RUSLE CP Factor Optimization for Soil Erosion Modeling in Tropical Watershed of Indonesia

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ABSTRACT

The Revised Universal Soil Loss Equation (RUSLE) model has been use widely to estimate soil erosion under various environment condition. The model enables a soil erosion mapping in a large scale for conservation planning purpose. Crop (C) and conservation practice (P) factors are important RUSLE parameters which significantly affect the calculated value of soil erosion. This study was performed to optimize the value of C and P factor of RUSLE by using reference values for soil erosion study in Indonesia. The C and P factor were calculated as CP factor and determined based of land use-land cover (LULC) map in the study site. The result revealed that the study site was covered by eight types of LULC. RUSLE model validation by using field measurement data of sedimentation showed that the CP value for those LULC types were 0 (building), 0.01 (forest), 0.02 (grassland), 0.01 (garden), 0 (settlement), 0.02 (rice field), 0.01 (shrub), 0.19 (moor) and 0.01 (swamp). Moor dominated by mixed crops contribute the most significant number of soil erosion in the study site. The result of this study provide a reference for soil erosion study particularly in tropical climate regions.

Keywords: *CP Factor, Land Use Land Cover, RUSLE Model, Soil Erosion, Tropical Watershed*

1. INTRODUCTION

Indonesia is a country with a huge number of watersheds and various in large and administration boundary. Watershed has an important role in supporting live system. In agricultural, watershed provides water for crops. land use without paying attention to conservation principles causes damage to watersheds and disrupts its hydrological functions [1]. Land conversion, especially the reduction of vegetation, can also cause a decrease in the hydrological conditions and functions of a watershed as happened in Upper Watershed of Mrica (PB. Soedirman) Reservoir. Conversion of protected forest into agricultural land in the watershed, especially for horticultural crops and lack of attention to conservation principles resulted in soil erosion and sedimentation [2]. More than 1000 ha of forest in the upstream area of Mrica reservoir has been lost due to deforestation and has caused the loss of water catchment areas and increased soil erosion [3].

As a tropical country, the rate of soil erosion in almost all watersheds in Indonesia tends to be high. In natural conditions, soil erosion occurs at a rate of 2-3 tons/ha/year, on agricultural lands at 40-400 tons/ha/year, and in bare soil areas at 120-460 tons/ha/year [4]. Soil erosion will remove the organic layer of the soil so that it has an impact on decreasing of land productivity. loose soil particles due to soil erosion will settle downstream and cause various problems. Analysis of the level of erosion hazard in a watershed is very important as a basis for determining soil and water conservation strategies to control and prevent environmental damage due to soil erosion.

In modelling studies, determining the value of soil erosion indicators is one of the keys that affect the accuracy of the analysis. One of the soil erosion models which is widely used in various climatic conditions is RUSLE [5]. One of the challenges in using the RUSLE model is determining the parameter values including factors C and P where the values are different for each region. In this study, the RUSLE model CP factor was optimized for soil erosion modeling in Indonesia's tropical watershed. The obtained CP value can be used

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as a reference for research on soil erosion using the RUSLE model in various climatic conditions.

2. MATERIAL AND METHODS

2.1. Study Site

This study was conducted in Mrica Watershed (total area is 1,017.39 km^2) , administratively located in Central Java Province of Indonesia (Figure 1). The Mrica watershed has a daily temperature of 18-32 ^{0}C, a daily humidity around of 70-90% and an average annual rainfall around of 3000-4000 mm. The data used in this study are rain, soil type, land slope and land use type to determine the parameter values of the RUSLE model.

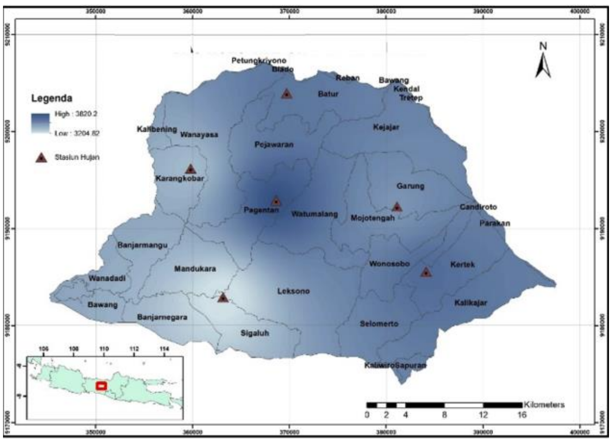

Figure 1. Map of Mrica Watershed

2.2. RUSLE Model

RUSLE model has five parameter for estimating soil erosion in a watershed scale (equation 1) [5,6]. The value of RUSLE's parameter has been estimated with various approach, affected by local condition of study site.

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

Where:

A = Average annual soil loss (t ha^{-1} yr^{-1})
R = Rainfall erosivity factor (MJ mm ha^{-1} h^{-1} yr^{-1})
K = Soil erodibility factor (t h MJ^{-1} mm^{-1})
LS = Length and land slope factor
C = Cropping management factor
P = Conservation factor

2.2.1. RUSLE R Factor

RUSLE R factor reflects the potency of soil to be destructed by rainwater energy. R factor in this study was calculated by using Lenvain equation (Equation 2). Rainfall data in the study site was needed to estimate R factor value.

$$Rm = 2{,}21\ (Rb)^{1.36} \quad (2)$$

Where :

Rm = Rainfall erosivity

Rb = Monthly rainfall (mm)

Rainfall data was collected from Meteorological, Climatological, and Geophysical Agency Indonesia or Badan Meteorologi, Klimatologi, dan Geofisika (BMKG) in 2021 for five last year. R factor was obtained as the sum of monthly rainfall erosivity (Rm)

2.2.2. RUSLE K Factor

RUSLE K factor indicates the susceptibility of soil to be destructed by soil erosion energy. K factor was determined based on reference value for various type of soil in Indonesia as shown in Table 1 [7].

Table 1 RUSLE K Factor Value for Some Types of Soils in Indonesia

ID	Soil Type	K Value
1	Latosol red	0.12
2	Latosol red yellow	0.26
3	Latosol	0.31
4	Latosol brown	0.23
5	Regosol	0.11
6	Lithosol	0.29
7	Grumusol	0.20
8	Alluvial	0.47

Soil type data in the study site was obtained from the ministry of public work Indonesia in 2021.

2.2.3. RUSLE LS Factor

RUSLE LS factor reflects the effect of length and land slope on soil erosion. LS factor was determined based on reference value for five classes of land slope in Indonesia as shown in Table 2 [7]. Land slope data was obtained from Geospatial Information Agency or Badan Informasi Geospasial (BIG) in 2021.

Table 2 RUSLE LS Factor Value

Class	Land Slope	LS Value
I	0 - 8 %	0.4
II	8 - 15 %	1.4
III	15 - 25 %	3.1
IV	25 - 40 %	6.8
V	> 40%	9.5

2.2.4. RUSLE CP Factor

RUSLE C and P factor indicated the effect of crop and conservation on soil erosion. In this study, C and P factor was calculated as CP factor. The value of CP factor was determined based on reference value for some types of land use in Indonesia as shown in Table 3

[7]. Land use data was obtained from Geospatial Information Agency or Badan Informasi Geospasial in 2021.

Table 3 RUSLE CP Factor Value

ID	Land use type	CP Value
1	Forest	0.01-0.50
2	Bush	0.01-0.10
3	Garden	0.02-0.20
4	Plantation	0.01-0.07
5	Grass	0.01-0.65
6	**Agricultural crops**	
	a. Tubers	0.51
	b. Grains	0.51
	c. Nuts	0.36
	d. Mixture	0.43
	e. Irrigated rice	0.02
7	**Farmland with conservation**	
	a. Mulch	0.14
	b. Terrace bench	0.04
	c. Contour cropping	0.14

All RUSLE parameter value were presented in raster format data with 30 meters resolution and analyzed by using summation function of raster calculator in Arc GIS 10.5. RUSLE CP factor optimization was performed through model validation by using sediment deposit data measured by PT. Indonesia Power Banjarnegara.

3. RESULT AND DISCUSSION

3.1. R Factor

The value of rain erosivity is influenced by the rainfall at each rain station. high rainfall will result in high erosivity of rain as well [8]. R factor was determined based on rainfall data from six rain gauge in the study site namely Sigaluh, Batur, Pagentan, Karangkobar, Garung, and Kertek (see Figure 1). Mrica watershed is an area with climate type A (Very Wet) which has an average annual rainfall of 4019.38 mm. Average monthly rainfall from six past year in the study site can be seen in Table 4. Rainfall variability in Indonesia as a tropical country is quite high, so rainfall data at the study site must be taken from several rain stations sourced from the BMKG. The number of distribution of rain stations and the completeness of the rain data is a challenge in obtaining rainfall information in the study site. Some existing rain stations do not have complete data for various reasons.

Based on the rain fall data collected from six stations, the R factor was then calculated by using the Lenvain equation. The value of rain erosivity (R) at each rain station in the watershed area can be seen as shown in Table 5. The highest erosivity value of 3820.2 MJ/ha/year was found at the Pagentan Rain Station and the lowest erosivity value of 3204.82 MJ/ha/year was found at the Sigaluh Rain Station.

The R factor value obtained was then presented in the form of a raster data which was analyzed using the IDW (Inverse Distance Weighted) method in Arc GIS 10.5. Variability value of R factor indicates a differences of rainfall duration in the study site under tropical climate condition [9].

Table 4 Average Monthly Rainfall in the Study Site

Month	Rainfall (mm)
January	515
February	498
March	495
April	344
May	264
June	154
July	101
August	60
September	208
October	305
November	507
December	567

Table 5 R Factor Value from Six Rainfall Station

ID	Station	Coordinate		R value
		Lat	Long	
1	Sigaluh	-7.39	109.76	3204.82
2	Batur	-7.20	109.82	3633.49
3	Pagentan	-7.30	109.81	3820.20
4	Karangkobar	-7.27	109.73	3365.67
5	Garung	-7.31	109.92	3510.57
6	Kertek	-7.37	109.95	3683.91

3.2. K Factor

Based on soil type data from the ministry of public work, the Mrica Watershed has four types of soil, namely Latosol, Regosol, Grumusol, and Alluvial. The erodibility value of each soil type is different. Based on the reference in Table 1, the highest K value was 0.47 for alluvial soils (easiest to erode) and the lowest was 0.11 for Regosol soils (the most difficult to erode). K value for four type of soil in the study site are shown in Table 6.

Table 6 K Value in Study Site

ID	Soil Type	K Value	Area (Ha)	(%)
1	Latosol	0.31	89118	87.59
2	Regosol	0.11	3338	3.28
3	Grumusol	0.20	7304	7.18
4	Aluvial	0.47	1980	1.95

K value indicates a strong effect of soil properties on soil erosion. Some types of soil with unstable aggregate are prone to erosion [10].

3.3. LS Factor

The length and slope of land are the two topographic elements that have the most influence on runoff and soil erosion. In this study, LS factor was determined based on land slope in the study site. Land slope data was obtained from Digital Elevation Model (DEM) Nasional Provided by BIG in 2021. DEM was analyzed by using spatial analysis tool in Arc GIS 10.5. LS factor value for four land slope classes is shown in Table 7.

Table 7 LS Value in Study Site

ID	Land Slope (%)	Value of LS	Area (km^2)	(%)
1	0 – 8	0.4	458.20	45.04
2	8 – 15	1.4	348	34.21
3	15 – 25	3.1	161.39	15.86
4	25 – 40	6.8	48.19	4.74
5	>40	9.5	1.61	0.16
	Total		1017,39	100

The watershed is dominated by low sloping area (0-8%), with a LS value of 0.4 and covers an area of 458.2 km^2 (45.04% of the total area). The high slope of the land will increase the LS value and increase the potential for soil erosion [11,12].

3.4. CP Factor Value Optimization

The land use in the study area was miscellaneous, as well as the CP value for each of these land uses (Table 8). The watershed area was dominated by dry farmland with an area of 315.23 km^2 (30.98%) and moor with an area of 298.81 km^2 (29.37%). CP value was determined based on reference value of CP factor for some land use types in Indonesia (Table 3). The highest CP value in study site was found for dry farmland (0.19) and lowest was found for vegetation (bush and forest). Water body was not be considered for soil erosion calculation.

Table 8 Land Use Type and CP Value of Study Site

ID	**Land Use Type**	**CP Value**	**Area (Ha)**	**(%)**
1	Dry Farmland	0.01	31523	30.98
2	Moor	0.19	29881	29.37
3	Dry Rice Field	0.02	13084	12.86
4	Bush	0.01	9499	9.34
5	Wet Rice Field	0.02	6866	6.75
6	Settlement	0.01	7682	7.55
7	Forest	0.01	1413	1.39
8	Fresh Water	0	693	0.68
9	Grass	0.02	593	0.58
10	Wet Land	0.01	506	0.50

The selection of the most suitable CP value was carried out through model validation, where the results of erosion calculations using the RUSLE model was compared with the results of measurements of sediment deposits downstream of the watershed. The value of CP was optimized so that the results of the calculation of erosion with the model was close to the value of sediment deposit downstream of the watershed measured in the Mrica Reservoir. Sediment deposit data was obtained from PT. Indonesia Power Banjarnegara.

The measurement results show that the average sediment deposition is 98.45 tons/ha/year or equivalent to 3.88 mm/year, while the measurement of soil erosion using the RUSLE model through the optimization of the CP factor value shows an average soil erosion value of 104,82 ton/ha/year or 4,13 mm/year. A small difference shows a good optimization result. The distribution of CP values at the study sites can be seen in Figure 2.

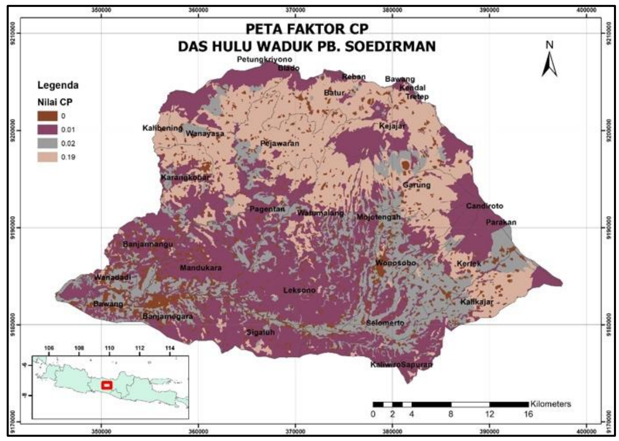

Figure 2. Distribution of CP Value in Study Site

The CP value close to zero indicates the area is well protected from soil erosion due to good vegetation and conservation [13]. A high CP value usually indicates the area is not well protected from soil erosion due to lack of vegetation and conservation. The forest vegetation cover area is only 14.13 km^2 (1.39% of the total area), indicates a high potential for soil erosion in the study site. Figure 3 showed an agricultural land with a conservation practices in the study site.

Figure 3. Agricultural Land in Mrica Watershed

Optimized CP value obtained in this study provide a reference for soil erosion study by using USLE/RUSLE model particularly in tropical regions.

AUTHORS' CONTRIBUTIONS

Chandra Setyawan: determine the concept of research, research and data analysis supervision, publication draft writing. **Hania Intan Saputri**: data collection, data analysis, publication draft writing. **Dimas Prabowo Harliando**: data collection, data analysis. **Abdurahman Khidzir**: data collection, data analysis. **Sahid Susanto**: research supervision, research concept advisory. **Muhamad Khoiru Zaki**: research supervision, publication draft review.

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