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Erosion Prediction and Soil Conservation Planning in Lawo Watershed Indonesia

Mahendra Harjianto[1*] Naik Sinukaban[1,2] Suria Darma Tarigan[2] Oteng Haridjaja[2]
1. Science of Watershed Management Major, Postgraduated Bogor Agricultural University, Jl, Meranti Kampus IPB Darmaga, Bogor, Indonesia 16680
2. Department of Soil Science and Land Resource, Faculty of Agriculture, Bogor Agricultural University, Jl, Meranti Kampus IPB Darmaga, Bogor, Indonesia 16680
*E-mail of the corresponding author: mahendraharjianto25@gmail,com

Abstract
Land conversion from forest to agricultural land is a serious problem in Lawo Watershed. Agricultural practices without implementing the adequate of soil conservation and agrotechnology has led to high erosion and decrease land productivity. Management of Lawo Watershed is should be made by integrating the soil and water conservation and the increament of agriculture production. The aim of this study is to analyze the prediction of erosion and arrange the land use and soil conservation planning which actual erosion (A) is greater than tolerable eorion (T) in Lawo Watershed. USLE equation and Erosion Hazard Index is used to predict the erosion and soil and water conservation planning in the location. The results showed that moderate rate of surface erosion is dominant in the location which area of 18,804.64 ha (53.46%), which is generally spread in the center of watershed, while tolerable erosion is varies between 17.56 - 54.77 ton ha^{-1} thn^{-1} in each land unit. Erosion hazard index is the ratio between erosion predictions on each land unit with tolerable erosion in the same land unit. Index erosion which is moderate, high and very high category is dominant with total area of 19,347.66 ha (55%), this condition indicates that A value is higher than T. Therefore, it is need to manage the land unit in Lawo Watershed through land use planning and apply the soil conservation, so that the sustainability of land in the watershed can be reached. Land use planning that suggested are reforestation of shrubland area and development of agroforestry in mixed farming, while soil and water conservation that recommended are bund teracce and garden terrace combined with teracce strenghtening crop as well as mulch of 6 ton ha^{-1} in slope 0 – 8%.
Keywords: USLE, Soil Erosion, Watershed, Erosion Index, Soil and Water Conservation.

1. Introduction

Watershed is a dynamic ecosystems that connects the upstream and downstream area. The dynamics of forest conversion to agriculture has caused damage to watershed ecosystem, including the increament of runoff coefficient (average runoff/c), if average runoff is higher, the flood discharge is also high. Others impact such as drough, land erosion, decline in land productivity, and unstable watershed hydrology, both *in site* maupun *off site*, (Sinukaban N, 2007; Halim F, 2014).

Lawo watershed area of 35,174 ha is one of watershed in South Sulawesi that very important to be managed, because of degradation and increasing forest conversion countinuosly and uncontrol. Degradation form and pattern is very diverse such as: (1) decreasing of vegetation density; (2) changes in land cover type; (3) impermeability, such as conversion from cultivated land into settlement; and (4) conversion of forest into non forest land. The last pattern in this watershed reached 4 887 ha (33.48%) from total area of watershed, while the encroachmented forest of 8,718.93 ha or 58.29 % from total area of forest area of 14,597 ha. The distribution of primary forest in Lawo watershed now is only 1,023.14 ha (2,91%), and secondary forest of 8,768.37 ha (24.93%), while the dominant land use is mixed farm of 18,123.05 ha (51,52%) with dominant plant species are cacao (*theobroma cacao*), mulberry (*Morus sp*), coconut (*Cocos nucifera L.*) (BPDAS 2012).

Land use change pattern in Lawo Watershed also effected discharge fluctuation with Q_{max} range between 0,7 m^3/s - 1,44 m^3/s and Q_{min} between 0,18 m^3/s – 0,36 m^3/s. Ratio Q_{max}/Q_{min} > 30 (41.33) which occurred in 2010, while the variation of flood water level a long Lawo river is between 1.9 meters to 13 meters, and annual discharge plan for 50 year periode is 433.795 m^3dtk^{-1}. Other impact is the extent of land degradation. Land with erosion hazard index are heavy and very heavy rate of 14,279.27 ha or 40.60% from total area of Lawo Watershed (Dinas PSDA Sulawesi Selatan 2012; Pertiwi *et al*., 2011; BPDAS Jeneberang Walanae 2012).

Production of several types commodity is decrease because land degradation, such as rice, ground nuts, soybeans, and corn, each production of 5.34 ton ha^{-1} (rice), 3,57 ton ha^{-1} (corn), 1,38 ton ha^{-1} (soybeans) and 1,66 ton ha^{-1} (ground nuts) (BPS, Soppeng dalam Angka 2013).

Refer to existing problem in Lawo Watershed, it is needed to manage the Lawo Watershed intensively and continuously in order to reach the sustainability of watershed. Watershed management which combine soil and water conservation practices with the increament of agriculture production as well as community welfare. Sustainability of watershed management and development can be reached with the proper allocation of land use in watershed. Thereby, it is require land capability evaluation that connecting land use pattern and its carrying capacity (Panhlkar S., 2011; Yalew G; dan Yilak T., 2014). The aim of this study is to examine erosion prediction and arrange land use and soil conservation planning in Lawo Watershed when the actual erosion (A) is higher than tolerable erosion (T).

2. Data and Method

2.1. Study Site

Lawo Watershed which is located in 119º45’0” – 119º58’30” N and 4º24’0” – 4º10’30” S has total area of 35,174.62 Ha. Administratively, Lawo Watershed is in Soppeng Regency, South Sulawesi Province. A part of this watershed is function as depresion storage and water recharge, which flow directly to Tempe Lake. Research is done on July 2013 – February 2014 (Figure 1).

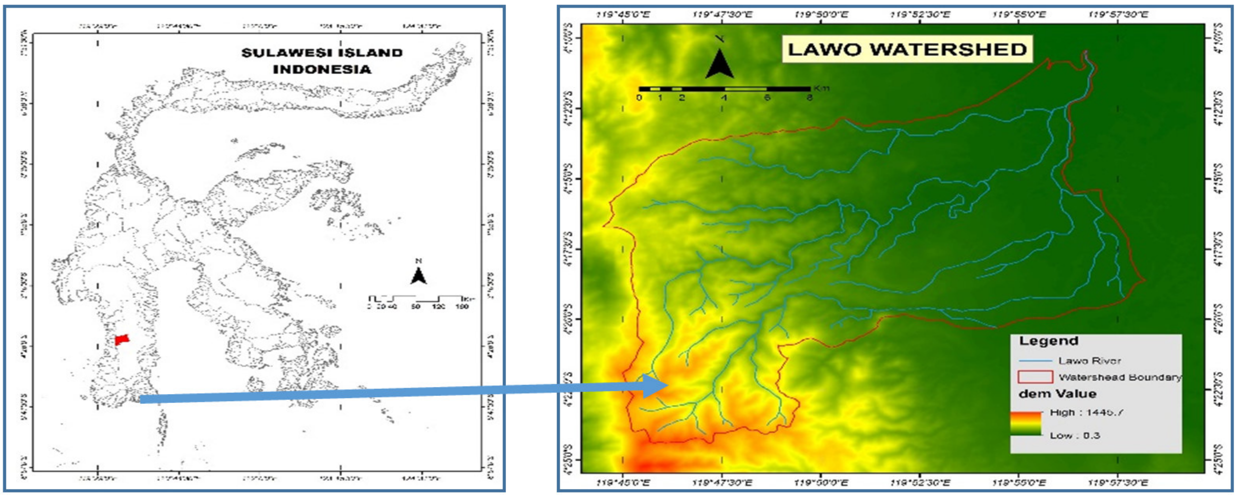


Figure 1. Study Area

2.2. Data Collection and Tools

The working map, GPS (Geographycal Position System), abney level or clinometer, compass, ring sample, stop watch and others equipment for soil survey/sampling is required for this research. Beside, plots for erosion and runoff measurement are builded. Soil and sediment sample is analyzed in soil laboratory. Laboratory equipment, stationery and computer is also required in this research.

2.3. Method

a. Determination of Observation Land Unit

The smallest land unit of 25 ha is used to predict erosion with USLE method. Land unit is resulted from overlay process of slope, soil type and land use map.

b. Erosion Prediction in Observation Land Unit

Erosion is calculated by USLE in selected land unit (Wischmeier dan Smith, 1978). USLE was developed by National Run Off and Soil Loss Data Centre that established in 1954 by The science and education administration of United State in cooperation with Purdue University (Wischmeier dan Smith, 1978). The equation of USLE is:

$$A = R\ K\ L\ S\ C\ P$$

where:

A : eroded soil (ton per hektar per year)
R : rainfall indeks factor (erosivity)
K : soil erodibility factor
L : slope length factor
S : steepness slope factor
C : cover crop and crop management factor
P : soil conservation factor.

USLE is easy to apply and can be applyglobally with exactly value of each factors and can predict erosion in long term in different land use type. This mode can be used to choose the better agrptechnology method.

c. GIS Modelling

Erosion calculation with USLE method is done using GIS Application, both LS factor calculation and erosion prediction as well as land use planning in Lawo Watershed.

d. Rainfall Erosivity Factor (R)
Rainfall erosivity is rainfall erosion index that show relationship between total rainfall energy (E) with maximum 30-minutes rainfall intensity (I_{30}) yearly. Wischmeier and Smith (1978), used EI_{30} as an index of rainfall erosivity index, because the multiplication of rainfall energy and maximum rainfall intensity for 30 minutes show the strongest relationship with eroded soil. Rainfall kinetic energy is calculated by E = 210 + 89 log I. In Indonesia, because the lack of daily rainfall data, so that the equation of rainfall kinetic is using the EI formula which is developed by Bols (Arsyad 2010).
According to Bols (1978), rainfall erosivity factor (R) is summary from the value of monthly raifall erosion and calculated by:

$$EI_{30} = 6.119 + (Rain)^{1.21}\ (Days)^{0.47}\ (Maxp)^{0.53}$$

where:
EI_{30} = average monthly rainfall erosivity
Rain = average monthly rainfall (cm)
Days = average rainfall day per month
Maxp = average maximum rainfall in 24 hours every month.

e. Soil Erodibility Factor (K)
Soil erodibility is rate of erosion per rainfall erosivity index for soil in a standar plot with length of 22 m and slope of 9% without crop. This parameter is influenced by texture, organic matter content, permeability, and soil structure. The equation of K is developed by Wischmeier dan Smith (1978) as follow:

$$100K = \{1,292\ (2,1\ M^{1,44}\ (10^{-4})(12 - a) + 3,25\ (b - 2) + 2,5\ (c - 3)\}$$

where :
K = soil erodibility
M = soil texture class (% very fine sand + % silt)(100 - % clay)
a = % organic matter
b = soil structure code
c = soil profile permeability code.

f. Slope Length and Steepness Factor (LS)
Slope length factor is an index between erosion on a slope length with erosion on slope length of 22 m identically. While slope factor is an index between erosion on a certain slope with erosion on slope 0f 9% identically. The both factor can be calculated directly by (Wischmeier dan Smith, 1978):

$$LS = \sqrt{X}\ (0.138 + 0.00965\ S + 0.00138\ S^2)$$

where: X = slope length (m) and S = steepness of slope (%).

g. Crop and its Management Factor (C)
C factor describe an index between erosion from land with crop and its management to erosion from land without crop and unmanaged. This factor measures the effect combination of crop and its management. C value is identified from publication of research which conducted in Indonesia. C factor in this study is based on land cover map derived from landsat imagery interpretation of Lawo Watershed in year 2001 and 2013.
h. Conservation Factor (P)
The value of human factor in soil conservation factor is an index between erosion from land with applying specific conservation technique with erosion from land without application of conservation technique. Soil conservation including strip cropping, contour tillage, ridges, and teracce. The base P value for land without conservation treatment is one.

f. Tolerable Erosion
Tolerable erosion is calculated based on equation by Wood and Dent (1983 in Arsyad 2010). The equation is desirable the soil minimum depth, the rate of soil formation, equivalent depth, and resources life. The equation is:

$$T = \frac{D_e - D_{min}}{UGT} + LPT$$

where:
T = tolerable erosion
D_e = equivalent depth (Arsyad, 2000)

= soil effective depth (mm) x soil depth factor
D_{min} = minimum soil depth (mm)
UGT= resources life, 250 year for continuos use and intensively (Sinukaban, 1989)
LPT = rate of soil formation, 1.2 mm/year (Sinukaban, 1999).

h. Decision Making for Land Use Planning in Lawo Watershed

Land use planning in lawo Watershed is done spatially by map overlay of erosion prediction and tolerable erosion map for each land unit. If land unit with value of erosion prediction is bigger than tolerable erosion ($A \geq T$), then soil conservation agrotechnology is necesssary to be applied in order to reduce land erosion and reach the sustainability of land carrying capacity in Lawo Watershed.

3. Results and Discussions

3.1. Intensively Observation of Land Unit Characteristics in Lawo Watershed

Land unit is a part of land which has unique characteristics. Seyhan (1977) said that watershed is divided into two categories, namely (1) land factor and (2) vegetation and land use factor. There is 25 land unit from overlay soil, slope and land use map of Lawo Watershed (35,174.62 ha). The distribution of land physical characteristics in each land unit is presented in Table 1.

Tabel 1. Distribution of Physical Characteristics in Land Unit of Lawo Watershed

Land unit	**Soil**		**Management Factor**			**Slope**		**Area**
	type	**K**	**Land Use**	**C**	**P**	**Steepness**	**LS**	**(Ha)**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	Dystropepts	0.25	Shrubland	0.3	1	15 - 30 %	2.01	382.62
2	Dystropepts	0.33	Shrubland	0.3	1	30 - 45 %	4.09	97.05
3	Tropaquepts	0.26	Shrubland	0.3	1	3 - 8 %	1.16	170.34
4	Dystropepts	0.31	Crop Forest	0.005	1	30 - 45 %	4.09	123.67
5	Dystropepts	0.30	Primary Forest	0.005	1	15 - 30 %	6.12	52.26
6	Dystropepts	0.35	Primary Forest	0.005	1	30 - 45 %	4.89	970.88
7	Dystropepts	0.25	Secondary Forest	0.005	1	15 - 30 %	5.00	2321.64
8	Dystropepts	0.26	Secondary Forest	0.005	1	30 - 45 %	4.89	6446.72
9	Dystropepts	0.23	Plantation Forest	0.005	1	15 - 30 %	5.00	188.72
10	Dystropepts	0.42	Mixed Farm	0.5	1	0 - 3 %	0.30	176.48
11	Dystropepts	0.21	Mixed Farm	0.2	1	3 - 8 %	0.98	550.31
12	Dystropepts	0.34	Mixed Farm	0.3	1	8 - 15 %	0.79	3232.39
13	Dystropepts	0.28	Mixed Farm	0.2	1	15 - 30 %	1.48	6779.60
14	Paleudults	0.31	Mixed Farm	0.2	1	3 - 8 %	0.80	265.17
15	Paleudults	0.43	Mixed Farm	0.2	1	8 - 15 %	0.57	263.99
16	Tropaquepts	0.17	Mixed Farm	0.3	1	3 - 8 %	0.80	5582.49
17	Tropaquepts	0.34	Mixed Farm	0.2	1	8 - 15 %	0.79	1272.62
18	Dystropepts	0.26	Upland Agriculture	0.2	1	15 - 30 %	2.46	63.34
19	Tropaquepts	0.28	Upland Agriculture	0.2	1	3 - 8 %	0.98	416.11
20	Tropaquepts	0.26	Upland Agriculture	0.2	1	8 - 15 %	1.82	95.15
21	Dystropepts	0.26	Paddy Field	0.01	1	3 - 8 %	0.98	251.37
22	Tropaquepts	0.17	Paddy Field	0.01	1	0 - 3 %	0.30	101.87
23	Tropaquepts	0.27	Paddy Field	0.01	1	3 - 8 %	0.98	4687.10
24	Fluvaquents	0.21	Thicket swamp	0.01	1	0 - 3 %	0.30	328.50
25	Tropaquepts	0.17	Thicket swamp	0.01	1	0 - 3 %	0.30	354.23

Agricultural characteristics in Lawo Watershed is differentiated into two groups of mixed farm, ie. mixed farm with cocoa (*Theobroma cacao*), banana (*Musa sp*), coconut (*Cocos nucifera*), hazelnut (*Aleurites moluccana)*, mulberry (*Morus sp*) and fruits crop with low through high canopy density. Additionally, there is seasonal crop agriculture with corn (*Zea mays* ssp), ground nut (*Arachis hypogaea* L.) and paddy field (*Oryza sativa* L). This location is use traditional agricultural systems without soil and water conservation practices. In that way, it will affects the high erosion and sedimentation in Lawo Watershed.

3.2. Erosion Factors

a. Rainfall Erosivity Factor

Rainfall is climate factors that most influence on erosion. It is include the amount, intensity, and rainfall distribution. Those factor will determine runoff power and land degradation due to erosion (Arsyad 2010). Analysis results from daily rainfall for 28 years of data (1985-2012) showed that raifall erosivity in Lawo

Watershed of 1,674 (Table 2). According to Arsyad (2010), energy of rainfall kinetic affect erosion, but the most correlated with erosion is multiply between total of rainfall energy and 30 minutes maximum rainfall intensity (EI30).

Table 2 Monthly Rainfall Erosivity in Lawo Watershed

Month	Rain (cm)	Days (day)	Maximum (cm)	Monthly EI30	R Value
1	14.7	10	4.5	118.94	1674.44
2	17.4	10	5.6	163.79	
3	15.9	10	4.9	136.83	
4	20.6	12	5.7	186.15	
5	24.1	13	6.4	230.49	
6	15.8	10	4.5	129.80	
7	14.4	8	5.2	139.10	
8	6.3	5	2.5	43.28	
9	6.1	3	2.4	51.78	
10	13.4	7	4.0	118.13	
11	17.7	9	5.8	179.00	
12	18.8	10	5.5	178.16	

Source: Analysis result from Agency of Water Resources Utilization, South Sulawesi Province 2013.

Heavy erosion occurs from November to July when the observed distribution of EI30 for 10 years. This is due to the higher EI30 in these month than other months. The high EI30 related to rainfall both rainy days and 24 hours maximum rainfall. The heavy rainfall will make the energy generated by rainfall is getting bigger for splash and transport soil particle. Interaction of high rainfall which supported by high intensity and rainfall duration as well as the growing size of rain drops will lead the maximum power, especially when kinetic energy reach maximum. Thereby, rainfall power to ruin the soil aggregates will increase. The distribution of EI30 can be used as a guide in determining the time of crop in order to reduce hit power in the right time.

b. Soil Erodibility Factor

There are 4 groups of soil in Lawo Watershed based on the map of Regional Physical Planning Project for Transmigration (RePPProT) 1987. These soil are classified by FAO-UNESCO classification ie dystropepts, fluvaquents, paleudults, and tropaquepts. Calculation of K factor or soil erodibility is done for each land unit because they have unique biophysics characteristics that effect soil erodibility. Soil erodibility is affected by organic matter, soil permeability, slope and land cover (Nguyen M 2011).

Soil resistance against erosion and transport of soil particles by rainfall kinetic energy is presented by soil erodibility index. Classification of soil erodibility index for each land unit in Lawo Watershed is presented in Figure 2 and Table 3.

Table 3 Classification of soil erodibility index in Lawo Watershed

Erodibility		**Land Unit**	**Area**	
Value	**Class**		**(Ha)**	**(%)**
0.11 - 0.20	Low	16, 22, 25	6,038.59	17.17
0.21 - 0.32	Medium	1,3,4,5,7,8, 9,11 ,13, 4, 18,19 ,20, 21,23,24	23,122.63	65.74
0.33 0.43	Moderate	2,6,10,12,17	5,749.41	16.35
0.44 - 0.55	High	15	263.99	0.75
Total			35,174.62	100.00

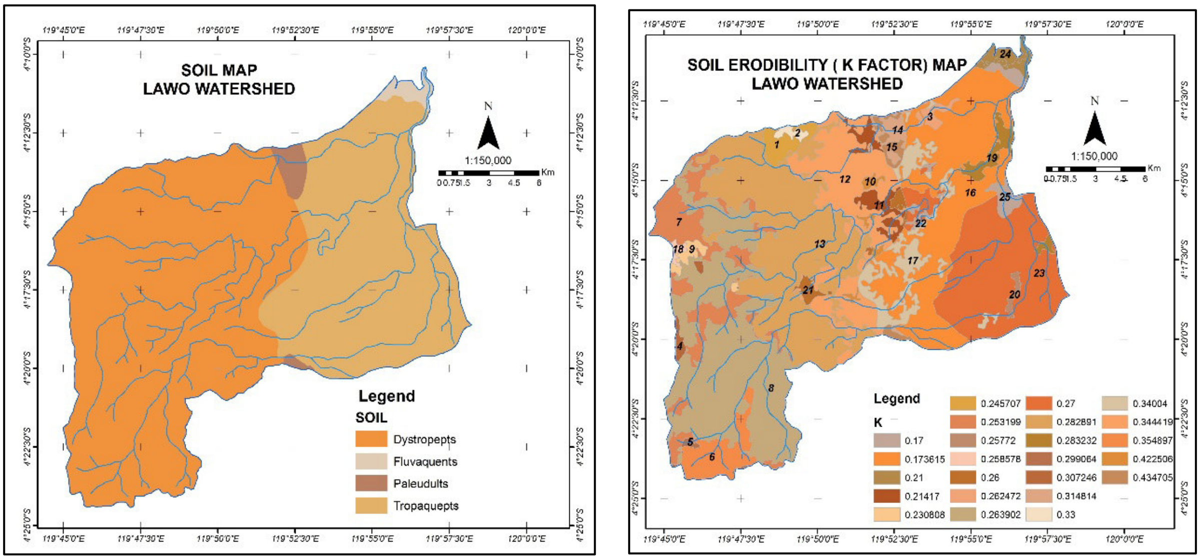


Figure 2. Soil Map and Soil Erodibility Map (K Factor) in Lawo Watershed

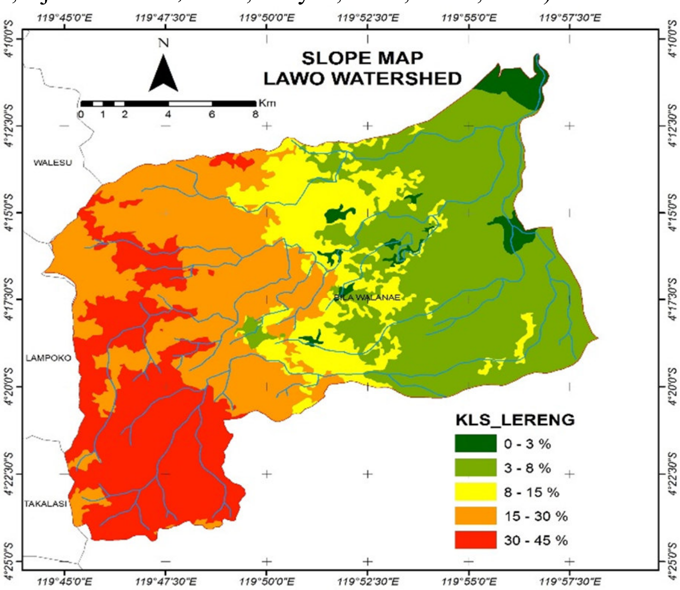
The lowest soil erodibility factor in Lawo watershed is 0.170 and the highest is 0.435. This classification of soil erodibility index is dominated by medium erodibility class which cover the area of 23,122.63 ha (65.74%). Erodibillity factor shows the resistency of soil to erosion, the high soil erodibility then eroded soil is high. Table 3 shows that most areas in Lawo Watershed requires to manage both soil conservation and adequate soil tillage even in area which moderate and high class of erodibility.

c. Topographic Factor

Slope is a topographic character which has important role in erosion process. Arsyad (2010) said that slope factor (both slope and slope length) are topographic characteristics that most influence the runoff and erosion. Slope is one factor that trigger the erosion, slope steepness is effected fluctuation of total runoff and transport energy of water to soil particles, if the steepness of slope is growing increase, then soil aggregat which splashed by rainfall drop will high. This is due to by the biggest of gravity where the slope is getting steep from horizontal plan so that the eroded top soil is getting bigger. If the slope becomes twice of steep, then the erosion per unit area into 2.0 – 2.5 more (Banuwa *et al.,* 2008; Jijun HE *et al.,* 2010; Arsyad, 2010; Saida, 2013).

Table 4. Slope Classes in Lawo Watershed

Slope Classes	Area	
	Ha	%
0 - 3 %	961.09	2.73
3 - 8 %	11,922.89	33.90
8 - 15 %	4,864.14	13.83
15 - 30 %	9,788.19	27.83
30 - 45 %	7,638.32	21.72
Jumlah	**35174.62**	**100.00**



Figuer 3. Slope Map of Lawo Watershed

Table 4 and Figure 3 shows that distribution of slope class is dominated by 3 – 8% which cover area of 11,922.89 ha (33.90 %) , followed by slope class of 15-30 % of 9,788.19 ha (27.83%). LS Coefficient in Lawo watershed range between 0.3 – 6.12. Distribution of the highest LS is in upper watershed which coefficient LS of 4.09 – 6.12 with area of 9,980.22 ha (28.73%). The erosion sensitivity in this location is bigger then other location in whole watershed.

d. Land Use and Conservation practice factor (CP)

Interpretation results from TM 8 Landsat imagery 2013 showed that the dominant land use in Lawo watershed is agricultural area of 18,697.65 ha (53.16%), followed by forest area of 9,980.22 ha (28.37%), paddy field area of 5,040.34 ha (14.33%), shrub area of 650.01 ha (1.85%), swamp area of 682.73 ha (1.94 %) and cleared area of 123.67 ha (0.35 %). Mixed farm in Lawo Watershed is divided to 3 types ie mixed farm with high density, mixed farm with medium density and mixed farm with low density. The distribution of land use in Lawo Watershed is presented in Table 5 and spatially in Figure 4.

Table 5 Land use and C Factor in Lawo Watershed

Landuse	CP Factor		**Area**	
	C	P	**Ha**	**%**
Shrub	0.300	1	650.00	1.8
Swamp	0.010	1	682.73	1.9
Primary Dry Forest	0.005	1	1023.14	2.9
Secondary Dry Forest	0.005	1	8768.37	24.9
Forest Plantation	0.005	1	188.72	0.5
Moor	0.200	1	9131.68	26.0
- Medium Density	0.300	1	8814.88	25.1
- Low Density	0.500	1	176.48	0.5
Dry Land Agriculture	0.200	1	574.60	1.6
Paddy Field	0.010	1	5040.34	14.3
Forest Plantation	0.005	1	123.67	0.4
Total			**35174.62**	100.0

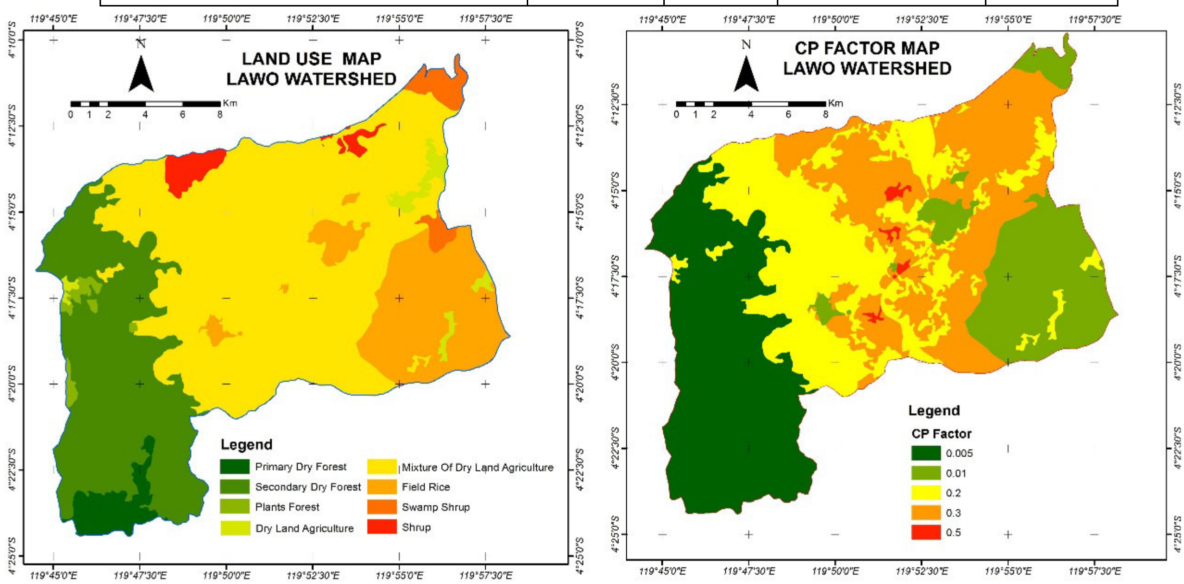


Figure 4. Land Use Map and CP Factor Map in Lawo Watershed

3.3. Erosion Prediction

Prediction of erosion performed on every land unit using USLE (Universal of Soil Loss Equation) equation. Mapping of erosion prediction is done based on five classification of erosion prediction value namely 1) very low (0 – 15 ton/ha/yr), 2) low (>15 – 60 ton/ha/yr), 3) medium (>60-180 ton/ha/yr), 4) high (>180 – 460 ton/ha/yr), 5) very high (> 460 ton/ha/yr). Analysis result spatially presented in Figure 5 and in Table 6 for detail in calculation of erosion prediction.

Erosion prediction on actual land use of Lawo Watershed range between 3.77 - 677.73 $tonha^{-1}yr^{-1}$, and overall erosion prediction in Lawo watershed of 2,365,838.89 $tonyr^{-1}$, with an average erosion of 80.33 $tonha^{-1}yr^{-1}$. Land unit number 2 (SL2) with shrub land cover and slope of 30 – 45 % showed the highest erosion prediction of 311.70 $tonha^{-1}yr^{-1}$. The lowest erosion is found on land unit number 5 (SL 5) with high density of primary forest cover and slope of 15 – 30 % of 3.77 $tonha^{-1}yr^{-1}$.

Tabel 6. Erosion Prediction in Lawo Watershed

Category of Surface Erosion	Area	
	Ha	(%)
Very mild	15,774.71	44.85
Mild	52.26302	0.15
Moderate	18,804.64	53.46
Severe	445.9612	1.27
Very severe	97.04633	0.28
Total	**35,174.62**	**100.00**

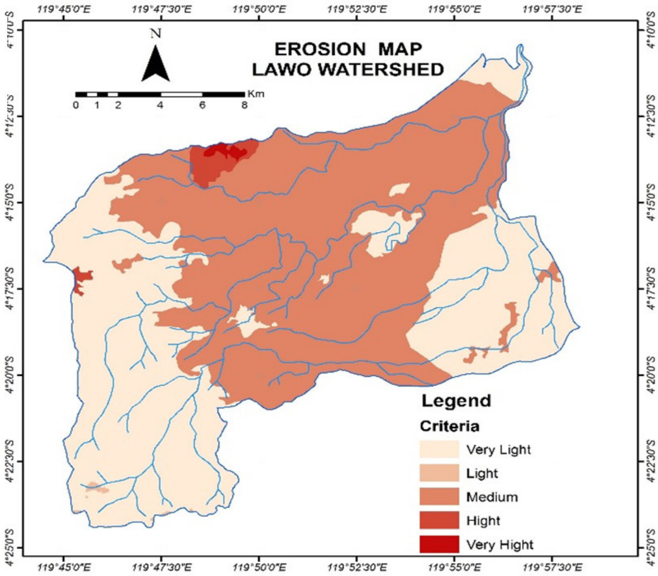


Figure 5 Erosion Map of Lawo Wateshed

Table 6 and Figure 5 shows the distribution of erosion in this watershed and dominated by moderate category which covering area of 18,804.64 ha (53.46%) in the central of watershed. Erosion in Lawo Watershed is varies from very mild to very severe (Table 2). Very mild erosion is found in land unit number 4, 6, 7, 8, 9, 21, 22, 23, 24, and 25. This is due to the low value of CP factor associated with dominant land use of primary forest and paddy field. High density of natural forest and high litter can reduce destructive power of rainfall to soil and reduce runoff rate. While on paddy field which is constructed the moderate to good of terrace which functionally to reduce the slope length and retain the water, so that velocity and total runoff and erosion can be reduced, as well as absorption water by soil (Arsyad, 2010).

Mild erosion is found on land unit number 5 which associated with forest plantation. Moderate erosion found in land unit number 3, 10, 11, 12, 13, 14,15,16,17,19 and 20, associated with mixed garden, upland agriculture, and shrub land. This rate of erosion is being caused by the high CP in each land unit because the minimum of conservation practices as well as not optimally planting of cover crop so that rainfall destruction energy is increase. The high erosion found on land unit number 1 and 18, associated with shrubland and upland agriculture. CP value in these land unit is high because the slope is range between 0 to 40%, were classified as bumpy and steep. The steep slope without conservation practices will reduce soil infiltration capacity, increase the total runoff and its velocity so that the transport capacity is enlarge.

3.3. Tolerable Erosion

Tolerable erosion is analyzed only in land unit number 1 – 20 because erosion predition on land units number 21 – 25 is very small. Tolerable eroison (T) in Lawo Watershed is varies in every land unit. The differences is effected by soil type, depth of soil, root minimum depth and soil volume. Under Annex 4, soil depth factor for sub order Tropept of 1.00, Aquept of 0.95 and Andept of 1.00. The minimum soil depth for agricultural crop of 30 cm, forest by 75 cm and shrubland at 30 cm. Bulk density of soil varies between 1.03 - 1.52 g cm^{3-1}. Soil formation rate is determined of 1.00 mm yr^{-1} (Hardjowigeno 2007) and resource lifetime of 250 year (for continuously and intensively use, Sinukaban 2007). Based on these data, tolerable erosion (T) in Lawo Watershed range between 17.56 - 54.77 ton ha^{-1} yr^{-1}.

3.4. Erosion Hazard Index and Soil Conservation Planning in Lawo Watershed

Erosion hazard index is an indicator for erosion risk in a land unit, which purpose to know the effect of erosion to soil productivity sustainability. The index is a ratio between erosion prediction with tolerable erosion on the same land unit (Hardjowigeno dan Widiatmaka, 2007). Erosion hazard index classification in Lawo Watershed is presented in Table 7 as follow.

Table 7. Tolerable erosion, erosion prediction and erosion hazard index on land units of Lawo Watershed

Land Unit	Area (Ha)	T (ton/ha/yr)	A (ton/ha/yr)	Erosion Hazard Index	
				Value	Class
1	382.62	48.63	247.69	5.09	High
2	97.05	54.77	677.73	12.37	Very High
3	170.34	25.44	153.22	6.02	High
4	123.67	36.72	10.52	0.29	Low
5	52.26	17.56	15.33	0.87	Low
6	970.88	22.25	14.52	0.65	Low
7	2321.64	30.37	10.59	0.35	Low
8	6446.72	29.34	10.80	0.37	Low
9	188.72	26.07	9.66	0.37	Low
10	176.48	45.74	106.89	2.34	Medium
11	550.31	35.64	70.44	1.98	Medium
12	3232.39	39.14	135.85	3.47	Medium
13	6779.60	44.26	140.52	3.18	Medium
14	265.17	30.58	84.55	2.76	Medium
15	263.99	42.36	82.55	1.95	Medium
16	5582.49	35.39	69.94	1.98	Medium
17	1272.62	42.64	89.41	2.10	Medium
18	63.34	40.88	212.83	5.21	High
19	416.11	40.73	93.16	2.29	Medium
20	95.15	35.27	156.79	4.45	High

Legend: A= Erosion prediction ; T = tolerable soil erosion.

Erosion hazard index which categorized medium, high and very high is dominant with total area of 19,347.66 ha (55%). This condition indcates that there is a requirement to manage the land in these are in order reach the land sustainability and carrying capacity of Lawo Watershed such as land managament through an adequate soil conservation practices and acceptable by communities in research location. Agrotechnology and soil conservation recommendation in the location is as follow in Table 8.

Tabel 8. Land use and soil and water conservation planning in Lawo Watershed

Land Unit	Land Use Existing	Slope	Erosion Hazard Index		Agrotechnology Planning	
			Value	Class	Land Use	Soil and Water Conservation
1	Shrubland	15 - 30 %	5.09	High	Forest	CT + VB
2	Shrubland	30 - 45 %	12.37	Very High	Forest	GT
3	Shrubland	3 - 8 %	6.02	High	Forest	CT
4	Forest Plantation	30 - 45 %	0.29	Low	Land use existing	Consistence
5	Primary Forest	15 - 30 %	0.87	Low	Land use existing	Consistence
6	Primary Forest	30 - 45 %	0.65	Low	Land use existing	Consistence
7	Secondary Forest	15 - 30 %	0.35	Low	Land use existing	Consistence
8	Secondary Forest	30 - 45 %	0.37	Low	Land use existing	Consistence
9	Forest Plantation	15 - 30 %	0.37	Low	Land use existing	Consistence
10	Moor	0 - 3 %	2.34	Moderate	Agroforestry	CT + M 6 ton/ha
11	Moor	3 - 8 %	1.98	Moderate	Agroforestry	CT + M 6 ton/ha
12	Moor	8 - 15 %	3.47	Moderate	Agroforestry	CT + VB
13	Moor	15 - 30 %	3.18	Moderate	Agroforestry	CT + VB
14	Moor	3 - 8 %	2.76	Moderate	Agroforestry	CT + M 6 ton/ha
15	Moor	8 - 15 %	1.95	Moderate	Agroforestry	CT + VB
16	Moor	3 - 8 %	1.98	Moderate	Agroforestry	CT + VB
17	Moor	8 - 15 %	2.10	Moderate	Agroforestry	CT + VB
18	Agriculture	15 - 30 %	5.21	High	Agroforestry	CT + VB
19	Agriculture	3 - 8 %	2.29	Moderate	Agriculture	CT + M 6 ton/ha
20	Agriculture	8 - 15 %	4.45	High	Agriculture	CT + VB

Keterangan : TI = Individual Terrace ; CT = Countour Terrace; M = Mulch; VB = Vegetation Barier; GT=Garden terrace

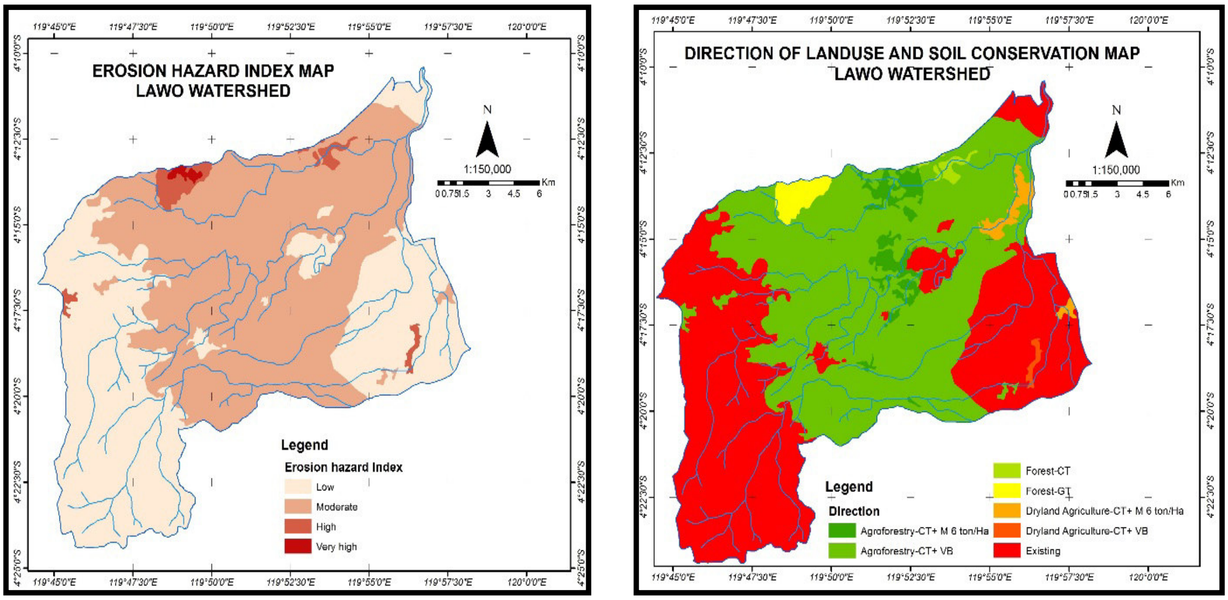


Figure 6 Erosion Risk Index Map and Recommendation aof land use and soil and water conservation Map in Lawo Watershed

4. Conclusion

1. Soil erosion can be controlled effectively if the soil erosion is accurately predictable. USLE equation is a method of erosion prediction from land that acceptable and widely used in Indonesia. Agencies of Indonesia Government is applied this method and erosion hazard index in legal policy for planning the soil conservation and management priority of watershed.
2. Commonly, erosion in Lawo Watershed is higher than tolerable erosion which cover area of 19,347.66 ha (55%). So that, the development of upland agriculture and plantation area should be followed by applying an adequate agrotechnology in order to reduce erosion.
3. Planning of soil and water conservation in Lawo Watershed needs to be done in land units which actual erosion is exceed the tolerable erosion (T), include land use change management such as conversion from shrubland to forest, develop mix farming with agroforestry pattern (fto increase the population and crop density), as well as construct individual terrace and bund terrace with mulching 6 tons and crop for strenghthening the terrace.

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