The Erosion Model Based on Grainsize Distribution Ratios of Weathering Product of Quaternary Volcanic Deposits (4218)

Emi SUKIYAH, R. Febri HIRNAWAN, and Dicky MUSLIM (Indonesia)

Key words: erosion model, soil erodibility, Quaternary volcanic deposits

SUMMARY

This summary on the paper on erosion model based on grainsize distribution ratios of weathering product of Quaternary volcanic deposits in Bandung Basin, West Java, is the latest development in these issues in Indonesia. USLE formula known as formula for annual erosion prediction is no longer accurate, which needs a modification, in term of involvement of soil variables determining erosion for the validation of the formula before being used for the prediction of annual erosion in the area of distribution of weathered Quaternary volcanic deposits. This modification of USLE was conducted during a research in southern Bandung Basin using deterministic and probabilistic approaches.

Based on the ratio between silt to clay content of soil mass, the validation of the erosion formula mentioned above generated the modification of USLE for both silt soils (symbolized MH) E_{MH} = 0.77 RKLSCP and clay soils (CH) E_{CH} = 0.51 RKLSCP respectively. These new formulas, possessing the errors about 6%, represent the grainsize distribution proportion and also cohesion of soil mass which explain the characteristic of its erodibility. Large erodibility of silt soil is also indicated by large correlation coefficient between silt content and coefficient of erosion r = 0.93.

RINGKASAN (Summary in Indonesian)

Ikhtisar model erosi yang didasarkan atas perbandingan distribusi besar butir dari pelapukan endapan volkanik Kuarter di Cekungan Bandung, Jawa Barat, adalah pengembangan mutakhir tentang isu ini di Indonesia. USLE sebagai formula untuk prediksi erosi tahunan sudah tidak teliti sehingga memerlukan modifikasi sebelum digunakan untuk prediksi erosi tahunan di wilayah penyebaran hasil pelapukan endapan volkanik Kuarter. Validasi rumus melibatkan variabel-variabel tanah yang menentukan erosi. Penelitian ini dilakukan di Cekungan Bandung bagian selatan menggunakan pendekatan deterministik dan probabilistik.

Berdasarkan perbandingan kandungan lanau dan lempung, validasi menghasilkan modifikasi USLE untuk tanah lanau (MH) E_{MH} = 0,77 RKLSCP dan lempung (CH) E_{CH} = 0,51 RKLSCP. Formula baru ini dengan sesatan sekitar 6% mewakili proporsi distribusi ukuran butir dan kohesi massa tanah yang menjelaskan karakteritik erosinya. Eroribilitas tanah lanau juga ditunjukkan oleh koefisien korelasi yang tinggi antara kandungan lanau dan koefisien erosi r = 0,93.

The Erosion Model Based on Grainsize Distribution Ratios of Weathering Product of Quaternary Volcanic Deposits (4218)

Emi SUKIYAH, R. Febri HIRNAWAN, and Dicky MUSLIM (Indonesia)

ABSTRACT

The erosion problem is an important subject of interest to be studied. Natural disasters occur in many places due to erosion. Flood, landslide, and dam silting are hazardous which may become natural disaster because of uncontrollable erosion in highlands. USLE is a formula for annual erosion prediction, especially used for sheet erosion cases. In many cases this formula is no longer correct that needs to be calibrated before being used for estimating the erosion in many areas of distribution of different type of soils. This paper discusses the result of research conducted in the drainage basins on Quaternary volcanic deposits in Bandung Basin, West Java, Indonesia. This modification of the USLE was conducted using deterministic and probabilistic approaches.

As the result of this research, it is known that erosion modeling depends on the characteristic of the soil it self. This gives us a guideline that USLE can't be implemented for every kind of soil of different characteristic. Total erosion can't be generalized for every type of soil. Soil erodibility is determined by silt ratio than clay ratio; the larger the silt ratio the larger the soil erodibility. This phenomenon is also indicated by either the correlation coefficient r between coefficient of erosion and silt ratio or clay ratio. Silts exhibits r is 0.92, whereas clay shows 0.44, which means that silts produces larger total erosion than clays in the area of same geomorphology. Based on the silt and clay ratios, the validation of the erosion formula mentioned earlier generated the modification of USLE for both silt soils E_{MH} = 0.77 RKLSCP and clay soils E_{CH} = 0.51 RKLSCP respectively. These formulas, possessing the errors about 6%, represent the grainsize distribution proportion and also cohesion of soil mass which explain the characteristic of its erodibility. Large erodibility of silt soil is also indicated by large correlation coefficient between silt content and coefficient of erosion r = 0.93.

The modified USLE generated through this research enables us to assume total erosion accurately in areas of distribution of weathered Quaternary volcanic deposits. It is very important for the support of land management, erosion hazard mapping related to spatial planning, and mitigation strategy.

1. INTRODUCTION

The intensity of erosion is a function of rainfall erosivity, soil erodibility, morphology, and land use. These variables determining the erosion formula formulated as Universal Soil Loss Equation or known as USLE (Wischmeier & Smith, 1978 in El-Swaify *et al*., 1982). USLE already been used widely as model of erosion prediction. Currently, the USLE applications cannot use for base assumptions, since the formula is no longer correct that causes wrong generalization (El-Swaify *et al*., 1982).

Generally, geomorphology of Bandung basin and the surroundings had covered by Quaternary volcanic deposits (Alzwar *et al*., 1992; Silitonga, 2003). Some parts of the deposits not yet lithified. These unconsolidated deposits are easily weathered, cohesionless, which are prone to erosion and landslides. Many active faults in Bandung basin exhibit reactivated Tertiary faults. They frequently generate earthquake occurrences, which cause Bandung city and the surroundings as one of earthquake prone regions in Indonesia (Soehaimi et al., 2004).

Beside the above-mentioned hazard, the characteristics of the region are as follows. Other natural hazards related to erosion in Bandung basin are floods at Sub district of Dayeuhkolot, landslides along southern hillsides, dam silting along Citarum river, and sediment accumulation in low lands caused by uncontrollable erosion product from the upstream areas. The other natural hazards are land subsidence, e.g. at a place between Cicalengka and Majalaya, and volcanic eruption (Tjetjep, 2004). These hazards related to tectonic phenomenon might be a triggering factor of erosion escalation in several areas in Bandung basin (Sukiyah *et al*., 2006). The objective of study of erosion discussed in this paper is to answer the problem about how far can USLE implemented for erosion prediction in Quaternary volcanic terrain in tropical area. This problem is able to be answered using validation formula of USLE in order to achieve valid and reliable erosion measurement in Quaternary volcanic terrain of tropical areas, especially in southern part of Bandung basin (Figure 1).

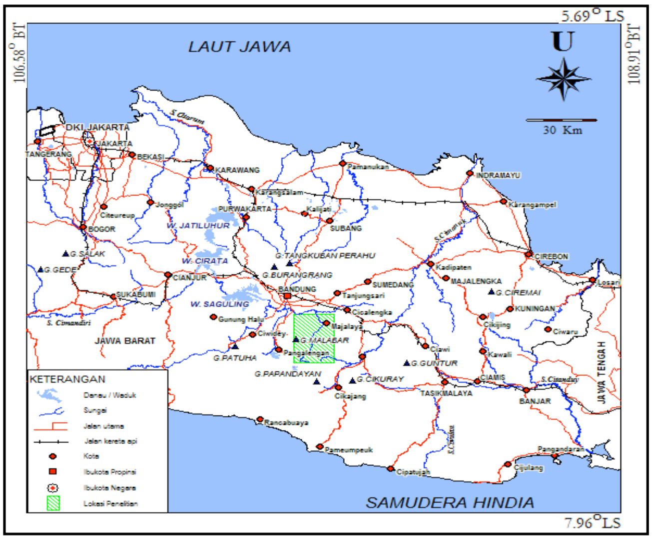

Figure 1. Location of research area

Klompé (1956, in Koesoemadinata, 1992), Silitonga (2003), Alzwar *et al*. (1992), and Dam (1994) have studied the geology and the evolution of Bandung basin. From Late Tertiary until

Recent the lithology distributed in Bandung Basin exhibits the products of volcanic activity. Dam (1994) opines that sedimentation process in Bandung basin started about 126,000 years ago. The sediments consist predominantly of volcanic clastic and lake deposits. In southern part of Bandung area Quaternary volcanic rocks may be divided into several units, as Guntur-Pangkalan-Kendang volcanic rocks, Mandalawangi volcanic rocks, and Malabar volcanic rocks (Alzwar *et al*., 1992).

Some classifications of soil known in soil mechanical term, among other based on proportion of clay (C) – silt (M) – sand (S) distribution and Unified Soil Classification System (USCS). Jumikis (1967) expressed the soil classification based on proportion of clay, silt, and sand. Result of grain size analysis plotted on triangular coordinate known as the Feret triangular. Soil denomination based on USCS; refer to laboratory test result covering grain size and Atterberg limits (Jumikis, 1967; and Wesley, 1977). USCS validate both residual soil as well as non-residual soil.

Erosion is gradual exogenous process caused by activities of water, wind, and snow (SCSA, 1976, in El-Swaify *et al*., 1982; Field & Engel, 2004). Arnoldus (1974, in El-Swaify *et al*., 1982) proposed to classify erosion into geological and accelerated erosions. The geological erosion occur naturally in geologic times (millions years duration), while accelerated erosion caused by human activities to change the natural condition. On the other hand, Van Zuidam (1983) proposed to classify erosion into four types; splash erosion, sheet erosion, rill erosion, and gully erosion.

Ambar (1986) said that USLE is a popular formula to predict the annual erosion value of an area, especially in the tropics like Indonesia. General equation of USLE (Wischmeier & Smith, 1962, 1965, 1978; in El-Swaify *et al*., 1982; Mitasova, 1999; Stone, 2000) described below, though it is valid only for measurement of sheet and rill erosion based on the assumption that the area is similar to what Wischmeier & Smith (1978, after El-Swaify et al, 1982) had proposed.

$$\mathbf{A = RKLSCP} \qquad (1)$$

where
A = mean total of lose soil material on a location every year (ton/ha);
R = erosivity index of run off;
K = soil erodibility index;
LS = topographic index, (L= slope length, S= steepness of slope);
C = index of land use for plant;
P = index of soil cultivation.

Some researchers have studied erosions in Bandung basin, *i.e.* Ambar (1986), Haryanto (1994), Yuzirwan (1996), Sjafrudin (2003), and Sukiyah *et al.* (2006). Generally, researches about land use. The latest research worked by Sukiyah *et al.* (2006) discussed erosion through geological approaches with probabilistic and descriptive method.

2. RESEARCH METHOD

The outline of research implementation divided into some liveliness steps, *i.e.* preliminary, field survey, laboratory and studio analyses, data analysis, and erosion modeling. Every step includes mutual synergies liveliness support erosion modeling success. Figure 2 shows the mind frame of erosion model research.

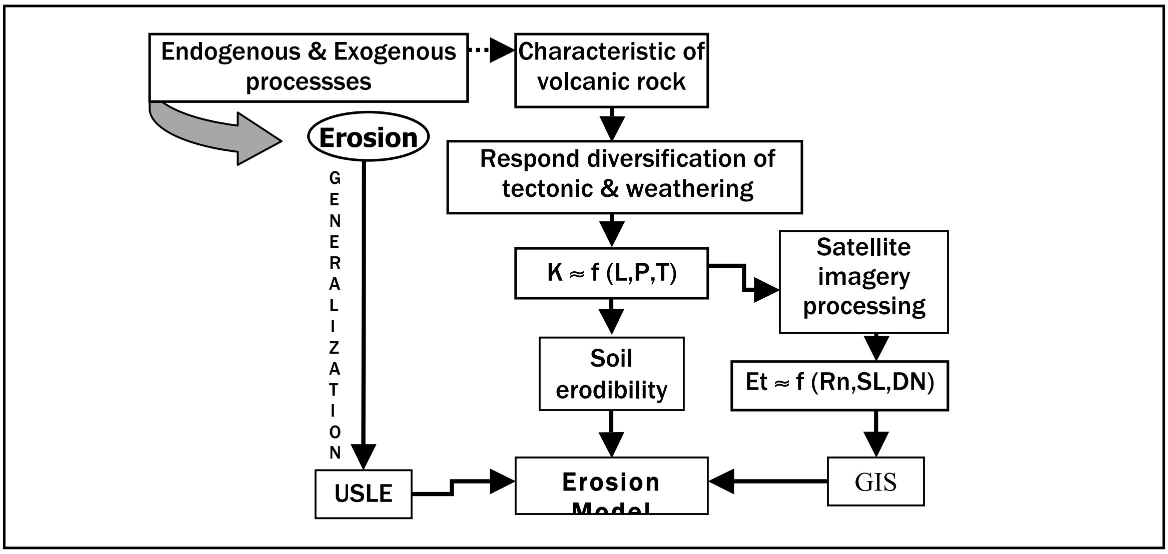

Figure 2. Mind frame diagram to find erosion model in this research.
K: erodibility, f: mathematics and algorithm function, L: lithology, P: weathering, T:geological fault, Et: erosion grade, Rn: tone, SL: band channel, DN:digital number, GIS: Geographic Information System, and USLE: Universal Soil Lost Equation.

Data were analyzed using deterministic (mathematical equation model) and probabilistic (statistical test) approaches. The equation model is verified by gaining the smallest error size (r), while statistical test is used to gain the lowest level of significant (α). Basic USLE equation is used to find the general erosion intensity of the study area, while modified equation (USLEv) is specific for volcanic terrain referring to the weathering product of Quaternary deposit.

The meaning of deterministic system is everything that occurs as result of constant casualty relation and accurate among interaction variables (Haneberg, 2000). Dahrin (2001) enounced that deterministic model occur dependence accompany variables is consistent and indubitable. Hirnawan (2007) said that deterministic cases concern unmistakable system; consist of dynamic components and sub components and contribute fit its role with synergism decide phenomena. Deterministic cases use deducto-hypotetico-validation mind frame that is mathematic verification toward phenomena as research subject to gain error size. Meanwhile probabilistic approach uses statistic test. Statistic using in this research in order that research result has certain significance level that valid in geology. Hirnawan (2007) said probabilistic approach by verification, that is statistic test toward phenomena as research subject to gain significance level α as credibility size. The completions of probabilistic cases had known as deducto-hypotetico-verification. The statistic tests need preferable understanding of the existing data.

3. RESULT AND DISCUSSION

Erosion is a system, involving interaction of various components such as lithology, slope, and the trigger factors. Each component or factor and their variables are subject to be tested for their variability and role in the system. Figure 3 below shows the interaction of variables in the erosion system.

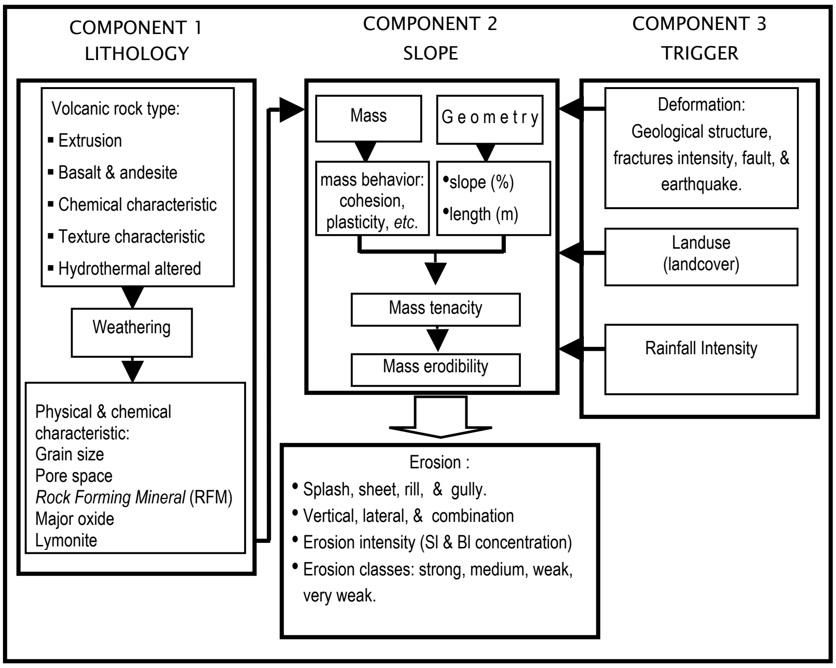

Figure 3. Flowchart of variables interaction of erosion system

Erosion Intensity of an area estimated by knowing about conditions of climate, morphology, lithology and its weathered, tectonic, and land use. The factors of erosion calculation using USLE are spatial data. That data consist of two major components, that is graphic and attribute components. Therefore, it needs tool for manage spatial data in order that more effective. For example, that tool is GIS software. The little modification of GIS application needed to support erosion calculation using USLE. The simple grid method is a method for upgrade GIS application in data spatial analysis (Sukiyah *et al.*, 2007). The simple grid involve grid as smallest area unit in spatial data analysis. A grid layer loads thousands of grids of certain area, depend data accuracy. Value of various factor indexes connected with spatial data of every layer. The simple mathematical calculation uses existing tool. The erosion that gain then modified, refer to soil characteristic as weathering product of Quaternary volcanic deposits in southern part of Bandung basin.

There are eleven demonstration plots (demplot) of location for erosion measurement in the field. They reflect the condition of Quaternary volcanic terrain. Result of erosion measurements and their validation shown by Table 1.

Table 1. The result of erosion calculation and their validation

Demonstration plot	Erosion (ton/year)	USLE				k	USLEv			
		USLE (ton/year)	ΔE	Proportion of ΔE	error		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

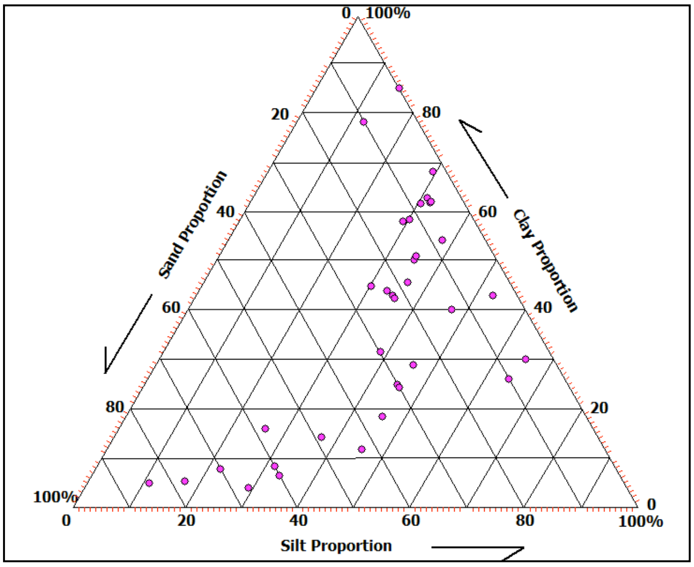

Figure 4. Result of grain size analysis of soil samples in the southern part of Bandung basin; plotted on the Feret triangular diagram.

The application of USLE modified in Quaternary volcanic terrain concern to characteristic of physical material. It is a component of erosion intensity determination. Result of grain size analysis of soil samples plotted on the Feret triangular diagram (Figure 4). Based on soil mechanical analysis of 37 samples; it is gained various soil types as weathering result of Quaternary volcanic deposit. Soil classification used is Unified Soil Classification System (USCS). Soil as weathering result of Quaternary volcanic deposit that success identified in research area are CH (high plasticity clay), MH (high plasticity silt), ML (sandy silt), and SM (silty sand).

The ratio of C-M-S (k_{v2}) over reflect soil erodibility than clay ratio (k_{v1}). Erosion coefficient (k) and (k_{v2}) has very strong correlation than correlation between (k) and (k_{v1}). The result of hypothesis test using deterministic and probabilistic approaches show that ratio between fine fraction and coarse fraction of soil decide soil erodibility; form follow equation:

$$E_v = k' \left(\frac{M}{S + C} \right) RKLSCP \quad \text{.......} \quad (2)$$

Where:
E_v = erosion intensity in volcanic terrain in ton/ha/year;
k' = C-M-S ratio constant; 0.88 for high plasticity silt and 1.07 for high plasticity clay;
M = silt proportion in %, S = sand proportion in %, C = clay proportion in %,
RKLSCP = calculation factors of erosion for USLE

Formula (2) can formed a simple erosion formula follow:

$$E_v = k\,[RKLSCP] \quad \text{.......} \quad (3)$$

Where K = erosion coefficient of USLE; 0.51 for high plasticity clay (CH) and 0.77 for high plasticity silt (MH). Based on USLE validation and soil characteristic, and then do correction of erosion coefficient for various land use types (Table 2).

Table 2. The k_{M-C-S} correction for various land uses

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

The cohesion value of clayey soil is higher than sandy or silty soil. Therefore, the increase of clay proportion will decrease the erodibility factor and also the erosion coefficient of soil. Meanwhile, cohesion of silt is lower than clay causing silty soil is more erodible than clay. The increase of silt proportion of certain soil will be able to increase its erosion coefficient.

In general the residual soils originated from weathered Quaternary volcanic deposits in southern Bandung basin are highly plastic. Based on physical properties of the residual soils, as a result of laboratory test, these soils distributed in the researched area can be divided into four types according to USCS (Unified Soil Classification System). These soil types are inorganic clays of high plasticity (CH), inorganic silts of high plasticity (MH), sandy silts of low plasticity (ML), and silty sands (SM). Result of laboratory analysis of residual soils as weathered bed rocks underlying the surficial soils exhibit the same soil type.

Correlation between erosion coefficent (k) and cohesion (c) of the soils mainly originated from weathered Quaternary volcanic deposits mentioned above is significant as shown in Figure 5.

Figure 5. Correlation between erosion coefficient k and cohesion of soils of weathering product of Quaternary volcanic deposits

4. CONCLUSION

Residual soils originated from weathered Quaternary volcanic deposits in southern Bandung basin are highly plastic. The result of verification of hypothesis using deterministic approach exhibits that ratio between fine-grained to coarse-grained soil fractions determines the soil erodibility.

On the other hand, results of tests using statistical approach are as follows:
- Different soil type is indicated by different erosion coefficient k;

- Negative correlation between cohesion c and erosion coefficient k is significant at significance level α = 0.05, which exhibit that the larger the soil cohesion the lower the erosion intensity;

- Negative correlation between clay content C and C-M-S ratio constant k' is significant at α = 0.05; the larger the clay content the lower the erosion intensity;
- Positive correlation between silt proportion M and C-M-S ratio constant k' is significant at α = 0.05; the larger the silt proportion the larger the erosion intensity.

ACKNOWLEDGEMENT

The authors are grateful to Prof. Adjat Sudradjat, Prof. Emmy Suparka, Dr. Ildrem Syafri, Dr. Mega F. Rosana, and Dr. Lobo M. Balia for supporting this research. They also would like to thank Dr. Hendarmawan and Mr. Yuyun Yuniardi, MT on behalf of Faculty of Geological Sciences and Engineering, University of Padjadjaran, for financial support for the presentation of this paper.

REFERENCES

Alzwar, M., Akbar, N. & Bachri, S. 1992. Geological Map of Garut and Pameungpeuk Sheet, Java, scale 1:100,000. Geological Research and Development Centre, Bandung, Indonesia. *)

Ambar, Supriyo. 1986. Aspects of vegetation and landuse in erosion process in catchment area of Jatiluhur Dam, West Java. Ph.D. Thesis, Post Graduate Program, University of Padjadjaran, Bandung. *)

Dahrin, Darharta. 2001. Statistic Analysis of Earth Science. Penerbit ITB, Bandung. **)

Dam, Marinus A. C. 1994. The Late Quaternary evolution of The Bandung basin, West-Java, Indonesia. Thesis, Department of Quaternary Geology, Faculty of Earth Sciences, Vrije Universiteit. Amsterdam, Netherland.

El-Swaify, S. A., Dangler, E. W. & Armstrong, C. L. 1982. Soil erosion by water in the tropics. Department of Agronomy and Soil Science, University of Hawaii, Honolulu.

Field, L.Y & Engel, B. A. 2004. Best Management Practices for Soil Erosion. Agricultural Engineering, Purdue University. <http://abe.www.ecn.purdue.edu> [03/08/2004].

Haneberg, William C. 2000. Deterministic and probabilistic approaches to geologic hazard assessment. Environmental & Engineering Geoscience, Vol. VI, No. 3: 209-226.

Haryanto, Edi Tri. 1994. Erosion mapping and monitoring using remote sensing and GIS techniques. Thesis, Postgraduate Program of Science in Applied Geomorphology and Engineering Geology, ITC, Enschede, Netherland.

Hirnawan, R. F. 2007. Research, the running scientific process. 1st Edition, Unpad Press, Bandung. *)

Jumikis, Alfreds R. 1967. Introduction to soil mechanics. Van Nostrand Company, New York.

Koesoemadinata, R. P. 1992. Geology of Bandung area. Guide Book of "Field trip to Rajamandala and Bandung area", GEOSEA V: 50-64.
Mitasova, Helena. 1999. Modeling soil detachment with RUSLE 3d using GIS. University of Illinois at Urbana-Champaign. *<http://skagit.meas.ncsu.edu> [15/03/2005].*
Silitonga, P. H. 2003. Geological Map of Bandung sheet, Java, Scale 1:100,000. 3th Edition, Geological Research and Development Centre, Bandung, Indonesia.
Sjafrudin, Achmad. 2003. Erosion and Aquatic Weeds Problems in the Saguling Dam West Java. Mathematica et Natura Acta, Vol. 2, No. 3: 22-38.
Stone, R. P. 2000. Universal Soil Loss Equation (USLE). Factsheet E-Journal on-line. <http://www.gov.on.ca> [15/03/2005].
Sukiyah, E., Sudradjat, A., Hirnawan, R.F., & Muslim, D. 2006. Watershed Morphometry on Quaternary Volcanic Terrain in Southern Margin of the Bandung Basin: It's Implication in Distribution of Flood Area. Map Asia Conference 2006, Bangkok.
Sukiyah, E., Sudradjat, A., Hirnawan, R.F., Muslim, D., & Rosana, M.F. 2007. The Simple Grid Method in GIS Application for Delineation of Erosion and Flood Zones: Case study at Bandung Basin. SKIM X 29 – 31 Mei 2007, University Kebangsaan Malaysia, Bangi.
Tjetjep, W.S. 2004. Bandung basin: Geodynamic, Problem, and development. Proceeding of Bandung basin seminar: 1-22.*)
Van Zuidam, R. A. 1983. Guide to Geomorphologic - aerial photographic interpretation and mapping. Section of Geology and Geomorphology, ITC, Enschede, Netherland.
Wesley, L.D. 1977. Soil mechanics. 6th Edition, General Occupation Publishing, Jakarta.*)
Yuzirwan. 1996. Various land use and its effect toward run off, erosion, and sedimentation in Cikapundung Gandok Sub basin, Upper Citarum basin, West Java. Ph.D. Thesis, Postgraduate Program of University of Padjadjaran, Bandung.*)

*) in Indonesian with English abstract
**) in Indonesian

BIOGRAPHICAL NOTES

Emi Sukiyah was graduated from Ph.D. Program of Geosciences, University of Padjadjaran, Bandung, Indonesia in 2009. She has been working as lecturer in Geology Department, Faculty of Mathematic and Natural Sciences, University of Padjadjaran, since 1997. Since 2007 this department has been Faculty of Geosciences and Engineering. Since 1997 up to now she carried out many geological investigations and researches in some region in Indonesia about environmental geology, GIS, land development, morphometry, remote sensing, etc. She is a member of a famous Indonesia Association of Geologists (IAGI) in the country. She often follows some international activities that held by ADPC, NGI, etc. She had published her papers in many journals of geosciences and international seminars.

R. Febri Hirnawan was graduated from Ph.D. Program of Geosciences, University of Padjadjaran, Bandung, Indonesia in 1993 majoring in engineering geology. He was appointed as a professor in geology in 2000. He has been working as lecturer in Geology Department, Faculty of Mathematic and Natural Sciences, University of Padjadjaran, since 1973. Since 2007 this department has been Faculty of Geosciences and Engineering. Since 1970 up to now he carried out hundreds of geological investigations and researches in many regions in Indonesia about engineering geology, geotechnics, tectonics, neotectonics, and areal development geology. He is a member of a famous Indonesia Association of Geologists (IAGI) in the country. He had published his papers in many journals of geosciences and wrote few books. His technology invention in slope stabilization system has been patented and was presented before in 1995 IAMG (International Association for Mathematical Geology) Annual Conference in Osaka, Japan. Two other inventions of his about holistic valuation of terrain being based on genetic approach for spatial planning, and sand column infiltration well named GEOINFILTRANT are being finalized in a substantive examination by patent office to achieve patents.

Dicky Muslim was graduated from Doctor of Science (Dr), Graduate School of Science, Dept. of Geosciences, Osaka City University, Japan, in 2003. He has been working as lecturer in Geology Department, Faculty of Mathematic and Natural Sciences, University of Padjadjaran, since 1993. Since 2007 this department has been Faculty of Geosciences and Engineering. Since 1993 up to now he carried out many geological investigations and researches in some region in Indonesia and Japan about neotectonic, disaster, engineering geology, land development, remote sensing, etc. He is a member of Indonesia Association of Geologists (IAGI). He often follows some international activities that held by ADPC, NGI, etc. He had published his papers in many journals of geosciences and international seminars.

CONTACTS

Dr. Emi Sukiyah
The Faculty of Geosciences and Engineering, University of Padjadjaran
Bandung-Sumedang road km 21, Jatinangor
Bandung
INDONESIA
Tel. + 62227796545
Fax + 62227796545
Email: emi_s@unpad.ac.id
Web site: http://www.unpad.ac.id