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AN ASSESSMENT OF THE EROSION INTENSITY OF QUATERNARY VOLCANIC ROCKS IN THE UPPER STREAM OF CITARUM RIVER SOUTHERN PART OF BANDUNG BASIN

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ABSTRACT

The erodibility of the area in the drainage basin of Citarum river tributaries in southern part of Bandung basin influences the intensive deposition in Citarum river bed. It presumably generates the acute flooding in the southern part of Bandung. To estimate the amount of the eroded materials (A), the Universal Soil Loss Equation (USLE) formula A= RKLSCP (El-Swaify et al., 1982) is commonly used. It involves the erosivity index of the ground surface (R), soil erodibility (K), topography (L, length and S, slope), the vegetation covers (C) and land management (P). The formula was derived from the generalization of predominant geological elements. Prior to the application in Citarum upper stream basin, the validity of the formula has been evaluated. The upper stream of Citarum river is located on the formation of volcanic products of Quaternary age (Alzwar, et al., 1992; Silitonga, 2003). The evaluation consists of 1,184 grid boxes each of about 25 ha covering the entire investigated area. The results show that the erosion intensity strongly and positively correlates ($r = 0.93$) with the silt grain size of the weathered volcanic rocks. The ratio between very fine fraction of clay (C), fine silty clay (M, mud) and fine to coarse sands (S) determines the erodibility index. Those fractions relate closely with the geological processes consisting of weathering, alteration, and tectonics. A further calculation yields the corrected USLE formula for the erosion intensity of volcanic terrain (E_v) with a constant of $[M.(S+C)^{-1}]$, the formula thus becomes $E_v = k'[M.(S+C)^{-1}]$. RKLSCP, where k' is C-M-S ratio constant of weathered volcanic rocks product in the investigated area. The high plasticity clay and high plasticity silt of volcanic rocks weathered product attain the erosion coefficient of 0.51 and 0.77 respectively. Based on the results of the investigation, it is recommended to delineate the physical characteristic of volcanic rocks weathered product, then the land management controlling the erosion. The remote sensing method might be beneficial to identify those types of rocks and their weathered product with a manipulation process of various channels.

INTRODUCTION

The erodibility of an area is determined by various elements. The erosion in the upper drainage basin of Citarum River in southern part of Bandung Basin presumably influenced the degree of siltation that might cause the acute flooding. In almost every year during the wet season the densely populated area in the southern part of Bandung Basin is flooded. The present study is aimed to reveal the PROCEEDINGS PIT IAGI LOMBOK 2010 the 39th IAGI Annual Convention and Exhibition 2 roles of the erodibility of the upper part of the drainage basin in the flooding. The results might contribute to mitigate flood in this area. The investigated area is located in the southern flank of Bandung Basin in the upper part of the tributaries of Citarum River at 107.630 to 107.787 E and 7.013 to 7.240 S in the vicinity of Majalaya (FIGURE 1).

The erosion intensity is measured by applying the Universal Soil Loss Equation (USLE) developed by Weischmeier & Smith in 1978. The formula has been used widely as a model to predict the degree of erosion involving various independent variables (El-Swaify et al., 1982). The weakness to apply the method is the generalization of many existing elements among others the geological condition. It is therefore, the validation is needed before the formula is applied.

Bandung Basin is predominated by the volcanic deposits. In plain the rock consists of lake deposit with the materials derived from the volcanic rocks. In the slope of the Basin the rocks composed of volcanic rocks of Quaternary age. In the southern part of Bandung Basin where the investigation was carried out the volcanic rocks consists or pyroclastic deposits of fine to coarse size and lava flows. Lahar deposits were found locally. Lava flows dominated the upper part of the volcano complex (Alzwar et al., 1992, Silitonga, 2003).

The tectonics took place forming faulting in the volcanic rocks. The late volcanic activity altered the volcanic deposits. As the result, the altered rocks with very fine fragments are not easily eroded. The rocks consist of clay size materials with high plasticity.

Based on the previous study, it was concluded that as many as 1,047,600 ton of materials were transported annually in the upper Citarum river (Sukiyah, et al., 2006). Three water reservoirs were very concerned with the degree of siltation. The study of interrelation between various factors is needed in an effort to reduce the erosion. The present study put the emphasis on the geological condition that might contribute to the intensity of the erosion.

METHODOLOGY

The quantitative analysis is applied to measure the interrelation between variables controlling the erosion intensity. The investigated area was divided into 1,184 grid boxes or cells. The cell represents 25 hectare land area. The calculation of erosion used simple grid method (Sukiyah et al., 2007).

Remote sensing interpretation using ER Mapper 6.4 version and MapInfo 8.0 version software support the delineation of geologic rock units, structure and the altered area. In addition the vegetation cover was also interpreted using remote sensing method. The digital analysis on the based of the pixel was also undertaken.

The laboratory works was done consisting of chemical analysis, petrographic study, grain size analysis, and clay analysis using PIMA method and SEM. The results were used as the back ground information in the erosion intensity measurement. The reference was made to the rainfall observation by the Meteorology Agency. In particular area the erodibility index map using USLE was already published by Ministry of Forestry. Those materials were used for evaluation in the present study.

The interrelation between variables of the geological components and the stimulus involved in USLE formula was verified. The quantitative method applying deterministic and probabilistic approach was done. The controlling variables were categorized into three groups, namely (a) the characteristics of rocks, (b) the slope condition and (c) the stimulus factors. The erosion phenomena were the final result of the interrelation between those variables.

The measured variables were the ratio between grain size of the soil, the proportion of oxidized elements and LOI, the proportion of the altered rock forming minerals, the technical characteristics of the soil, including porosity, plasticity and cohesion indices and the geomorphological aspects. The quantitative geomorphologic investigation consisted of various ratios of river segments, density, sinusoid index, degree of steepness and the lineaments analysis.

RESULTS

The results of the investigation showed that the physical and chemical characteristics of the rocks controlled by the degree of erosion. The weathering process resulting in the progressing degree of plasticity was a significant factor. The results might be summarized as follows:
a. The weathering, deformation and tectonics process determined the erodibility index; b.The physical and chemical characteristics of the volcanic rocks controlled the intensity of the erosion; c.The close relation observed between the

digital number of the pixel and the physical characteristic of the volcanic rocks. The erosion intensity strongly and positively correlated ($r = 0.93$) with the silt size fraction. The ratio between the fine fraction of clay, silty clay and fine to coarse sand were the dominant factor controlling the erosion intensity. The ratio between the erosion coefficient with the coarse materials represented by volcanic sand was insignificant ($r = 0.44$). The physical characteristics of the lithology thus, controlled the erosion coefficient. The grain size of materials was determined by the geological process namely weathering, alteration and tectonics. Based on the ratio between the oxidized elements and the LOI it was concluded that the erosion coefficient was strongly controlled by the degree of alteration. The degree of alteration was also represented by the degree of plasticity. The degree of weathering to some extents was readily identifiable in the imagery. The remote sensing method might contribute to the delineation of physical characteristic of weathered volcanic rocks. Further calculation of the erosion intensity applying USLE formula and the result of the field measurement suggests a modification involving the geological condition. The USLE formula was based on the condition in northern hemisphere. Furthermore the geological condition was generalized. The application of such formula in tropical region needs to be verified. The intensive weathering and tectonic processes are the main geological factors controlling the erosion. In the investigated area of USLE formula is modified for the erosion coefficient in volcanic terrain with tectonic control and intensive alteration. USLE general formula A= RKLSP, where A represents the eroded materials, R erodibility index, K soil erodibility, L length of the topography, S slope and C vegetation cover. The geological condition was generalized. Based on the result of the field measurement the USLE formula was proposed to be modified involving various characteristics of geological condition. The following modification was constructed from the calculation of the measurement carried out in the field and the application of USLE formula. The constant consisted of the ratio between clay (C), fine silty clay or mud (M) and fine to coarse sand (S). The erodibility in tropical volcanic terrain is proposed to be represented by E_v the abbreviation of erosion in volcanic terrain. The measurements in the field showed the erosion coefficient of silt and clay high plasticity volcanic soils were respectively 0.77 and 0.51. Modifying the USLE formula for tropical volcanic terrain thus instead of $A = RKLSCP$ it becomes $E_v = k'[M(S+C)^{-1}]\ RKLSCP$.

DISCUSSION

The results of the field measurement showed that the application of the USLE formula in the tropical condition should first to be verified. In the volcanic terrain the tropical condition has resulted in the very intensive weathering altering the rocks into finer materials (silt soils) with higher degree of plasticity. It appeared that the silt soils contributed very significantly to the degree of erosion.

The tectonic process might also contribute to the degree of alteration. The area with highly deformed condition could produce the broken rocks easily altered. The natural heat from the volcanic body or intrusions might also intensify the alteration process. Thus, the modification of the USLE formula is needed before it is instantly applied.

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions might be drawn: 1. The physical characteristics including the alteration due to weathering, deformation and heat from the volcanic activities determined the erodibility of material; 2. The plasticity resulted from the alteration was the prevailing variables in the degree of material erodibility; 3. The chemical condition determined the alteration process thus it controlled the physical characteristic; 4. The material erodibility was also influenced by the tectonic activities in the area. The degree of deformation correlated with the degree of alteration; 5. The physical characteristic of materials might be delineated by using remote sensing method.

In the investigated area high degree of erosion produced the high amount of the materials transported in Citarum River. The siltation at the river bed was very intensive. Therefore in the rainy season the acute flooding occurred unavoidably. The amount of transported materials also added very significantly to the water volume drained in Citarum River. This in turn would cause the intensive flooding.

Because the physical characteristic determined the erodibility, it is suggested to map the distribution of the rock and soil with the evidence of physical characteristic. A better land management in those area might contribute to the mitigation of the flood in the southern part of Bandung Basin. At the same time it might also reduce the amount of siltation in three important reservoirs in Citarum River.

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Demonstration plot	Erosion (ton/year)	USLE					USLEv			
		USLE (ton/year)	ΔE	Proportion of ΔE	error	k	USLEv (ton/year)	ΔE	Proportion of ΔE	error
Upstream Cirasea	296.77	353.30	56.53	0.19		0.84	272.04	24.73	0.08	
Barugbug	81,844.70	99,810.63	17,965.90	0.22		0.82	76,854.19	4,990.51	0.06	
Cicangkuang	10,296.10	12,870.08	2,573.98	0.25		0.80	9,909.96	386.14	0.04	
Cirawa	216,421.92	281,067.46	64,645.54	0.30		0.77	216,421.94	0.02	0.00	
Sadatapa	68,376.35	91,168.44	22,792.09	0.33		0.75	70,199.70	1,823.35	0.03	
Wangisagara1	605.80	931.98	326.18	0.54		0.65	717.62	111.82	0.18	
Ciramose	2,851.14	5,001.99	2,150.85	0.75		0.57	2,551.01	300.13	0.11	
Malimping 2	8,128.00	15,335.90	7,207.90	0.89		0.53	7,821.31	306.69	0.04	
Malimping 1	7,821.30	15,335.90	7,514.60	0.96		0.51	7,821.31	0.01	0.00	
Galugah1	7,970.82	16,267.01	8,296.19	1.04		0.49	8,296.18	325.36	0.04	
Galugah13	395.65	879.24	483.59	1.22	0.61	0.45	448.41	52.76	0.13	0.06

TABLE 1: The result of erosion calculation and their validation (Sukiyah, 2009)

Land use	CP	k_{M-C-S}			
		CH	MH	ML	SM
Residential area	0.60	0.41	0.62	0.64	0.26
Mixture farming & grove	0.30	0.20	0.31	0.32	0.13
Paddy field	0.05	0.03	0.05	0.05	0.02
Farming field	0.75	0.51	0.77	0.80	0.33
Plantation field	0.40	0.27	0.41	0.43	0.18
Forest	0.03	0.02	0.03	0.03	0.01

TABLE 2: The k_{M-C-S} correction for various land uses (Sukiyah, 2009)

FIGURE 1: Map shows the location of the investigated area, South Bandung Basin, West Java. The investigated area is the source of the eroded materials transported by the tributaries of Citarum. The intensive deposition of the materials contributed to the acute flooding in southern part of Bandung Basin.

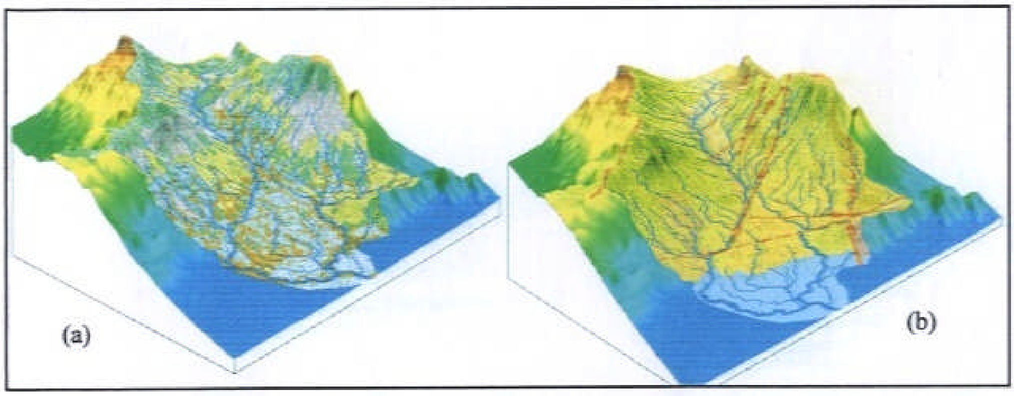

FIGURE 2: Block diagrams show (a) land use setting and (b) geological setting of the Citarum river upper stream area

FIGURE 3 : Photo shows the altered rocks due to the volcanic activities in Patrol. The intensive weathering of the area has caused the intensive erosion. The present investigation concludes that the plasticity of the altered rocks determines the degree of erodibility. (Photographed by Sukiyah).

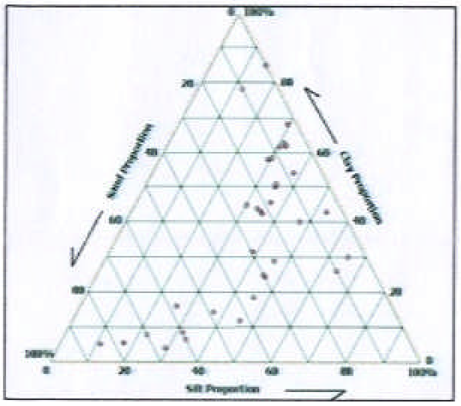

FIGURE 4 : Result of grain size analysis of soil samples in the southern part of Bandung basin; plotted on the Feret triangular diagram. Those soils are weathering product of Quaternary volcanic rock in the Citarum river upper stream area

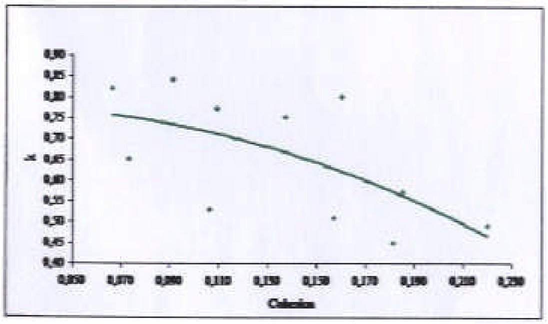

FIGURE 5 : Graph shows correlation between erosion coefficient k and cohesion of soils of weathering product of Quaternary volcanic rocks in the Citarum river upper stream area

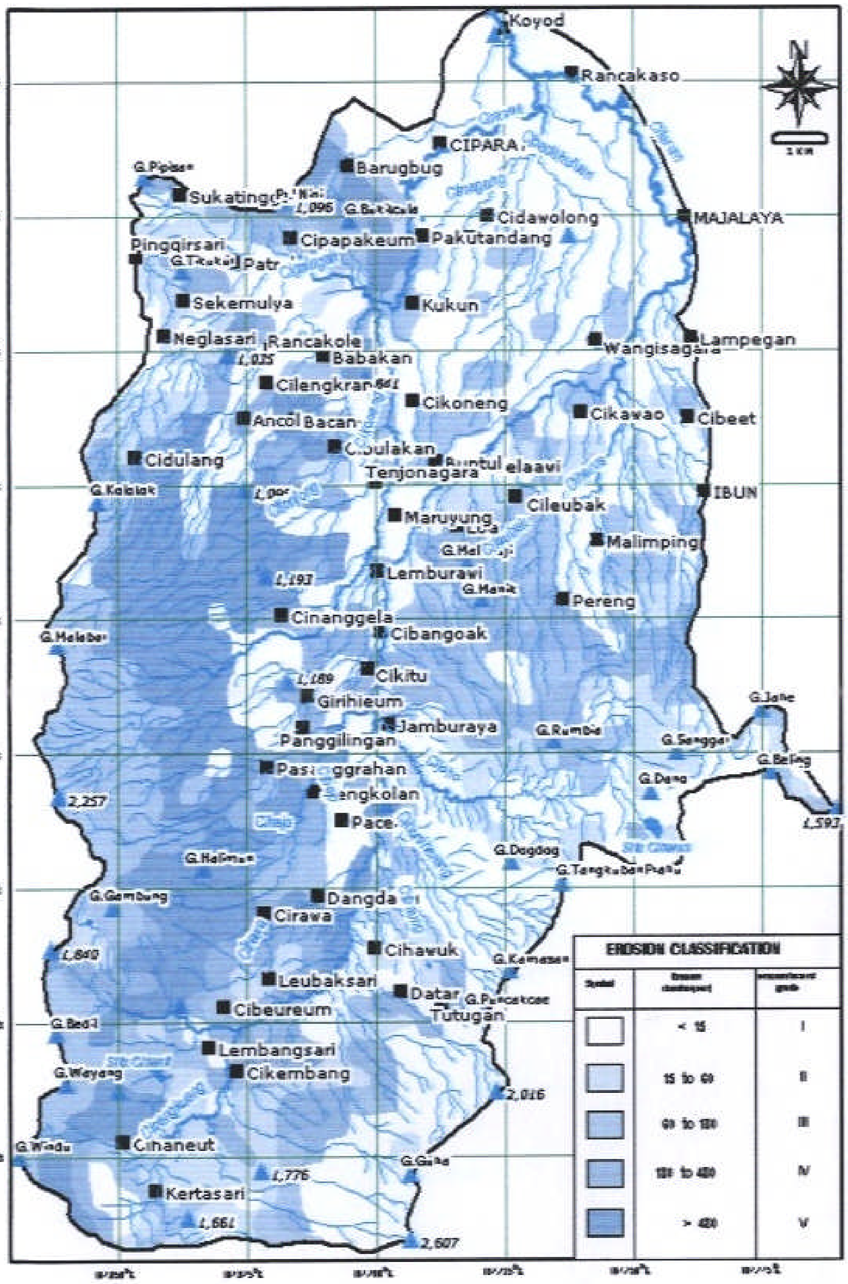

FIGURE 6: Map of spatial distribution of erosion grade in the Citarum river upper stream area. Erosion intensity calculated by USLE formula.

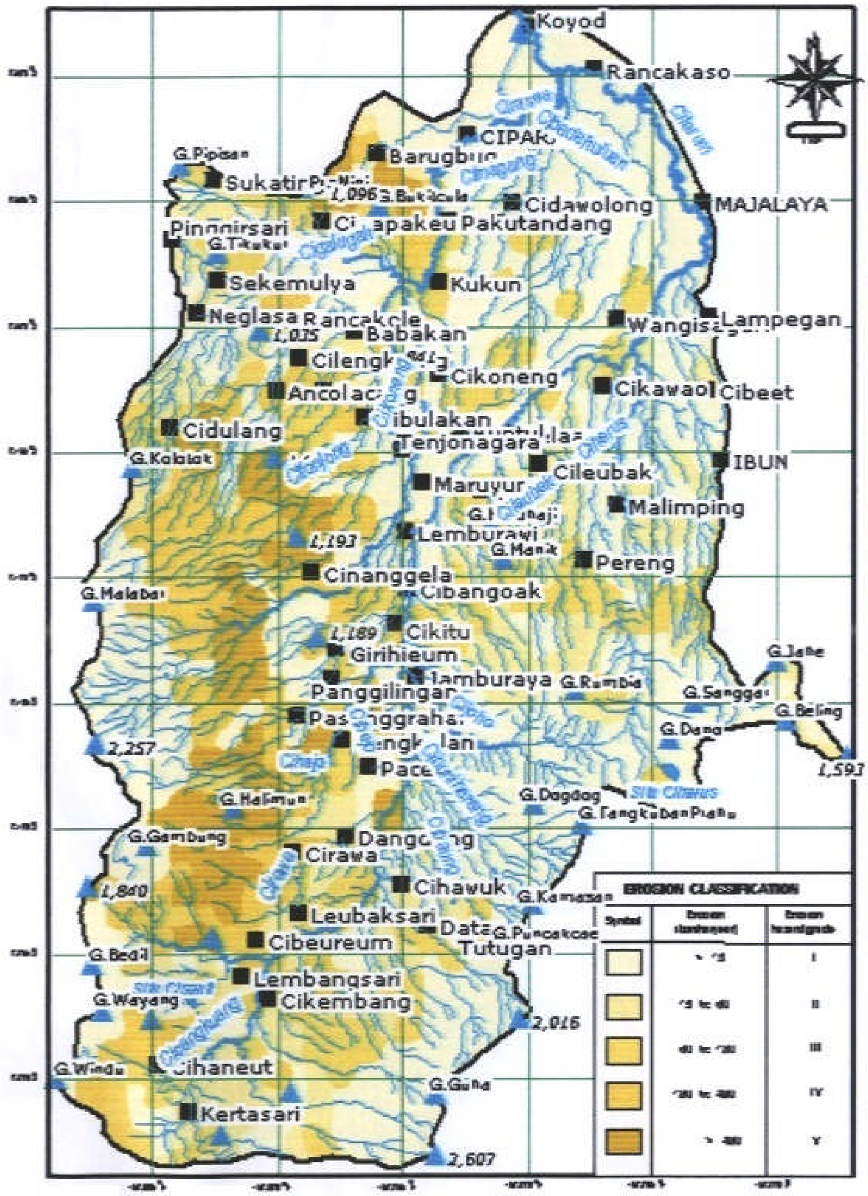

FIGURE 7 : Map of spatial distribution of erosion grade in the Citarum river upper stream area. Erosion intensity calculated by **USLE**, formula.