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ASSESSMENT MODEL FOR DETERMINING SOIL ERODIBILITY FACTOR IN LOMBOK ISLAND

MODEL PENILAIAN UNTUK MENENTUKAN FAKTOR LINGKUNGAN TANAH DI PULAU LOMBOK

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ABSTRACT One of soil parameters that affects the rate of erosion is the soil erodibility. Soil erodibility studies had been conducted in one of the watershed of Lombok in 2015. The tests were carried out for five soil profiles by taking samples from each layers. Samples were analyzed for particles sizes and organic matter contents. The analysis was performed using two assessment models of soil erodibility, the Universal Soil Loss Equation (USLE) and Erosion Productivity Impact Calculator (EPIC) models. Obtained soil erodibility (K factors) values varied from 0.07 to 0.74 for USLE models and 0.18 to 0.46 for EPIC models. Statistical similarity (R) test resulted R=-0.28*10^{-19}. It has indicated that there was no statistical difference between the results of both methods. The older volcanic rocks give a high erodibility factor. In this study, vertisols soils show a higher erodibility factor than other volcanic rocks, such as inceptisols, andisols and entisols soil. Lower soil organic matter and clay contents are the factors that influence high soil erodibility.

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Kata kunci: Erodibility, erosion, Universal Soil Loss Equation (USLE), Erosion Productivity Impact Calculator (EPIC), Lombok.

ABSTRAK *Salah satu parameter tanah yang sangat berpengaruh terhadap besarnya erosi adalah faktor erodibilitas tanah. Studi erodibilitas tanah telah dilakukan di salah satu DAS di Pulau Lombok dengan uji lapangan. Uji lapangan dilakukan pada 5 profil tanah dan pengambilan sampel pada setiap lapisan untuk uji laboratorium terhadap kandungan partikel pasir, debu, liat dan bahan organik tanah. Analisis dilakukan menggunakan 2 model prediksi erodibilitas tanah yaitu model* Universal Soil Loss Equation *(USLE) dan* Erosion Productivity Impact Calculator *(EPIC). Nilai erodibilitas tanah dengan model USLE berkisar 0.07-0.74 dan 0.18-0.46 dengan model EPIC. Analisis statistik dengan tes R menghasilkan R=-0,28*10^{-19} yang menandakan nilai K yang diperoleh oleh kedua metode tidak berbeda. Endapan batuan vulkanik yang lebih tua di wilayah studi menghasilkan tingkat erodibilitas yang tinggi. Jenis tanah vertisols yang berasal dari endapan batuan volkanik tua menghasilkan tingkat erodibilitas tanah yang lebih tinggi dibandingkan jenis tanah lain yang terbentuk dari endapan batuan vulkanik seperti tanah inceptisols, andisols dan entisols. Semakin rendahnya kandungan bahan organik dan liat dalam tanah mengakibatkan semakin tingginya erodibilitas tanah.*

Keywords: *Erodibilitas, erosi,* Universal Soil Loss Equation (USLE), Erosion Productivity Impact Calculator (EPIC), *Lombok.*

INTRODUCTION

Indonesian watershed or river basin areas usually have complex social problems such as poverty, overpopulation, territorial conflict, weak economy, deforestation, and pollution. These societal problems often result in uncontrolled and unsustainable economic development in the river basin. Some problems occurred in the river basin of Lombok Island, such as soil erosion, sedimentation, and landslide (Bonita, 2014), while the decline of forest area of 37 ha/year increased critical land and surface water pollution in Ancar, Babak and Jangkok River (BPDAS DMS., 2009, Ministry of Public Works, 2010). According to data from WWF (2008) *in* World Agroforestry Centre (2010), there has been a degradation in Jangkok sub-watershed as characterized by the decrease of the average of discharge Jangkok river of 5.6% annually. High population growth, rapid development of industry, and the decrease of productive land and forest are among many factors causing a present phenomenon in the coastal area, especially in the watershed area. It has long-term effects on the quality of cultivable soil and the agricultural productivity, quality of water, transport of sediments, the changes in river channel and impacts on flooding (Morgan, 1995).

Soil erosion is one of the phenomena which often occurs and becomes a problem in land management and it is the primary source of sediment that pollutes streams (rivers) and lakes in the watershed zone. The eroded sediments carry nutrient, particular phosphate to waterways and contribute to eutrophication of lake and river. In fact, sediment usually causes hindrance to surface water flow. The sediment itself can alter stream channel characteristics and adversely affect aquatic ecosystems of the rivers (Schwab, *et al.,* 1996). A detachment of soil particles by wind and/or water forces which is named the soil erosion becomes a global problem especially in vulnerable environments (Panagos, *et al.,* 2012; Bagarello, *et al.,* 2012; Manyiwa and Dikinya, 2013). Erosion is a natural geomorphic process that was active during the whole geological time and formed from the earth's surface (Bathrellos and Skilodimou, 2007).

The ability of rainfall to cause erosion is called erosivity, whereas the capability of a soil to cause runoff, be detached, and be transported is known as soil erodibility. The latest soil erodibility (K) factor study due to erosion assessment, mostly based on USLE model has been done in several countries such Iran (Imani, *et al.,* 2014), Irak (Hassan and Agha, 2012), India (Chatterjee, *et al.,* 2013), Malaysia (Yusof, *et al.,* 2011), Chile (Bonilla and Johnson, 2012), Indonesia (Herawati, 2010; Utami, *et al.,* 2012; Anasiru, *et al.,* 2013), and China with comparison of USLE, RUSLE, EPIC and Dg models (Wang, *et al.,* 2013).

Soil erodibility is a common parameter for evaluating soil erosion and essential for erosion prediction and conservation planning. Soil erodibility is commonly used in both applied and fundamental soil erosion research. Knowledge concerning the soil erosion in a small island of Lombok is important not only to plant growth but also because it is linked to the nutrient supply of the soil.

In this study, USLE and EPIC methods were used for calculating soil erosion. Universal Soil Loss Equation (USLE) has the most useful and frequently used for soil erodibility term, while Erosion Productivity Impact Calculator (EPIC) was developed in 1981 and 1985 the model was ready for use in the RCA (Soil and Water Resources Conservation Act). Soil properties required in USLE are soil texture, organic matter, structural group, and permeability class. Meanwhile, to calculate the soil erodibility with EPIC are organic matter and soil texture. The differences between both methods are in soil structures and permeability parameters while the EPIC model does not include it.

Environmental degradation that occurs in the river basin of Lombok such as sedimentation and increasing critical land is due to soil erosion. Hence, this study is aimed to describe erosion potential from various soils in the study area by determining soil erodibility factor using USLE and EPIC models, and finally examining which is the most appopriate method between these two models that suitable for various purposes of erosion assessment.

STUDY AREA

The study area is located in West Lombok district of West Nusa Tenggara province, extends from 390.000-426.600mE to 9.045.000-9.070.000mN. The geology of the study area consist of volcanic rocks, sedimentary rocks and intrusive rocks of Tertiary to Quaternary age (Mangga, *et al.*, 1994). The west part of the study area is dominated by alluvial deposits (Qal), Quaternary volcanic deposits of Lekopilo formation (Qvl), consists of pumice, tuffs, breccias and lava and Pengulung formation (Tomp) of breccia, lavas, tuffs with limestone lenses occupies the northeast of study area (Figure 1).

The soil types of the study area are classified into inceptisols with sub-order of aquepts which is developed on alluvial deposit, vertisols with sub-order of aquerts which is developed on breccia and lava in older volcanic plain, entisols with sub-order of orthents which is developed on steep slope consist of breccia and lavas and andisols with sub-order of vitrands order which is developed on volcanic ash deposits (ICALRD, 2012). Land use in the study area on the slopes of wet climate areas is forest, whereas in the dry climate area in the southern part, savannahs and shcrub are found. Land cultivation of rice (paddy) is developed in the flat areas through which the rivers flow, and agriculture dryland, mixed garden and plantations are in the area of slopes <40% (Djuwansah, *et al.*, 2015).

METHODS

Laboratory analysis. Five location of soil sampling were selected representing the four major soil orders of West Lombok district, derived from four different parent materials. Soil samples were collected from each layer of soil order around the plot areas. Soil organic matter content laboratory analysis was performed using the method of Walkley and Black (1934) *in* USDA (2014) and soil texture was determined

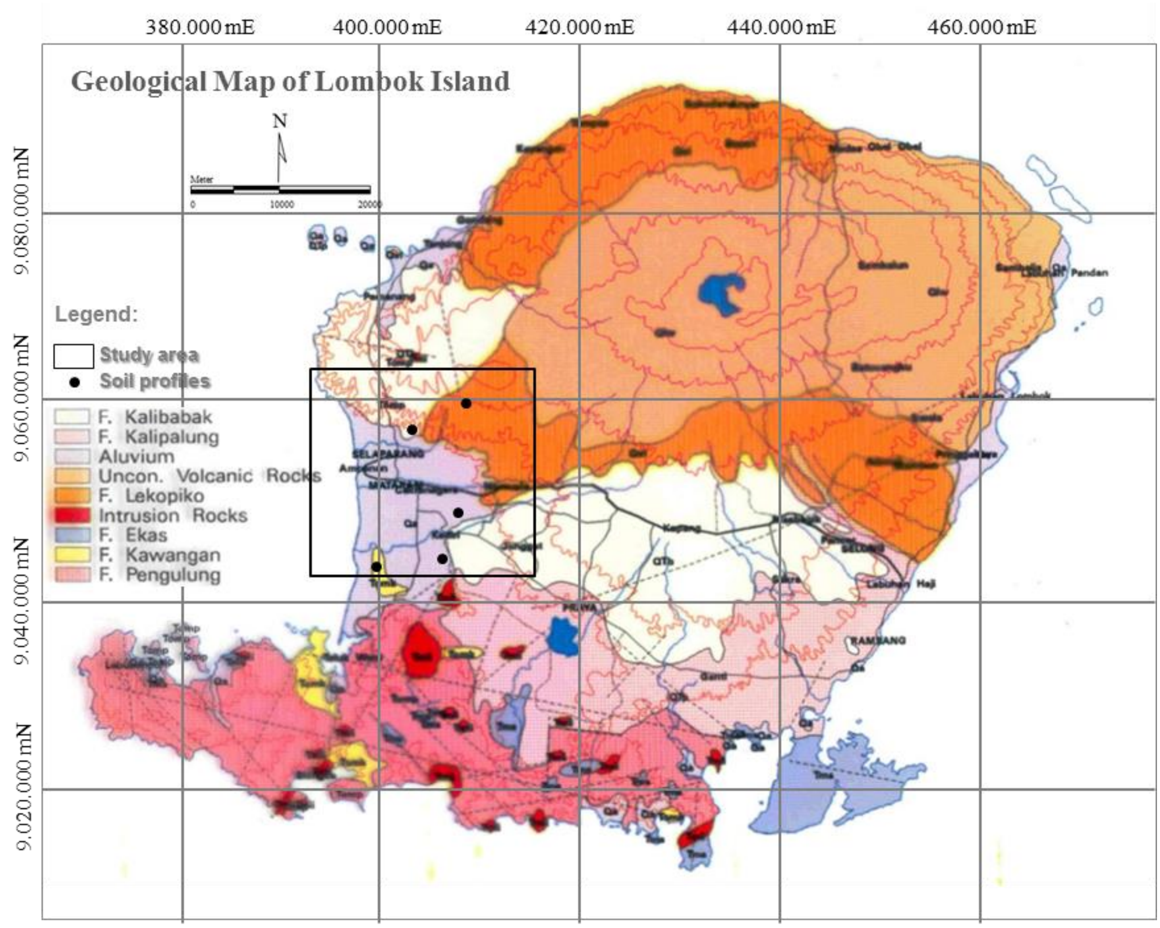

Figure 1. Geological map and location of study area (modified from Mangga *et al.*, 1994).

by pipette method (Soil Research Institute, 2005). Soil texture was determined using the percentage of primary particle based on USDA soil texture triangle in TAL software (Teh, 2002). Soil structure and soil permeability values are determined according to soil texture, and each soil texture is assigned a structure code and permeability class (USDA, 1983). The percentage of silt, sand, clay and organic matter content were used to determine soil erodibility factor (K) using soil erodibility by USLE (Wischmeier and Smith, 1978) and Erosion Productivity Impact Calculator (EPIC) (Sharply and Williams, 1990) models. The estimation of USLE soil erodibility factor (Wischmeier *et al.*, 1971) was used with equation (Wischmeier and Smith, 1978) as follows :

$$K = \frac{[2.1 \times 10^{-4}(12 - OM)M^{1.14} + 3.25(St - 2) + 2.5(P' - 3)]}{100}$$

where M represents a newly defined term that was the product of the silt + very fine sand (0.002-0.1 mm) and 0.1-2 mm sand fractions, expressed as percentages; St and P' denote soil structure and soil permeability class respectively; and OM denotes the soil organic matter content (%).

The EPIC model was used to calculate the soil erodibility (Sharply and Williams, 1990), the equation is as follows :

$$K = 0.2 + 0.3e^{\left(-0.0256SAND\left(1-\frac{SILT}{100}\right)\right)} \times \left(\frac{SILT}{CLAY + SILT}\right)^{0.3} \times \left(1 - \frac{0.25OM}{OM + e^{(3.72-2.95OM)}}\right) \times \left(1 - \frac{0.7SN}{SN + e^{(22.9SN-5.51)}}\right)$$

where *SAND* is the sand content (%); *SILT* is the silt content (%); *CLAY* is the clay content (%); *OM* is the soil organic carbon content (%); and *SN*=1-SAND/100.

Similarity (R) test of K- values resulted by both models have been calculated as follows :

$$R = \frac{rB - rW}{M/2}$$

where rB is the average of rank similarities of pairs of samples (or replicates) originating from different sites, rW is the average of rank similarity of pairs among replicates within sites, and $M = n(n - 1)/2$ where n is the number of samples. R values is constrained between −1 to 1, where positive numbers signify more similarity within sites and negative number signify more similarity between sites than within sites. Values close to zero represent no difference between within sites and within sites similarities.

RESULTS AND DISCUSSION

Deposition of young volcanic rock formed Andisol soils order or soil with the younger formation (entisols or Inceptisols) which is rich in mineral glass (vitric).

Andisols in SPT-60 (Table 1) was found at Old volcanic mountain landform and parent material consist of Breccia and lava with sub-order of vitrands, great group of udivitrands, sub-group of Typic Udivitrands (Figure 2) with fragmental, mixed, isothermic. Alluvial soils (aquepts) located along the river valley that forms meandering plains. Inceptisols in SPT-13 was found at alluvial landform and parent material

Table 1. Soil physical characteristics.

Soil Unit (SPT)	Soil Type	Soil Order	Landform	Parent Material
13	Typic Epiaquepts	Inceptisols	Alluvial	Deposition of clay and sand
42	Typic Vitrandepts	Inceptisols	Volcanic hillslope	Volcanic ash and andesite
56	Typic Endoaquerts	Vertisols	Old volcanic plains	Calcareous breccia, lava
59	Lithic Ustorthents	Entisols	Volkan hills	Breccia and lava
60	Typic Ustivitrands	Andisols	Old volcanic mountain	Breccia and lava

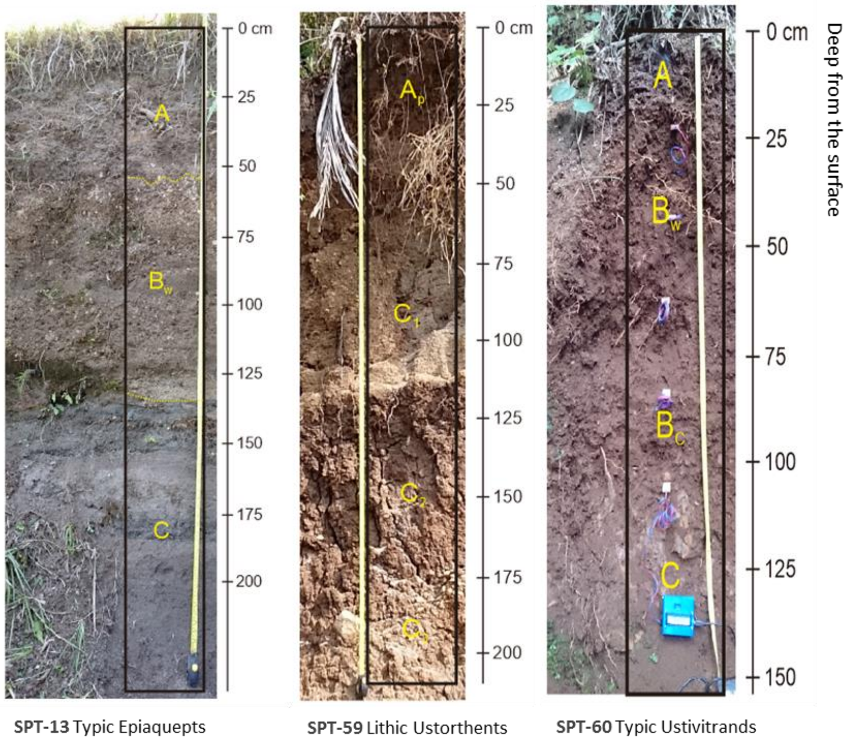

Figure 2. Soil profile horizon of SPT 13, SPT 59 and SPT 60.

consisting of deposition of clay and sand with sub-order of Aquepts, great group of Epiaquepts, sub-group of Typic Epiaquepts with sandy loam texture at the soil surface.

The older volcanic rocks formed a vertisols. Vertisols in SPT-56 was found at old volcanic plains landform and parent material consist of calcareous breccia, lava with sub-order of aquerts, great group of Endoaquerts, sub-group of typic Endoaquertswith silt loam texture at the soil surface. Whereas in volcanic hills areas with slopes generally formed young soils (entisols) shallow (orthents) on top of the hard rock (lithic contacts). Entisols in SPT-59 was found at volcanic hills landform with sub-order of orthents, great group of ustorthents, sub-group of lithic ustorthents with ashy-skeletal, glassy and nonacid.

In Figure 2, A layer is the zone of leaching / eluviation of materials in solution / suspension, and accumulation of organic matter. This layer is usually dark in color and fine in texture and porous. B layer is the mineral horizon characterized by enrichment of organic matter, sesquioxides, or clay and usually has dark colors relative to the C horizon and strongly influenced by illuviation process and receiving materials eluviated from the A layer. The B horizon also has a higher bulk density than the A horizon due to the enrichment of clay particles. C layer was the mineral horizon is comparatively unaffected by the pedogenic processes and composed of weathered parent material operating in A and B horizons.

Soil texture triangle in TAL software showed that class of soil texture for all A layer in the study area had silt loam to sandy loam in each layer of soil (Table 2 and Figure 3). Most of the soil is composed of a sand particle at A layer. Table 3 showed that the soil unit consists of 40.51-69.27% of sand particles and showed a very small percentage of clay particles of 0.67-6.24%. This is apparently influenced by the geology of the research area which largely consists of young volcanic breccias and lava and some form of alluvial deposition.

Soil structure at soil surface in study area is classified as fine granular at SPT 13, 42, 59 and 60, while SPT 56 classified as medium-coarse granular (Table 2). Fine granular soil structure according to Schwab, *et al.,* (1992) categorized as 1-2 mm size and 2-10 mm size of medium-coarse granular. Soil permeability at the soil

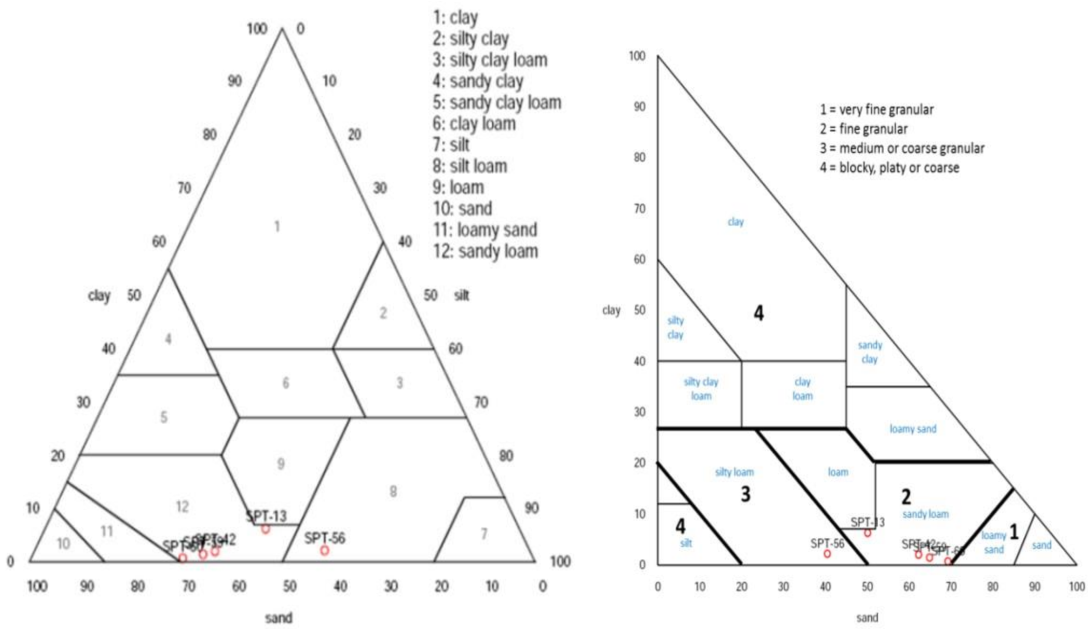

Figure 3. Soil texture and structure triangle.

Table 2. Soil structure and permeabilityclass.

Soil Unit (SPT)	Soil Type	Soil Depth (cm)	Soil Texture	Soil Structure	Soil Permeability
13	Typic	0-60	Sandy Loam	Fine granular	Moderate –rapid
	Epiaquepts	60-80	Sandy Loam	Fine granular	Moderate –rapid
		80-150	Sandy Loam	Fine granular	Moderate –rapid
42	Typic	0-35	Sandy loam	Fine granular	Moderate –rapid
	Vitrandepts	35-100	Loamy sand	Very fine granular	Moderate –rapid
		100-140	Loamy sand	Very fine granular	Moderate –rapid
		140-160	Sandy loam	Fine granular	Moderate –rapid
56	Typic	0-30	Silt loam	Medium-coarse granular	Moderate
	Endoaquerts	30-80	Silt loam	Medium-coarse granular	Moderate
		80-130	Silt loam	Medium-coarse granular	Moderate
		130-150	Sandy loam	Fine granular	Moderate –rapid
59	Lithic	0-50	Sandy loam	Fine granular	Moderate –rapid
	Ustorthents	50-110	Loamy sand	Very fine granular	Moderate –rapid
		110-175	Silt	Blocky, platy or massive	Moderate
		175-200	Silt loam	Medium-coarse granular	Moderate
60	Typic	0-25	Sandy loam	Fine granular	Moderate –rapid
	Ustivitrands	25-60	Sandy loam	Fine granular	Moderate –rapid
		60-120	Silt loam	Medium-coarse granular	Moderate
		120-150	Silt loam	Medium-coarse granular	Moderate

surface in the study area is classified as moderate-rapid rated between 60-130 mm/h and 60-130 mm/h of moderate class (Schwab *et al.*, 1992).

Parameters to calculate the soil erodibility is shown in Table 3. From laboratory data (Table 3) most of the soils contained less than 15% of organic content, namely 1.27-3.74% at all SPT in surface layers that categorized as very low. Lithic ustorthents/SPT-59 (Entisols) type with sandy loam texture gives the highest concentration of organic content (3.74%) where palm plantations landuse use give effect to increase organic matter content in soils. Mixed garden in SPT-13 with typic epiaquepts (Inceptisols) as a second highest concentration of organic content in study area. The low organic

Table 3. Parameter used for the calculation of Soil erodibility (K factor).

Soil Unit (SPT)	Soil Depth (cm)	Silt+very fine sand (%)	Sand (%)	Clay (%)	Organic Matter	K factor	
						USLE	EPIC
13	0-60	44,23	50,11	6,24	2,46	0,24	0,25
	60-80	41,31	57,41	2,6	1,57	0,25	0,25
	80-150	48,16	47,8	4,95	0,90	0,31	0,33
42	0-35	37,50	62,26	1,99	1,27	0,22	0,26
	35-100	20,65	78,47	0,97	0,56	0,08	0,20
	100-140	24,23	75,17	1,01	0,69	0,11	0,23
	140-160	42,18	58,75	0,7	0,73	0,28	0,31
56	0-30	59,42	40,51	2,16	1,42	0,45	0,32
	30-80	54,75	43,43	1,84	1,21	0,44	0,33
	80-130	58,45	42,61	2,02	0,47	0,47	0,38
	130-150	41,44	59,01	0,71	0,44	0,29	0,32
59	0-50	34,20	64,89	1,42	3,74	0,15	0,22
	50-110	18,69	80,86	1,08	0,34	0,07	0,18
	110-175	84,12	13,07	3,58	0,67	0,74	0,46
	175-200	66,31	24,16	11,52	0,44	0,50	0,42
60	0-25	30,84	69,27	0,67	1,83	0,17	0,21
	25-60	47,76	48,06	5,4	1,61	0,29	0,27
	60-120	79,81	18,75	3,72	1,67	0,60	0,36
	120-150	65,39	28,68	9,31	1,10	0,46	0,37

content at surface layer on typic vitrandepts/SPT-42 (Inceptisols) and typic endoaquerts/SPT-56 (Vertisols) soil type with mixed garden landuse.

The soil erodibility (K factors) is determined by USLE and EPIC models for all layers (Table 3). Based on Table 3, we found that the soil erodibility (K factors) varied from 0.07 to 0.74 for USLE models and 0.18 to 0.46 for EPIC models due to the effects of different organic content, parent material, and particles content. Meanwhile, vertisols at SPT-56 had the highest level of erodibility in surface soil with K factor of 0.45 (USLE) and 0.32 (EPIC). Soil erosion occurs mostly on the soil surface. The older deposition of volcanic rock gives a high erodibility factor in this study. In this study, vertisols, as developed by old volcanic rocks, results in a higher erodibility factor than other volcanic rock such inceptisols soil. The Inceptisol was similar to the Vertisol in color, but it is higher in organic content and lower in Silt+very fine sand content on topsoil. Clay content in vertisols is lower than Inceptisols soil.The deposition of younger volcanic rock formation formed entisols on SPT-59 have the lowest levels of soil erodibility in the surface layer.

The high erodibility level from one place to another is due to the condition of the soil texture with small percentage of clay. Grain size analysis results of our samples have shown the important influence of silt plus fine sand fraction content to the erodibility factor. According to Morgan (1995) the soil texture influenced soil erodibility where large-sized particles are resistant to haulage because of its size, while the fine particles are resistant to destructive power

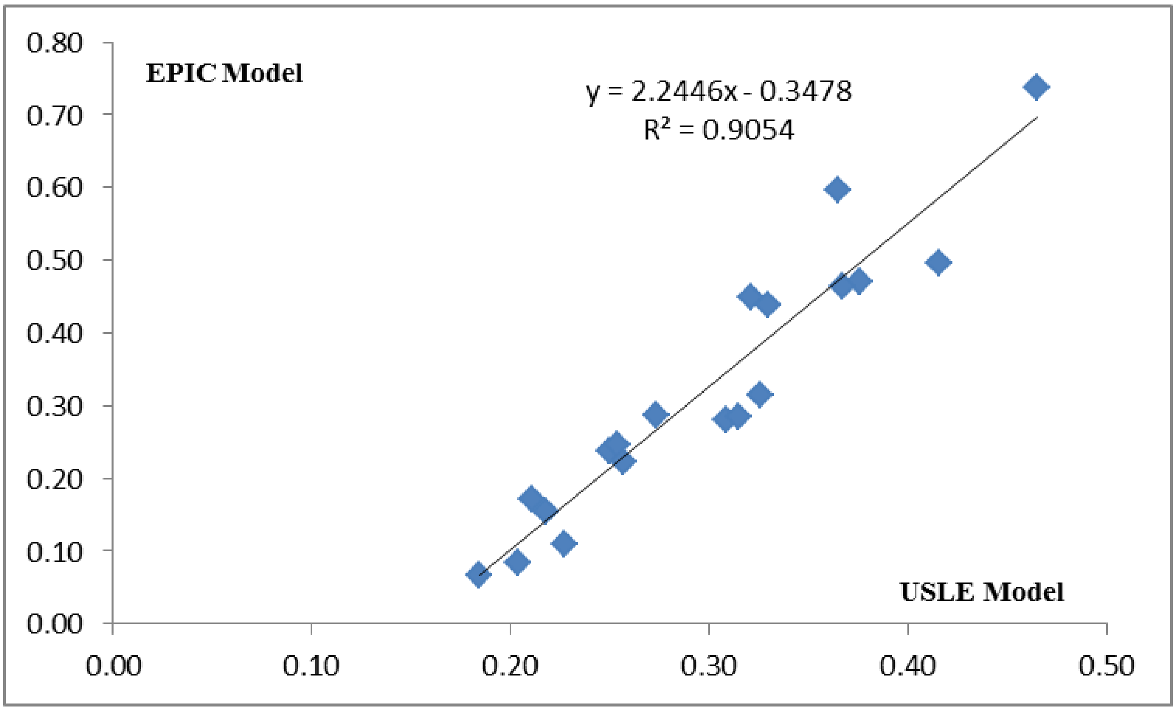

Figure 4. K factor for USLE and EPIC models.

due to the soil cohesion factor. Particles that are less resistant to both are silt and very fine sand. The shape of soil structure and stability of soil aggregates and aggregated percentage was instrumental in determining the sensitivity of the soil against erosion. Soil that is sensitive to soil erosion has the lowest percentage of clay aggregates. Wang *et al.,* (2013) found that the soil organic matter and clay contents are the principal factors that influenced soil erodibility.

The correlation (Figure 4) shows that K values obtained by both USLE and EPIC models is strongly correlated and could signify both methods representing the same performances for determining soil erodibility factor of the study area. Furthermore, similarity (*R*) testing (Clarke, 1993; Buttigieg *et al.,* 2014) for K values, obtained by both USLE and EPIC model, gives very low and negative similarity value (R = -2.84*10-*19*), signify K values obtained by both model does not show statistical different.

Meanwhile, standard deviation K values calculated by USLE model (σ = 0,183) is greater than that by EPIC (σ = 0,083), could indicate that the employment of USLE model results in more varied K values than EPIC. This outcome seems reasonable since USLE model includes soil structures parameter while the EPIC model does not include it. The above fact suggests that EPIC model for erosion assessments is more appropriate to a large extent, whereas USLE model is more suitable for more detailed studies in the restrained area.

CONCLUSIONS

Both USLE and EPIC model consider soil texture, mainly the content of silt and fine sand fraction, as the most important soil factor affecting erodibility. In this study, vertisols as developing by old volcanic rock results a higher erodibility factor than other volcanic rock such inceptisols, andisols and entisols. A lower soil organic matter and clay contents are the factors that influenced erodibility of soil. Soil with a high erodibility level need for soil conservation technique such terrace in agricultural slopes land. USLE method is more suitable for detailed studies, while the EPIC method is appropriate for a more generalized study of an extended area.

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REFERENCE

Anasiru, R. H., Rayes, M. L., Setiawan, B., and Soemarno, 2013. Economic Valuation of Soil Erosion on Cultivated Drylands inLangge Sub-watershed, Gorontalo, Indonesia. Journal of Natural Sciences Research, 3(8), 40-48.

Bagarello, V., Di Stefano, C., Ferro, V., Giordano, G., Iovino, M. and Pampalone, V., 2012. Estimating the USLE the Soil Erodibility Factor in Sicily, South Italy. Applied Engineering in Agriculture, 28, 199-206.

Bathrellos, G, Skilodimou, H., 2007. Using The Analytic HierarchyProcess To Create An Erosion Risk Map. A Case Study in Malakasiotiko Stream, Trikala Prefecture. Bulletin of the Geological Society of Greece, XXXX, 1904–1915.

Baver, I. D., Gardner, W. H., and Gardner, W. R., 1972. Soil Physics. John Willey & Sons, Inc. 498pp

Bonilla, C. A., and Johnson, O. I., 2012. Soil Erodibility Mapping and Its Correlation with Soil Properties in Central Chile. Geoderma, 189-190, 116 – 123.

Bonita, 2014. Characteristics of Dodokan Watershed in Mataram City, West Lombok regency (In Indonesian). Jurnal Media Bina Ilmiah, 8, 1.

BPDAS DMS., 2009. Identification and Critical Land Inventory NTB Report (In Indonesian). Center for Watershed Management Dodokan Moyosari. Mataram.

Buttigieg, P. L., Ramette, A., 2014. A guide to statistical analysis in microbial ecology: a community-focused, living review of multivariate data analyses. FEMS Microbiology Ecology, 90 (3), 543–550. DOI:10.1111/1574-6941. 12437.

Chatterjee, S., Krishna, A. P., and Sharma, A. P., 2013. Geospatial assessment of soil erosion vulnerability at watershedlevel in some sections of the Upper Subarnarekha river basin, Jharkhand, India. Environ Earth Sci. Springer-Verlag Berlin Heidelberg. DOI 10.1007/s12665-013-2439-3.

Clarke, K. R., 1993. Non-parametric multivariate analyses of changes in community structure. Austral Ecology. 18 (1), 117–143. DOI:10.1111/j.1442-9993.1993. tb00438.x.

Djuwansah, M. R., Narulita, I., Mulyono, A., and Rusydi, A. F., 2015. Optimization of Land Use For Sustainable Water Availability in Small Island (In Indonesian). Research Center for Geotechnology LIPI, Competitive Research Report 2015 (unpublished).

Hassan, K. F., and Agha, M. D., 2012. Effects of Calcium Carbonate on The Erodibility of Some Calcareouse Soils by Water Erosion. Mesoptamia J. of Agri., 40 (4) ISSN: 2224-9796.

Herawati, T., 2011. Erosion Hazard Level Spatial Analysis in Area Das Cisadane Watershed at Bogor Regency (In Indonesian). Journal of Forest Research and Nature Conservation, 7(4), 413-424.

Indonesia Center for Agricultural Land Resources Research and Development (ICALRD), 2012. Map of Land Resource 1:250.000 scale, Mataram Sheet. Indonesia Center for Agricultural Land Resources Research and Development.

Imani, R., Ghasemieh, H. and Mirzavand, M., 2014. Determining and Mapping Soil Erodibility Factor (Case Study: Yamchi Watershed in Northwest of Iran). Open Journal of Soil Science, 4, 168-173.

Mangga, S. A., Atmawinata, S., Hermanto, B., Setyogroho, B., and Amin, T. C., 1994. Geological Map of Lombok Sheet West Nusa Tenggara (In Indonesian).

Geological Research and Development Center, Bandung.

Manyiwa, T. and Dikinya, O., 2013. Using Universal Soil Loss Equation and Soil Erodibility Factor to Assess Soil Erosion in Tshesebe Village, Northeast Botswana. African Journal of Agricultural Research, 8, 4170-4178.

Ministry of Public Works, 2010. Water Resources Management Pattern Lombok Island River Area (In Indonesian). Decree of the Minister of Public Works of Water Resources Management Pattern River Region. No: 589/KPTS/M/2010.

Morgan, R. P. C., 1995. Soil erosion and conservation. Longman. 198pp.

Panagos, P., Meusburger, K., Alewell, C. and Montanarella, L., 2012. Soil Erodibility Estimation Using LUCAS Point Survey Data of Europe. Environmental Modeling & Software, 30,143-145.

Schwab G., Fangmeier D., Elliot W., and Frevert R., 1992. Soil And Water Conservation Engineering, 4th ed. Wiley, New York, 526pp.

Schwab, G. O., Fangmeier, D. D., and Elliot, W. J., 1996. Soil and Water Management Systems. John Willey & Sons, Inc. 371 pp.

Setiady, D., Sukmana, N., Kurnio, H., and Cahyo, N., 2001. Surficial Sea Bottom Sediments and Composition of Heavy Minerals In the Eastern Lombok Waters. Bulletin of Marine Geology, 16 (1), 23-33.

Sharply, A. N., and Williams, J. R., 1990. EPIC-Erosion/Productivity Impact Calculator I, model documentation. U.S. Department of Agriculture Technical Bulletin, No. 1768. (Washington, DC:USDA Agricultural Research Service), 235 pp.

Soil Research Institute, 2005. Hint Chemical Analysis Soil, Plant, Water and Fertilizers (In Indonesian). Centre for Research and Development of Soil and Agro-climate. Agency for Agricultural Research and Development. Agriculture Department.

Soil Survey Division Staff, 1993. Soil Survey Division Manual. Soil Conservation Service. U.S. Department of Agriculture Handbook No.18.

Soil Survey Staff, 1990. Keys for Soil Taxonomy. SMSS Technical Monograph No. 19 Fourth Edition. Cornell University.

Teh, C. B. S., 2002. A computer program to determine the soil texture class for any classification scheme. Agro-Search, 9, 19-21.

USDA, 1983. National Soil Survey Handbook. No. 430. US Department of Agriculture, USDA, Washington DC.

USDA, 2014. Kellog Soil Survey Laboratory Methods Manual. Soil Survey Investigations Report No. 42. Version 5.0 US Department of Agriculture, USDA, Washington DC.

Utami Dewi, I. G. A. S., Trigunasih, N. M., Kusmawati, T. 2012. Erosion Prediction and Soil and Water Conservation Planning in Saba Watershed (In Indonesian). Tropical Agroekotechnology Journal, 1(1), 12-23.

Wang, B., zheng, F. and Romkens, M. J. M., 2013. Comparison of soil erodibility factors in USLE, RUSLE2, EPIC and Dgmodels based on a Chinese soil erodibility database. Acta Agriculturae Scandinavica Section B, 63 (1) , 69-79.

Wischmeier, W. H., and Smith, D. D., 1978. Predicting rainfall erosion losses. A guide to conservation planning. United States Department of Agriculture Agricultural Handbook 537.

Wischmeier, W. H., Johnson, C. B., and Cross, B. V., 1971. A soilerodibility nomograph for farmland and construction sites. Journal of Soil and Water Conservation, 26, 189-193.

World Agroforestry Centre, 2010. Watershed Condition Assessment with PaLA Method and Flow Persistence model (In Indonesian). Brief No. 08 Policy Analysis Unit.

Yusof, M. F., Abdullah, R., Azamathulla, H. M., Zakaria, N. A., and Ghani, A. A. B., 2011. Modified Soil Erdodibility Factor, K for Peninsular alaysia Soil Series. 3rd International Conference on Managing Rivers in the 21th Century. Sustainable Solutions for Global Crisis of Flooding, Pollution and Water Scarcity. In 6-9 Desember 2011 Penang, Malaysia.