Advances in Environmental Biology, 10(1) January 2016, Pages: 101-106

AENSI Journals

Advances in Environmental Biology

ISSN-1995-0756 EISSN-1998-1066

Journal home page: http://www.aensiweb.com/AEB/

Estimation of Erosion Hazard Level Using Universal Soil Loss Equation (USLE) Method in Endanga Watershed, Southeast Sulawesi, Indonesia

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Received 28 December 2015; Accepted 28 January 2016; Available online 24 February 2016

ABSTRACT
This study was conducted in Endanga watershed, part of Konaweha watershed, located in Landono and Mowila Districts, South Konawe Region, Southeast Sulawesi Province, Indonesia. The area of watershed was ± 1.353,67 ha, comprising of primary forest, secondary forest, bush, reed, mix cropping and paddy field. Land slope varied from flat (0-8%), sloping (8-15%), slightly steep (15-25%) to hilly (25-40%). The survey method was used in this study. Based on the land characteristic which affected the land formation and its potential use, Endanga watershed was classified into 17 land units. This study used universal soil loss equation (USLE) to analyze erosion potential. Result showed that the amount of erosion was approximately 1.68 - 830.89 t/ha/year, with erosion average measured was 188.68 t/ha/year. The highest erosion occurred in land unit 15 (bush, slope 15-25%) with 830.89 t/ha/year and the lowest erosion was in land unit 5 (paddy field, slope 0-8%) with 1.68 t/ha/year. Soil loss tolerance (SLT) was approximately 21.28–40.32 t/ha/year, with SLT average was 29.5 t/ha/year. Most of the Endanga watershed (10 land units) had high to very high on erosion hazard level (EHL) and erosion hazard index (EHI).

KEYWORDS: Erosion Hazard Level (EHL), Erosion Hazard Index (EHI), Land slope, Land use, Erosion, Endanga watershed

INTRODUCTION

Land resource is needed as primary food source for human. The number of population is growing while the land area is constant causing the increasing need land resources for food supply. On the other hand, due to limited job opportunity affects people to farm those areas which are unsuitable for farming, hence creating land degradation.

Endanga watershed is a part of Konaweha watershed, which is located in Landono and Mowila District, South Konawe Region, Southeast Sulawesi Province, Indonesia. The area of watershed is ± 1.353,67 ha, which is comprised of primary forest, secondary forest, bush, reed, mix cropping and paddy field [3]. Land slope in Endanga watershed varies from flat (0-8%), sloping (8-15%), slightly steep (15-25%) and steep (25-40%). Observation of Endanga watershed shows that most of the forest has been converted to estate plantation, mix cropping and bush. The conversion of land use in a short period of time creates several problems, such as flood, drought, and high rate of erosion that subsequently causing river silting due to the increasing number of sedimentation that flows to the river.

Damage in land resources, particularly in watershed's upstream will decrease the land productivity, and also affect the ecological and hydrological functions of the watershed. Land degradation due to erosion in

watershed's upstream, will creating negative impact in the upstream (*on-site*) and downstream (*off-site*). The detrimental impact in upstream ranges from decreasing land productivity and farmer's income to the occurrence of land critical. Meanwhile, in downstream, there will be sedimentation, water pollution, drought and flood [4,6,7].

Assessment of future erosion in one area is called evaluation of erosion potential or erosion hazard level. This assessment is needed to provide the erosion hazard level of Endanga watershed, as guidance in planning land use alternative and suitable conservation in this area. Evaluation of erosion hazard level in this watershed can be conducted using USLE (universal soil loss equation) method [8].

METHOD AND MATERIAL

This study was conducted in Endanga watershed, Southeast Sulawesi, Indonesia, in 2014-2015. Descriptive survey method was used in this study, to collect primary and secondary data. Primary data was collected from direct observation and laboratory analysis. Secondary data was collected from various sources, such as government report and other related study's publications. The data of climate, topography, and soil were collected and analyzed in this study.

Endanga watershed was classified to several land units based on land characteristic that affected land formation and its potential use. Land characteristic that was chosen as references were geology formation, land slope, land use and soil type. Based on the overlay of the aforementioned characteristic, Endanga watershed then classified to 17 land units.

Analysis of erosion estimation used Universal Soil Loss Equation (USLE) [8]:

$$A= R.K.LS.C.P \quad (1)$$

where ; A = average of land erosion(t/ha/year), R = rain erosivity factor, K = soil erodibility factor, LS = topographic factor (length of slope and degree of slope), C = cropping-management or land use factor, dan P = conservation practice factor

To calculate the amount of rain erosivity, we used Lenvain equation as published in Bols, [2]:

$$R = 2.21 \text{ x } (Rain)m^{1.36}.. \quad (2)$$

where ; R = monthly rain erosivity index; (Rain)m = monthly rainfall (cm) Soil erodibility factor (K) was calculated using:

$$100K = 2.7132\ M^{1.14}\ (10^{-4})\ (12 - a)+3.25\ (b-2)+2.5\ (c-3) \quad (3)$$

Where: M = percentage (textured fine sand, silt and clay), a = organic matter content (1.724 x C-organic), b = soil structure code, dan c = soil permeability value.

Length of slope factor (L) and degree slope (S) could be calculated using equation to of topography factor (LS) which was:

$$LS = \sqrt{X}\ \{\ 0.0138+(0.00965 \text{ x } S\ )+(0.00138 \text{ x } S^2). \quad (4)$$

Where: X = length of slope in m, S = degree of slope in percent.

However, since it was difficult to calculate length of slope in this study due to the characteristic of the slope, which is multiple slope, the LS factor (Table 1) was obtained using equation (4) development, as mentioned by Gregory *et al* in Hardjowigeno dan Widiatmaka [5]

Table 1: slope class assessment (LS).

slope (%)	LS Value
0 -8y	0.25
8 -15	1.20
15- 25	4.25
25 -40	9.5
>45	12.00

Land use factor (C) and conservation practice factor (P) was based on the value as mentioned by Arsyad [1]. The soil loss tolerance (SLT) was determined using equation to calculate erosion rate limit by considering minimum soil depth and land resources life, which was:

$$\mathbf{SLT} = \frac{DE - DMIN}{WPT} + \mathbf{LPT}$$

Where :

SLT: soil loss tolerance (mm/th)
DE : equivalent depth (soil depth factor x soil effective depth)
DMIN : minimum soil depth (mm)
WPT : land resources life (year)
LPT: soil formation rate

Erosion hazard level (EHL) is an estimation of maximum soil loss compared to its thickness soil (solum), while erosion hazard index (EHI) is an indication of erosion hazard in particular area.

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$$\textbf{EHI} = \frac{Erosion\ actual}{SLT} \quad \textbf{(}t/ha/year)$$

Where :
EHI : Erosion hazard index
SLT : Soil loss tolerance

RESULT AND DISCUSSION

Erosion estimation (A):

Erosion estimation is the method of analysis to predict the amount of soil degradation in the future caused by current erosion. Erosion estimation was obtained by calculating rain erosivity factor, soil erodibility factor, length and slope ramp factor, and land use and conservation factor. The increase in the amount of erosion was caused by the increase in rain erosivity factor, soil erodibility factor, length and degree of slope factor, while the land use and conservation factor were decreased. The amount of erosion in Endanga watershed was approximately 1.68 - 830.89 t/ha/year, with erosion average measured was 188.68 t/ha/year (Table 2).

Tabel 2: Erosion estimation in Endanga watershed.

Land units	R	K	LS	C	P	A (t/ha/year)
1	1598.38	0.52	1.2	0.05	1	49.68
2	1598.38	0.57	1.2	0.05	1	54.85
3	1598.38	0.39	1.2	0.1	0.15	11.34
4	1598.38	0.44	1.2	0.1	0.15	12.66
5	1598.38	0.42	0.25	0.01	1	1.68
6	1598.38	0.54	1.2	0.3	1	310.58
7	1598.38	0.42	1.2	0.3	1	242.51
8	1598.38	0.25	4.25	0.21	1	361.86
9	1598.38	0.48	9.5	0.05	1	363.90
10	1598.38	0.56	4.25	0.01	1	38.13
11	1598.38	0.81	4.25	0.05	1	274.20
12	1598.38	0.49	4.25	0.1	0.75	248.17
13	1598.38	0.48	0.25	0.01	1	1.92
14	1598.38	0.24	4.25	0.3	1	491.86
15	1598.38	0.41	4.25	0.3	1	830.89
16	1598.38	0.70	9.5	0.01	1	106.90
17	1598.38	0.55	9.5	0.05	1	418.39
Erosion average						188,68

1. *Rain erosivity:*

Rain erosivity value in Endanga watershed was related to average rainfalls of the last 10 years, which was 1598.38 mm/year. Rain intensity and the amount of rainfalls affected soil dispersion ability. The high amount of rainfalls did not cause erosion if the intensity was low. Likewise, high rain intensity did not cause erosion as long as it occurred in a short period of time, since the amount of water could not transport the soil. Erosion occurred when rain intensity and the amount of rainfalls creating a runoff.

2. *Soil Erodibility:*

The land's sensitivity to erosion is called soil erodibility factor. This factor was affected by various physical, chemical, and biological properties of the soil, such as: texture, structure, soil organic matter, soil depth, properties sub surface and soil fertility. soil properties that affect the value of K were (1) percentage of silt and fine-sand, (2) percentage of clay, (3) percentage of organic matter content (4) soil structure, and (5) soil permeability.

The value of soil erodibility factor in Endanga watershed varied between 0.24 (medium) to 0.81 (very high). The higher value of soil erodibility factor means the erosion occurrence is easier. Based on the observation in Endanga watershed, from 17 land units, there were two land units (8 and 14) with medium soil erodibility value (0.25 and 0.24); five land units (3, 4, 5, 7 and 15) with slightly high soil erodibility value (0.39 – 0.44); six land units (1, 6, 9, 12, 13 and 17) with high soil erodibility value (0.48-0.55); and four land units (2, 10, 11 and 16); with very high soil erodibility value (0.56 - 0.80). Based on these data, the land use in Endanga watershed must be planned properly to create sustainable land productivity.

3. *Length and degree slope factor:*

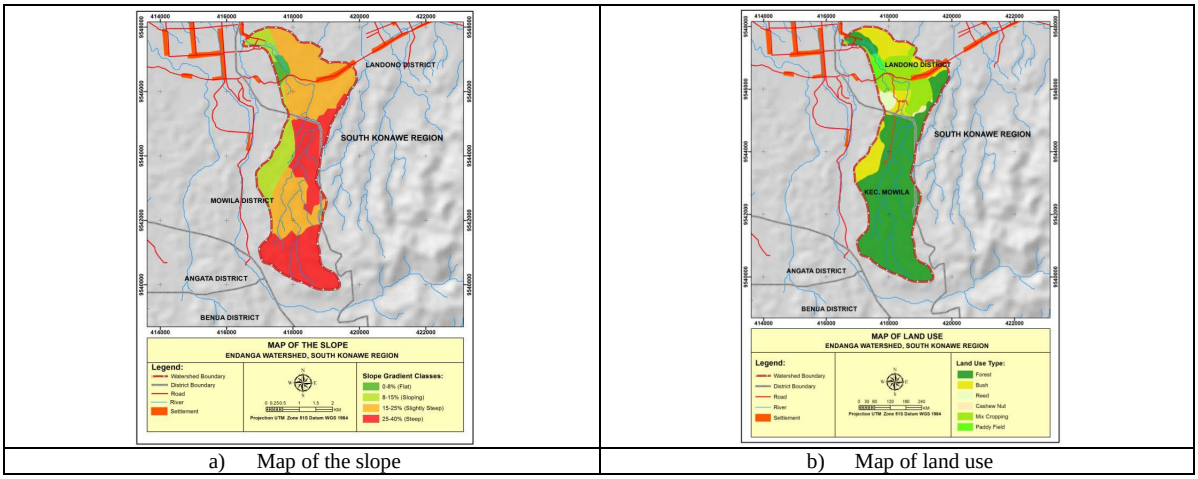
Slope and length are the topography properties that strongly affect the runoff and erosion. Slope with degree >15% has higher erosion potential compared to slope with degree <15%. Based on digitized map and direct observation, Endanga watershed (Figure 1a) has 30.14 ha (2.23%) flat area (slope 0-8%), 196.68 ha (14.54%) sloping (8-15%), 628.32 ha slightly steep (slope 15-25%) and 498.35 ha (36.82%) hilly area (slope

25-40%). Majority of the area in Endanga watershed is sloping and slightly steep (83.24%), hence it has a very high probability of erosion.

4. Land use:

Based on observation in Endanga watershed, it can be classified to six type of land use (Figure 1b), which is 744.75 ha primary forest (55.02%), 103.38 ha secondary forest (7.64%), 203.39 ha mix cropping (15.03%), 245.62 ha bush (18.14%), 26.39 ha reed (1.95%), and 30.14 ha paddy field (2.23%).

Land use of thick forest or grassland can neutralize the impact of rainfalls and topography on erosion (Arsyad, 2000). Vegetation's roots will increase the mechanical and chemical stability of soil aggregate. Root fibers will bind soil grains, while vegetation's secretion will produce chemical agent to soil aggregation.



a) Map of the slope | b) Map of land use

Fig. 1: Slope and land use in Endanga watershed.

Soil loss tolerance (SLT):

Soil loss tolerance (SLT) is the limit of soil loss in order to maintain the soil productivity. The value of soil loss tolerance is presented in Table 3.

Table 3: Soil loss tolerance in Endanga watershed.

Land units	Soil effective depth (mm)	soil Depth Factor	Resource life (year)	SLT (mm/year)	Bulk density (g/cm^3)	SLT (t/ha/year)
1	1200	0.8	300	3.20	0.97	31.04
2	1200	0.8	300	3.20	1.23	39.36
3	1100	0.8	300	2.93	1.29	37.84
4	1200	0.8	300	3.20	1.20	38.84
5	1200	0.8	300	3.20	1.25	40.00
6	950	0.8	300	2.53	1.10	27.87
7	1100	0.8	300	2.93	1.10	32.27
8	1000	0.8	300	2.67	1.29	34.40
9	750	0.8	300	2.00	1.13	22.60
10	900	0.8	300	2.40	1.22	29.28
11	800	0.8	300	2.13	1.17	24.96
12	700	0.8	300	1.87	1.14	21.28
13	1200	0.8	300	3.20	1.07	34.24
14	1200	0.8	300	3.20	1.26	40.32
15	1100	0.8	300	2.93	1.08	31.67
16	950	0.8	300	2.53	1.15	29.13
17	850	0.8	300	2.27	1.08	24.48
Average of SLT						29.50

The soil loss tolerance in Endanga watershed was very low compared to the amount of erosion (A). Average value of SLT in Endanga watershed was only 29.5 t/ha/year, while the amount of erosion had passed this value with 188.68 t/ha/year.

Erosion hazard level (EHL) and erosion hazard index (EHI):

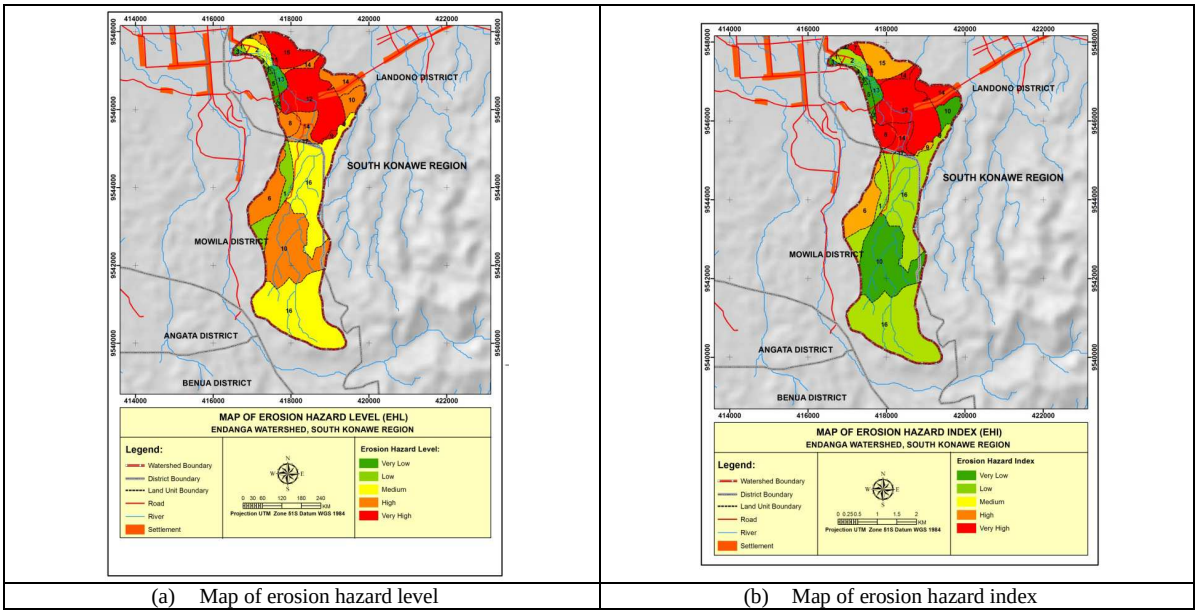
Erosion hazard level (EHL) is the estimation of maximum soil loss compared to soil depth, assuming no change in land use and conservation. Erosion hazard index (EHI) is the indication of erosion hazard in one area. Result of EHL and EHI calculation in Endanga watershed is shown in Table 4.

Table 4 shows that the erosion hazard level in Endanga watershed varied from very low (land units 3, 4, 5, 13), medium (land units: 1, 2, 16), high (land units 6, 7, 8, 10) to very high (9, 11, 12, 14, 15, 17). Likewise, the erosion hazard index in Endanga watershed also varied from low, medium, high, to very high. Distribution of EHL and EHI in Endanga watershed are presented in Figure 2.

Table 4: Erosion hazard level and erosion hazard index in Endanga watershed.

Land units	Soil depth (cm)	A (t/ha/year)	EHL criteria	SLT (t/ha/year)	EHI	EHI criteria
1	120	49.68	Medium	31.04	1.60	Medium
2	120	54.85	Medium	39.36	1.39	Medium
3	110	11.34	Very low	37.84	0.30	Low
4	120	12.66	Very low	38.84	0.33	Low
5	120	1.68	Very low	40.00	0.04	Low
6	95	310.58	High	27.87	11.15	Very high
7	110	242.51	High	32.27	7.52	High
8	100	361.86	High	34.40	10.52	Very high
9	75	363.90	High	22.60	16.10	Very high
10	90	38.13	High	29.28	1.30	Medium
11	80	274.20	Very high	24.96	10.99	Very high
12	70	248.17	Very high	21.28	11.66	Very high
13	120	1.92	Very low	34.24	0.06	Low
14	120	491.86	Very high	40.32	12.20	Very high
15	110	830.89	Very high	31.67	26.23	Very high
16	95	106.90	Medium	29.13	3.67	Medium
17	85	418.39	Very high	24.48	17.09	Very high

Erosion hazard level (EHL) is strongly affected by soil effective depth and the amount of erosion. Area with high amount of erosion may have low EHL value if the soil is deep. However, based on the calculation of EHL in Endanga watershed, land units with deep soil still had high to very high EHL. This was caused by the high amount of erosion in the area. Several areas had high amount of erosion due to the high soil erodibility factor and steep slope. Majority of Endanga watershed area is slightly steep (46.42%) with 15-25% slope and hilly (36.82%) with slope 25-40%. The soil erodibility factor in Endanga watershed also very high, therefore the erosion occurrence is very likely.



(a) Map of erosion hazard level (b) Map of erosion hazard index

Fig. 2: Erosion hazard level (a) and erosion hazard index in Endanga watershed.

Conclusion:

Based on the analysis that has been conducted, it can be concluded that:

1. The amount of erosion in Endanga watershed was approximately 1.68 - 830.89 t/ha/year, with average erosion measured was 188.68 t/ha/year. The highest erosion (830.89 t/ha/year) occurred in land unit 15 (bush) with 15-25% slope, while the lowest (1.68 t/ha/year) occurred in land unit 5 (paddy field) with 0-8% slope.
2. Soil loss tolerance (SLT) in Endanga watershed was approximately 21.28–40.32 ton/ha/year, with SLT average 29.5 t/ha/year.

3. Majority of Endanga watershed (10 land units) had high to very high erosion hazard level, while 9 land units had high to very high erosion hazard index.

ACKNOWLEDGEMNTS

This research was financially supported by BPOPTN of Universitas Halu Oleo. The authors thanks to Prof. Dr. Ir. H. Usman Rianse, MS, Rector Universitas Halu Oleo for his fruitful advises.

REFERENCES

[1] Arsyad, Sitanala, 2012. Konservasi Tanah dan Air. Ehisi Kedua. Bogor : IPB Press.
[2] Bols, P.L., 1978. The isoerodent Map of Java and Madura. Belgium Technical Assistance Project ATA 105. Soil Research Institute, Bogor.
[3] BPDAS (Balai Pengelolaan Daerah Aliran Sungai), 2012. Pola rehabilitasi lahan dan konservasi tanah DAS Sampara. Kendari.
[4] Gao, J., 2008. Detection of Changes in Land Degradation in Northeast China from Landsat TM and Aster Data. The International Archives of the Photogrametry, Remote Sensing and Spatial Information Sciences, 37:1533-1538.
[5] Hardjowigwno, S. and Widiatmaka, 2007. Evaluasi Kesesuaian Lahan dan perencanaan Tata Guna Lahan. Gadjah Mada University Press. Yogyakarta.
[6] Meusburger, K., D. Banninger and C. Alewell, 2010. Estimating Vegetation Parameter for Soil Erosion Assesment in an Alpine Catchment by Means of Quickbird Imagery. International Journal of Applied Earth Observation and Geoinformation, 12: 201-207.
[7] Tefera, B. and G. Sterk, 2010. Land Management, Erosion Problems and Soil and Water Conserbation in Fincha's Watershed, Western Ethiopia. Land Use Policy, 27: 1027-1037.
[8] Wischmeier, W., D.D. Smith, 1978. Predicting rainfall erosion losses-a guide to conservation planning. Handbook, 537. USDA-ARS.