ASSESSMENT OF SPATIAL DISTRIBUTION OF LAND BASED ON ANALYSIS OF SLOPE AND WATER CONSERVATION PROGRAMS

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Abstract

Soil erosion has tremendous impacts on most river systems. However, often accelerated by human activities, such as processing of agricultural land that is not suitable, clearing of forest land for mining activities and so on. This paper uses a spatially-explicit model to identify the sediment sources and delivery paths to channels and link these sediment supply processes to in-channel sediment transport and storage. The paper analyzes hill slope erosion and deposition rates using the Unit Stream Power Erosion and Deposition model in a GIS to estimate patterns of sediment supply to rivers in order to predict which portions of the channel network are more likely to store large amounts of fine sediments and thus are most sensitive to the effects of on and off-site soil erosion. This study focuses on the central Lematang area, Watershed of Lematang, Regional Unit of Musi River Basin, in Indonesia. The sedimentation influence has affected water quality and cause silting river that causes water to irrigation capacity is reduced. These predictions have been tested by sampling the fine sediment content of the streambed at key locations along the channel network and comparing the observed patterns to those predicted by the soil erosion model. From the analysis results obtained that the potential value erosion is highest on the slope 8-15% and the sediment was carried away on a rather steep slope 15-25%. Location erosion largest in the region irrigated by 2.139 ton/ha/year, at the largest of slope magnitude of erosion of 1,823 ton/ha/year with the yellow podzolic alluvial soil types.

Kewords : *Erosion, spatial, sediment, USPED*

1. 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 erosion 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 ilegal 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 (Morgan, 2005). 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 (Putranto, 2015). 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 (Toy et al., 2002).

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 modeling is to combine erosion sediment production processes that occur because lose topsoil (scour the land) by rainfall and water flow through the sediment transport processes. How does the process take place, depending on the scale and spatial resolution of the model was built and affected by time and space. Putranto, et al (2014; 2015;2016) has evaluated the magnitude of sub-soil moisture contents of the Upper until the center Musi River Basin, using spatial rainfall-runoff modeling and found the extent of soil erosion occurring on a slope of > 37%, with mixed land use and alluvial soil types. While sedimentation is commonly found in flat areas and basins, due to the non-working of the sediment transport process.

This paper discusses ways to obtain quantitative estimates of soil erosion to better understand the relationship between the slopes and river systems that are the source of irrigation for agricultural activities. The focus is on the relationship between the sediment supply that flows into the river, and is analyzed using soil erosion modeling and sediment transport that is implemented using GIS (Geographic Information Systems). By analyzing the degree of slope erosion, and predicting the sediment supply pattern to the river, the model can predict parts of the landscape that indicate larger amounts of sediment contribute to the channel network and in which areas, a large number of such sediments will tend to be deposited on the channel. This prediction was tested by taking a fine sediment sampling of the river bed at selected sites along the channel network and comparing the observed patterns with those predicted using soil erosion models. Thus, the model is focused on the interaction between topography, soil and land use in influencing the potential of soil erosion and how the spatial distribution of these factors causes variations in the distribution of erosion and deposition in the watershed.

2. Material and Methods

The Study Areas was conducted on the territory of Central Lematang sub watershed, which is part of the watershed Lematang, and part of the Regional Unit of the Musi River Basin. 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" E and between 3° 56 '23.64 "- 3° 42' 9.47" S.

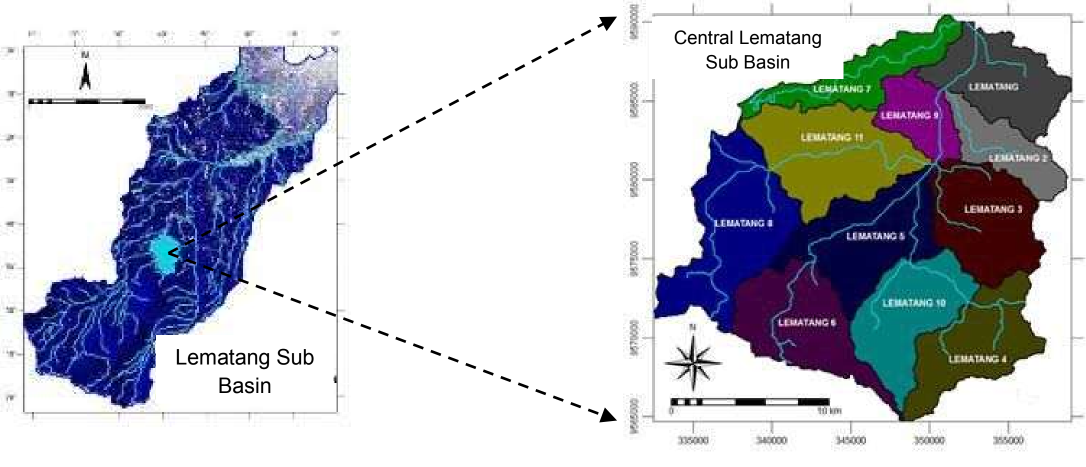


Figure 1. Location of Research area

The area of research sub-catchment central Lematang is 437.259 km2 with slope watershed central 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 ha. While covering an area of 2,941.69 hectares agricultural areas and open land area of 2,606, 28 hectares. Soil type is dominated by Podsolic reddish brown with rainfall intensity for 30 minutes (I_{30}) with a return period of 5 years, amounting to 79.57 mm / h

Model Formulation. The basis for the development of models of soil erosion that is used in the research area is the Revised Universal Soil Lose Equation (RUSLE) which predicts loss of soil yearly average as the product of five factors: rainfall, soil, slope length and slope of the land, as well as land use , To complete the model and obtain good estimates of the spatial patterns of erosion and deposition and to assess sediment delivery in the central Lematang sub basin, used analysis techniques utilizing USPED.

USPED (*Unit Stream Power Erosion and Disposition)* modeling first developed by Mistova et al. 1996 and Mitas and Mitasova, 1999 (Narcisa G Pricope, 2013) by assuming that the sediment transport depends on the strength of the kinetic energy of the water level erosion flow and is not affected on the supply of particles transported. Because estimates of soil mobility can not be obtained directly at the time of observation, there is uncertainty in an attempt to estimate the ratio of shipments. Uncertainty is particularly the case since the mobility of the sediment on the hillside depends on the distribution of the magnitude / frequency of occurrence and the fact that fluctuation sediment can be either the supply or transport of sediment are limited (the case of transport limited reference to the fact that the rate of transport of sediment determined by the forces of erosion of flowing water and is not limited by the amount of material transported). The model is not only important from a quantitative standpoint, but as a key instrument in making decisions in the monitoring and the elements that should go into the process of adaptive management continually on soil and water conservation activities.

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) (Renard et al., 1996):

$$E = R.\ K.\ LS.\ C.\ P \tag{1}$$

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 (Renard and Freimund, 1993, Wischmeier and Smith, 1978, Zaluski *et al.,* 2003). 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^o (9%) slope, and 22.13 m length (Wischmeier and Smith, 1978):

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

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, Kinnell (2004, pp. 3191) 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 hill slopes, because sediment deposition often occurs on hill slopes and the USLE does not account for deposition."

The value of sediment transport capacity used equation as follows

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

where *b* represents the local surface slope (degrees), *q* is the unit water flow rate (m^2/sec.), *Kt* 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, m^2/s) in the direction of the maximum hill slope gradient

Model Implementation. Elevation, soil, land cover, and hydrographic data for the central Lematang sub basin were acquired from a number of sources. These spatial data were used to derive the parameters needed for the soil loss equation, on which the entire modeling approach was based. The soil loss equation parameters have been derived as follows :

Erosivity factor (R) - The erosivity index is related to rain kinetic energy (E) relative to the mean annual depth of rainfall (R), and the intensity of rainfall and soil type for the study area. The largest R Value in central Lematang sub Basin was 27,003 kg /m2. While the value of the smallest level of R release is 0.559 kg / m2

Erodibility factor (K) - Most of the soil types in the sub area of central Lematang sub Basin are derived from Andosol, Alluvial, Regosol, Podsolic and Latosol species with wave surface shape up to hilly was obtained from the Agriculture Department South Sumatera Province, in both tabular and spatial formats.

Topographic index ($A^m \sin^n b$) – The topographic index was calculated using the 25m Digital Elevation Model (DEM, TM+8) obtained from the Balai DAS Musi Seamless Data Distribution database. The use of 25 m DEM has been documented by Putranto, *et a!.* (2000) to be the most reliable elevation data when higher resolution data is unavailable because it allows for lower levels of systematic errors and artifacts of analysis compared to the lower resolution DEMs that are available (25 m resolution DEM was also tested). Contributing area per contour width (A) was obtained through the D-Infinity flow algorithm available in TAS (Terrain Analysis System, Creed et al., 1996 and Creed et al., 2003).

Land cover and management factor (C) – The distribution of C factor values was based on Balai DAS Musi (2012) land cover map for the entire South Sumatera Area obtained from the TM+8 Satelite Image. The data were reclassified based on values for the C factor determined by Wischmeier and Smith (1978) and Renard *et a!.* (1996). Each type of Balai DAS Musi present in the central Lematang basin was assigned a C value based on the degree of protection offered by various canopy covers. Since the lowest degree of soil protection is provided by mined and barren lands, and croplands, these land uses get assigned the highest C values, in accordance with literature. Pastures and areas covered by shrubby vegetation, depending on the degree of coverage, are assigned C values lower than 0.1, whereas forested areas, which provide the highest degree of protection, are assigned the lowest C values (lower than 0.01).

Support practice factor (P) – The P factor was held constant (equal to 1) in the analysis due to the lack of reliable data sources necessary to document the various conservation practices applied in the basin through Balai DAS Musi. Thus, the resulting analysis does not account for differences in erosion and soil loss due to differing cropping and land use practices

3. Results and Discussion

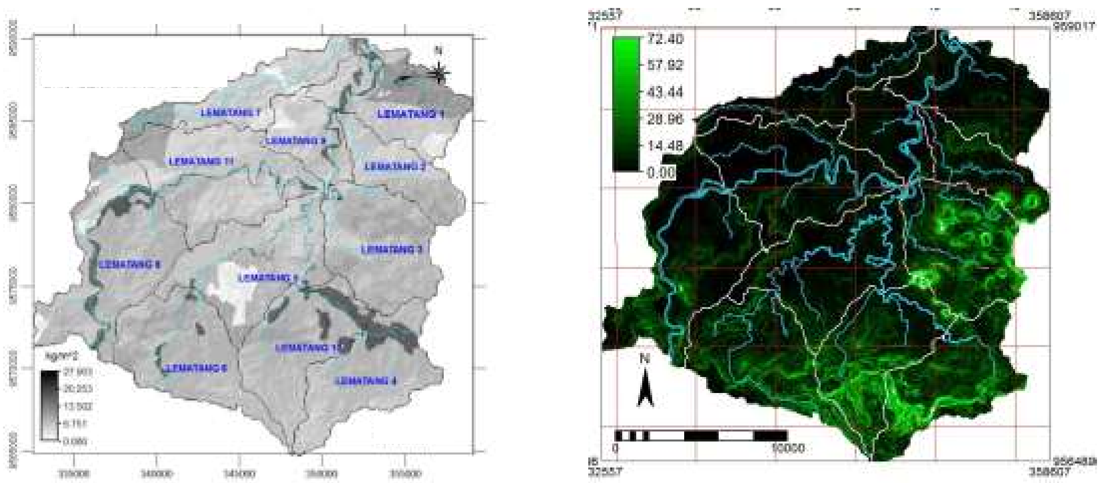
Analysis of Sediment Transport and deposition. Analysis of the sediment transport modeling USPED (Unit Stream Power Erosion and Deposition). In USPED modeling, slope factor considered comparable to topographic index. Topography index results with parameter values K (soil erodibility), the value of C (land use), and P (land management), in order to obtain sediment transport. The results of the analysis of sediment transport and deposition in the catchment area classified according to each sub basin.

The level of exfoliation and sedimentary 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.

Table 1. Value of Sediment Transport each sub Basin

Name of Sub Basin	Square (ha)	Sediment Transport (ton/ha/Year)	Average of ED(ton/ha/Year)
Sub Basin 1	3,808.3	1.794	-2.303
Sub Basin 2	2,241.4	1.176	1.265
Sub Basin 3	4.228,6	2.889	-1.651
Sub Basin 4	3.948,9	0.166	-0.456
Sub Basin 5	4.773,8	5.953	1.417
Sub Basin 6	4.423,1	2.832	-0.528
Sub Basin 7	2.975,7	0.243	-1.193
Sub Basin 8	5.914,0	0.161	0.001
Sub Basin 9	2.014,0	0.175	-0.037
Sub Basin10	4.133,0	0.483	-0.380
Sub Basin 11	5.266,2	0.281	-0.179

Based on the above analysis found that the sub-basins 1 has a high degree of exfoliation enough of 2.3035 ton/ ha /year. While the sub-basin 5 is a region of sediment deposition maximum of 1,417 tonnes / ha / year. 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 figure.



(a) (b)

Figure 2. Central Lematang sub-basin sediment transport rate with (a) and deposition resulting from various combinations of factors in the USPED model (b).

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 2. 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.

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.

TABLE 2. 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 (Ton/Ha)**
Village	9,191.875	0.8045
Irigation	1,640.8125	-2.1390
Dryland	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	36.5625	-0.0526

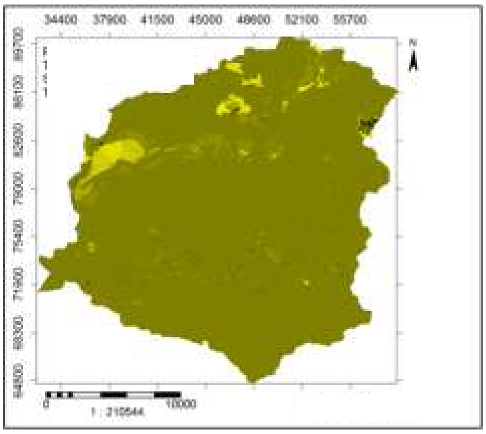


FIGURE 3. Sediment transport rate and the spatial distribution of erosion and deposition as a function of land use

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 build up of sediment in Table 3.

Tabel 3. 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

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

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 4. Value of ED per Soil Type

Soil Type	Teksture	Area (Ha)	Average of ED (ton.Ha)
Assosiation of Brown Alluvial	Lom 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.

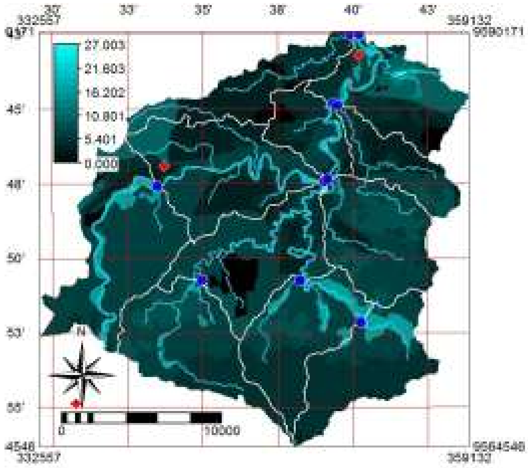


Figure 4. ED per Soil Type

The magnitude of the kinetic energy of rain can cause flaking ground. This is because the region with land cover that has a lot of trees can inhibit the kinetic energy that is not immediately fall to the ground and cause erosion. In addition to the reforestation area with steep elevation potentially receive high sediment deposit necessary countermeasures such as terracing or trap to the transport of sediments

4. Conclusions and Suggestion

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 erosivity based on land cover, slope and soil types obtained flaking areas with highest in irrigated area amounted to 2.139 tons / ha / year, the height of the ramps at 1.8239 ton / ha / year, and has the type of soil yellow podsolic alluvial and hydro amounted to 2.28591 tons / 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 podsolic and podsolic at 2:05 188 tons / ha / year ,

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