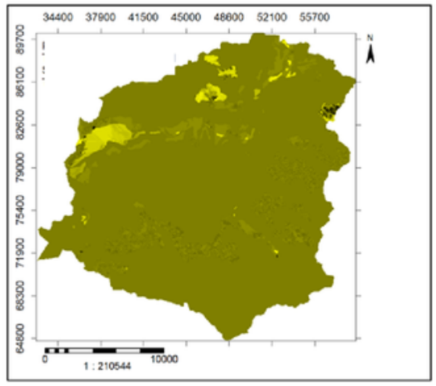


FIGURE 7. Sediment transport rate and the spatial distribution of erosion and deposition as a function of land use change

By adding the land cover factor in the computation, the patterns of both erosion and deposition shift t_o include areas of high erosion and deposition risk occurring at the contact line between cropland/pasture lands and forested lands, or on slopes of 15-25% that are less protected by the vegetation cover. This occurs as a result of the changes in the sediment transport rate associated with the transition from one land cover t_o another. For example, increasing transport rate in the direction of flow (as determined by local topography) would lead to net erosion.

CONCLUSION

Based on the research and discussion above it can be concluded some of the following:

1. From the analysis found that the value of slope erosion potential is highest at a rather steep slope (16-25%) and lees contained in the slope of ramps (8-15%).
2. From the analysis of the level of erosivitas based on land cover, slope and soil types obtained flaking areas with highest in irrigated area amounted to 2.139 ton/ ha / year, the height of the ramps at 1.8239 ton / ha / year, and has the type of soil yellow podzolic alluvial and hydro amounted to 2.28591 ton/ha/year. Meanwhile, who has a high sediment found in the waters of 5.2258 ton/ha/year, the region is rather steep at 2,1207 ton/ha/year and have the kind of alluvial soil brown podzolic and podzolic at 2.05188 ton /ha/ year.

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