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Analysis of rainfall erosivity factor (R) on prediction of erosion yield using USLE and RUSLE Model's; A case study in Mayang Watershed, Jember Regency, Indonesia

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ABSTRACT

The Rainfall erosivity has a relatively high effect on soil erosion, in addition to being very difficult to predict and control. The Universal Soil Loss Equation (USLE) and The Revised Universal Soil Loss Equation (RUSLE) model are commonly used to predict erosion yield in Indonesia. However, these models have several erosivity formulations that give different results. In this sense, identifying the sensitivity of different erosivity formulations in both models above is important. The aim of this study is to analyze soil erosion yield prediction influenced by the difference in erosivity equation on the same rainfall data used in the models while other parameters used are the same. The monthly rainfall and annual rainfall data were tested using the erosivity formulas. The (1) Bols and (2) Utomo equations were tested using monthly rainfall data, while the (3) Bols and (4) Hurni equations were tested using annual rainfall data. The results show that the prediction of soil erosion yields estimates using monthly rainfall data in both models have no significant differences. On the other hand, soil erosion estimates using annual rainfall data in the models have significant differences, whereas the USLE model estimation results in 63% erosion yield on low classification (0-15 ton ha^{-1} $year^{-1}$). Meanwhile, the RUSLE model estimates only 59% erosion yield on low classifications. Another result is that the USLE model estimates lower erosion yield than the RUSLE model when the models use annual rainfall data, which may give significantly different recommendations for soil conservation in Indonesia, especially in reducing erosion yield at the Watershed level.

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1. INTRODUCTION

Indonesia, with a tropical climate, has high rainfall intensity and has the potential to cause high erosion in some areas with high soil erodibility conditions and poor conservation management. A soil erosion prediction model is required for sustainable natural resource management and conservation planning to reduce erosion yields at the watershed level. The Universal Soil Loss Equation (USLE) and the Revised Universal Soil Loss Equation (RUSLE) models are two models that have been widely used to predict erosion yields in Indonesia. The models give better prediction results compare to other models (Luvai et al., 2022; Tiwari et al., 2000). The use of these two models was originally intended for the prediction of erosion on agricultural farmer land level (Renard et al., 1997; Wischmeier & Smith, 1978). However, the RUSLE model produces better estimates than its predecessor erosion model (Nugraheni et al., 2013). RUSLE is an empirical model of USLE development that has undergone many improvements, including weather/rain factors (Renard et al., 1997).

USLE and RUSLE have been widely applied in Indonesia. For example, Widodo et al. (2015) predicted erosion using the USLE method in Genengan Village, Karanganyar. Putra et al. (2018) conducted an erosion assessment based on the USLE method and conservation directives on the cold water watershed in Padang. Taslim et al. (2019) predict erosion in the East Java region using USLE and GIS. Hariyanto et al. (2019) used the USLE method to predict the rate of erosion in the Bogor Regency area. Andarwati et al. (2021) conducted the same analysis in the Sukoharjo Regency area. Examples of the application of the RUSLE model integrated with the GIS model in Jember District East Java, Indonesia such as Andriyani et al. (2020), which determines the level of erosion hazard of the Bedadung watershed in Jember Regency and Hanafi and Pamungkas (2021), which applies the RUSLE model to estimate upstream land loss in the Garang Sub-watershed, Central Java. Some studies use both erosion models, such as Nugraheni et al. (2013), which compare the predicted erosion rate of the Keduang watershed. These studies predict Erosion Hazard Level (EHL) using USLE and RUSLE, which are integrated with GIS.

USLE and RUSLE are widely applied because they are relatively simple, with input model parameters that are easily obtained. At the field level, USLE can be used to determine soil conservation practices (Taslim et al., 2019). Meanwhile, RUSLE calculated the erosion rate in areas with significant runoff (Hanafi & Pamungkas, 2021). However, USLE and RUSLE also have disadvantages. Estimation of soil erosion produced by USLE can be inaccurate if there is a mismatch in the value of the erosion factor used. Given the data information on the USLE is still limited (Renard et al., 1997). USLE can only be used to predict the erosion rate of sheets without calculating the sedimentation rate (Wischmeier & Smith, 1978). While the RUSLE model is less suitable for regions where runoff doesn't occur because the model is not designed for that (Hanafi & Pamungkas, 2021).

Other factors affecting erosion prediction results using the USLE and RUSLE models are the equations and rainfall data used in the models. Selecting the right equation and type of rainfall data will affect the erosivity value and ultimately provide different erosion prediction results. Meanwhile, due to the high rainfall in Indonesia, the erosivity value is also high. Therefore, it is necessary to analyze the sensitivity of erosion yields prediction results due to differences in the rainfall data on various equations used in the USLE and RUSLE models (Djoukbala et al., 2019).

Rainfall erosivity is a multi-year averaged index that measures the effect of rainfall on sheet and rill erosions based on the kinetic energy (E) and intensity of 30 minutes of rainfall (I_{30}) (Wischmeier & Smith, 1978). The kinetic energy of a storm (E) describes the volume of precipitation and runoff produced. Meanwhile, I_{30} shows the peak release of soil particles and runoff-generated rainfall. Thus, EI_{30} reflects the total energy and peak intensity resulting from the combination of several precipitation (Wischmeier & Smith, 1978). Rainfall data with an interval length of 15 or 30 minutes will produce relatively realistic rainfall erosivity (R) values (Vijith & Dodge-Wan, 2019). However, the difficulty of obtaining a 30-minute rainfall intensity directly makes the data unavailable in many areas, in addition to data processing that takes a long time (Belayneh et al., 2019). This prompted many studies to create rain erosivity equations with widely available monthly or annual rainfall data (Bols, 1978; Hurni, 1985). In fact, the method has been widely adopted and widely used (Andriyanto et al., 2015; Belayneh et al., 2019; Saha et al., 2022; Supriyono et al., 2021; Taslim et al., 2019; Vijith & Dodge-Wan, 2019).

In determining the rate of soil erosion yield as part of a comprehensive management and conservation of water and soil resources at a watershed level, the right approach is through the watershed approach (Osok et al., 2018). In the future, the function of the watershed is not only to serve as a supplier of water needs but also to play a role in absorbing carbon emissions in the context of climate change mitigation (Setiawan et al., 2019). Determination of soil erosion is important to determine the status of erosion that occurs, whether it is at the level of vulnerable or not vulnerable (Taslim et al., 2019). In this sense, choosing the right equation and data will affect the study's results.

The study aims to analyze whether there is a difference in the value of rain erosivity between monthly and annual rainfall use on USLE and RUSLE models, which influence erosion yield prediction. Moreover, the study tries to upscale the use of the models to predict erosion yield on the watershed level originally, these models were developed for farmer land level, using limited data of soil erodibility and crop management based on secondary data (soil and land use maps). Therefore, this study can be a reference in sustainable management and soil conservation in Indonesia, especially to reduce erosion yield at the Watershed level.

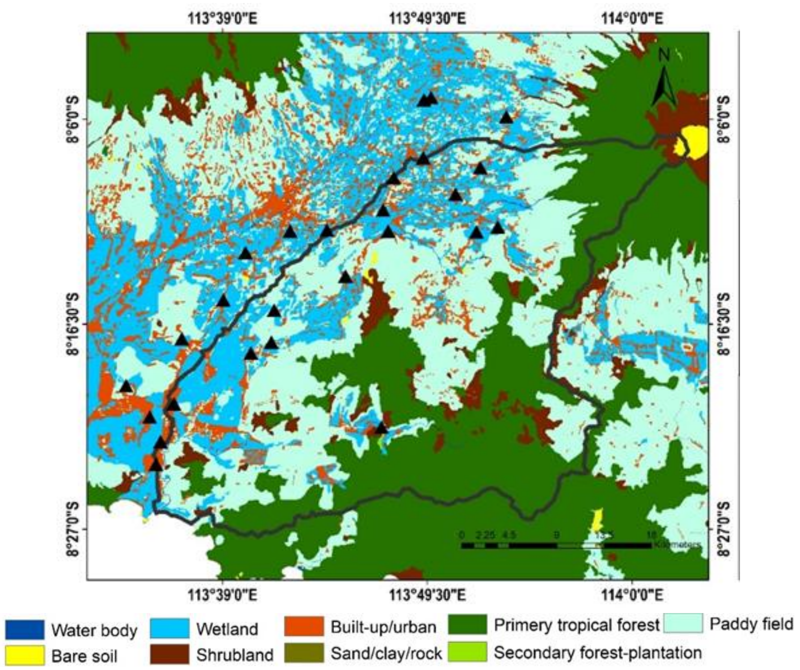


Figure 1. Land Use Map of Mayang Watershed

Table 1. K Factor value based on soil type

No	Soil Type	K Value	Erodibility rate
1	Alluvial	0.29	Moderate
2	Andosol	0.28	Moderate
3	Gley	0.29	Moderate
4	Latosol	0.26	Moderate
5	Mediterranean	0.16	Moderate
6	Regosol	0.31	Moderate

Source: Bappenas (2012)

2. MATERIAL AND METHODS

2.1. Study Area

Mayang Watershed, with an area of 1,110.16 km^2, was selected for this study (Fig. 1). Astronomically, Jember Regency stretches from 113°35'00"E to 114°03'00" E dan 8°06'0"S to 8°28'00"S. The region has interval average annual rainfall from 1,057 to 2,224 mm year^{-1}.

2.2. Data collection and analysis

2.2.1. Method of soil loss estimation

The models will be run on the Geographic Information Systems (GIS) platform using ArcGIS 10.3 software to analyze at the watershed level. Integrating USLE and RUSLE on GIS allowed for special analysis at the regional level (Roslee & Sharir, 2019). Estimation of soil erosion using USLE (Wischmeier & Smith, 1978) and RUSLE (Renard et al., 1997), expressed in Equation 1. The input Data are presented in Table 1.

$$A = R \times K \times LS \times CP \quad [1]$$

where A is annual soil loss (t ha^{-1} year^{-1}), R is rainfall erosivity factor [MJ mm ha^{-1} year^{-1}], K is soil erodability factor [t ha^{-1} MJ^{-1} mm^{-1}], LS is length and slope factor (dimensionless), CP is Cover management and Conservation practice factors (dimensionless).

2.2.2. Rainfall erosivity (R)

Rainfall erosivity estimation is differentiated by rainfall data type. Monthly rainfall data using equations from Bols (1978) for USLE (Eq. 2) and Andrianto et al., (2015) for RUSLE (Eq. 3). Annual rainfall Data using equations from Bols (1978) for USLE (Eq. 4) and Hurni (1985) for RUSLE (Eq. 5)

$$R = 6.119M^{1.21} \times D^{-0.47} \times Max^{0.53} \quad [2]$$

$$R = 10.80 + (4.15 \times M) \quad [3]$$

$$R = \frac{2.5P^2}{100(0.073P + 0.73)} \quad [4]$$

$$R = -8.12 + (0.562 \times P) \quad [5]$$

where R is the rainfall erosivity factor [MJ mm ha^{-1} year^{-1}], P is annual rainfall (mm), M is monthly rainfall (mm), D is the average number of rainy days per month (days), Max is the maximum rainfall in 24 hours per month (mm). Rainfall influences erosivity due to integrating the effects of raindrop impact and duration that result in runoff rates, coupled with the amount of energy within each rainfall pattern. The erosivity was calculated using monthly and annual rainfall data collected from the years 2001-2021 of 26 gauging stations in the Mayang watershed and interpolated using Inverse Distance Weighting (IDW) to create continuous raster rainfall data within the study area (Roslee & Sharir, 2019).

Table 2. CP Factor value based on map of land use.

No	Land use	CP Value
1	Lake/Reservoir	0.001
2	Forest	0.001
3	Plantation	0.300
4	Field	0.280
5	Sand	1.000
6	Residential areas	1.000
7	Swamp/Swamp Forest	0.010
8	Irrigated Rice Fields	0.020
9	Rain Fed Rice Fields	0.050
10	Shrubs	0.100
11	River	0.001
12	Dam	0.010
13	Vacant Land/Pasture	0.020

Source : Bappenas (2012)

IDW provides the most representative interpolation results with minimum error (Belayneh et al., 2019).

2.2.3. Soil erodibility factor (K)

The determination of the K factor is based on the soil type map of the Mayang Watershed, updated in 2018. The K value for each soil type depends on the soil type, as suggested by Bappenas (2012) (Table 2) (Andriyani et al., 2020).

2.2.4. Slope steepness and length factor (LS)

LS values were estimated using the SRTM DEM (30×30 m) downloaded from the United States Geological Survey (USGS) website (http://earthexplorer.usgs.gov) and then extracted based on the watershed study shapefile used. Estimating LS value begins with slope analysis, filling sinks, flow direction, and flow accumulation. Estimated values of LS are multiplied on a pixel-by-pixel basis using the ArcGIS 10.3 Raster calculator. The equation used to calculate the LS value is Equation 6.

$$LS = \left(\frac{\gamma}{22{,}13}\right)^{0{,}4} \times \left(\frac{\sin(\theta)}{0{,}0896}\right)^{1{,}3} \quad [6]$$

where γ is the slope length factor, is the horizontal projection (m) or (flow accumulation × cell size), and sin θ is the slope angle in degree (SRTM generated slope in degree × 0.01745).

2.2.5. Cover management and Conservation practice factors (CP)

CP factors were identified using a classification map of land use/land cover of the Rupa Bumi Indonesia Map (RBI) scale 1:25,000 downloaded from Ina-Geoportal (https://tanahair.indonesia.go.id/portal-web). The land use/land cover classification map with CP values entered was converted into a 30x30 m cell size raster map using the ArcGIS 10.3 "polygon to raster" tool. CP values suggested by (Bappenas, 2012) (Table 2).

2.2.6. Statistical and data analysis

The data were analyzed using variance analysis to determine the effect of treatment. Differences were assessed using the Independent T-test and Mann-Whitney test (α=0.05) to determine how different the results of erosion prediction using the same rainfall data (Andriyani et al., 2017). Next was the regression analysis to determine the level of correlation between rainfall erosivity and soil erosion yields (Ningsih & Dukalang, 2019). After that, a validity test was conducted to determine the accuracy of the rainfall erosivity method per year using Spearman's Rho test

3. RESULTS

3.1. Existing Erosion Rate

Figure 2 shows the average monthly rainfall in Mayang Watershed. The average monthly rainfall ranges from 11 to 316 mm month^{-1}. However, during extreme seasons (dry and wet seasons), rainfall can be the lowest value of 0 mm month^{-1} and can reach 455 mm month^{-1}. Figure 3 provides data on the dry season runs from May to October with a peak between July and September, indicated by receiving rainfall <100 mm.month^{-1}. The wet season runs from November to April, which is indicated by receiving rainfall >100 mm month^{-1}. The average annual rainfall ranges from 1,057 to 2,224 mm month^{-1}. Rainfall during the very dry season can be the lowest value of 145 mm month^{-1}. In contrast, the highest rainfall in the extreme rainy season can reach 4,801 mm year^{-1}. The highest rainfall erosivity value based on the monthly rainfall data is 1,333.04 MJ mm year^{-1} (Bols equation) and 877.24 MJ mm year^{-1} (Utomo equation). However, based on the annual rainfall data, the highest rainfall erosivity value is 758.34 MJ mm year^{-1} (Bols equation) and 1,241.86 MJ mm year^{-1} (Hurni equation). The erosivity of rainfall at each rainfall station is presented in Figure 3a to Figure 3d.

From Fig. 3e, the Mayang Watershed is dominated by latosol soil types, with an area of 88,440.76 hectares or 79.67% of the total area. This soil type has a moderate erodibility level with a K-value of 0.26. Soil erodibility factor is a different numerical value from 0 to 1, where the K Factor value close to 0 is less susceptible to soil loss (Kayet et al., 2018). The results of LS Factor Analysis at the study site can be seen in Figure 3f. Mayang Watershed is dominated by a slope of 0% – 8% (flat) with an area of 57,456.04 ha (51.75%). The length of the slope affects the volume of surface runoff, while the slope of the slope affects the speed of surface runoff (Taslim et al., 2019). Land loss per unit area will increase as the length and slope of the slope increases (Ganasri & Ramesh, 2016).

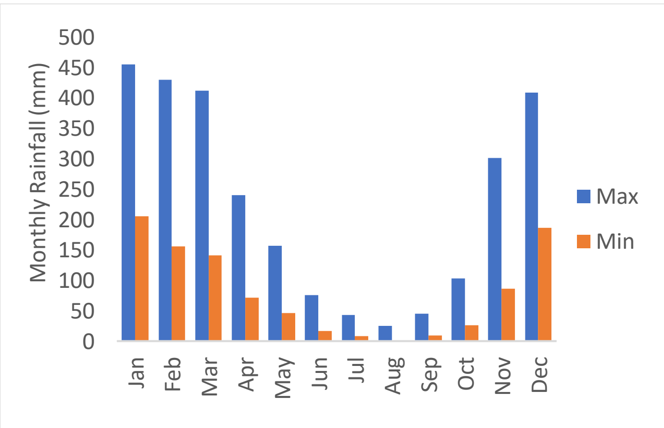


Figure 2. Histogram of monthly rainfall; Source: own elaboration

Table 3. Results of Normality Test for each soil loss estimation

Soil Erosion	Statistic	df	p-value	Interpretation
A1	0.183	26	0.025	Not Normally Distributed
A2	0.175	26	0.040	Not Normally Distributed
A3	0.161	26	0.080	Normally Distributed
A4	0.161	26	0.081	Normally Distributed

Remarks: A1 = Bols equation (monthly rainfall), A2 = Utomo equation (monthly rainfall), A3 = Bols equation (annual rainfall), A4 = Hurni equation (annual rainfall).

The results of the interpretation map of land use in the Mayang Watershed are presented in Fig. 3g. The largest land use in the Mayang watershed is forest (green color) with an area of 37,524.03 ha or 33.80% of the total area. A CP value close to 0 indicates that the soil is highly protected (not easily eroded). Meanwhile, a CP value close to 1 interprets that the soil has just been treated (very susceptible to erosion), resulting in a lot of runoff (Renard et al., 1997). High CP values also indicate that no application of soil conservation measures was undertaken (Taslim et al., 2019).

Figure 3h to Figure 3k shows the estimated soil erosion from each rainfall erosivity method. Average soil erosion from all methods of rain erosivity is 65.81 tonnes ha^{-1} year^{-1} (Eq. 2), 60.37 tonnes ha^{-1} year^{-1} (Eq. 3), 50.03 tonnes ha^{-1} year^{-1} (Eq. 4), and 81.89 tonnes ha^{-1} year^{-1} (Eq. 5). Although the area, soil erosion in the Mayang watershed in each method is still dominated by the type of soil erosion is very light (0-15 tonnes ha^{-1} year^{-1}); where on Figure 4, the area (Eq. 2) by 66.70% (74,047.41 Ha), the area (Eq. 3) by 66.99% (74,369.35 Ha), the area (Eq. 4) by 62.86% (69,784.41 Ha), and the area (Eq. 5) by 58.80% (65,277.17 Ha).

3.2. Erosion Rate Result and Map from each Rainfall Erosivity Model

A1 and A2 have abnormal data distribution (p<0.05), while A3 and A4 have normal data distribution (p>0.05) (Table 3). This is indicated by the histogram of the normality test, where A1 and A2 have positive data skewed, while A3 and A4 have symmetrical data skewed (Fig. 5). Normal skewed occurs when the mean is equal to the median mode^{-1}, while positively skewed occurs when the mean is higher to the median mode^{-1}. From the Mann-Whitney test, A1 treatment has no significant difference with A2 (Table 4). From the independent t-test, A3 treatment significantly differs from A4 (Table 5). There is a difference in rainfall erosivity (R) calculation between the USLE and the RUSLE models, as indicated by the Sig. (2-tailed) Mann-Whitney value less than α = 0.05. Rainfall erosivity factor (R) USLE and RUSLE significantly influence the erosion rate and positive direction.

Regression analysis presents that erosivity value using formulation A2 gives a higher correlation than other formulas (Fig. 6).

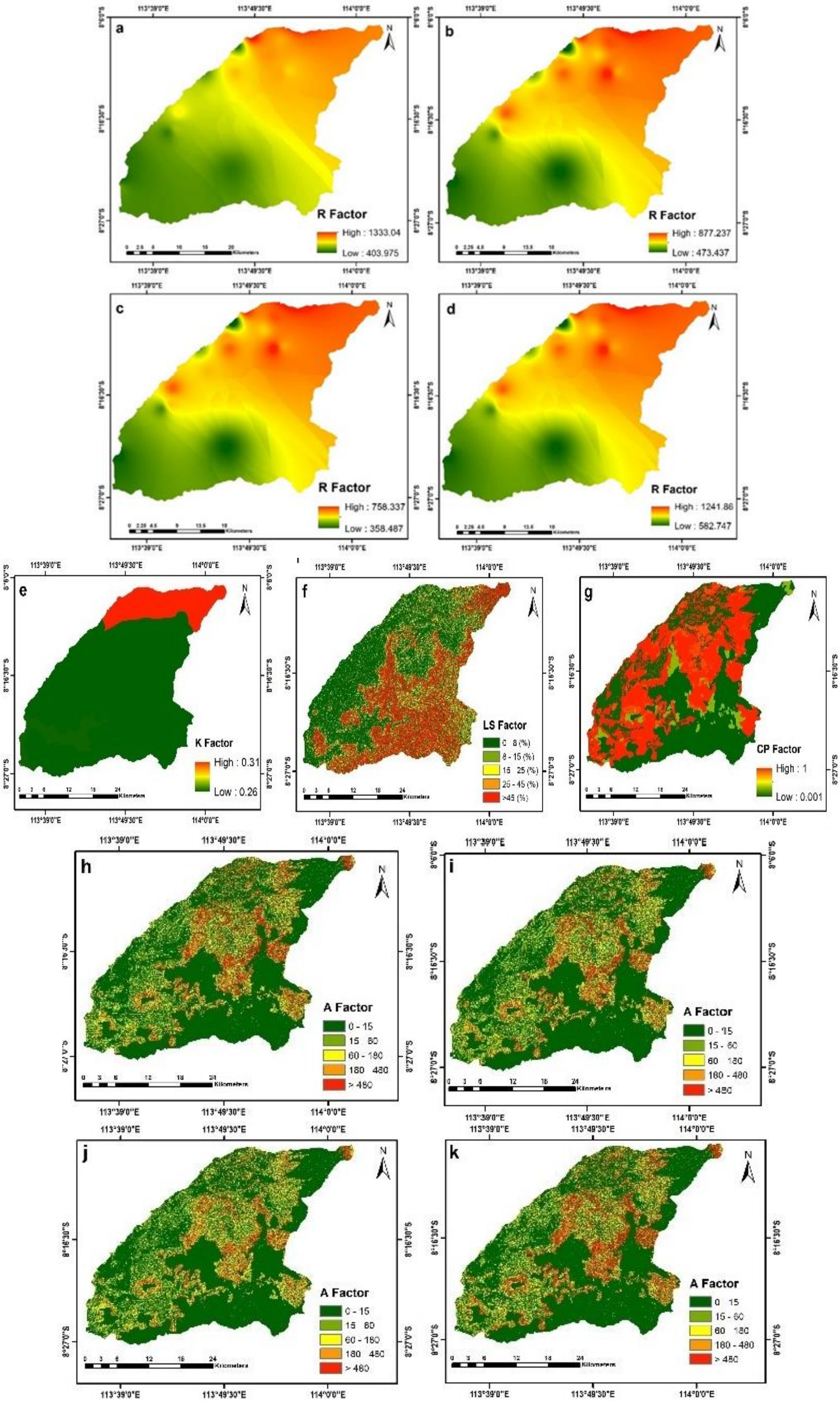
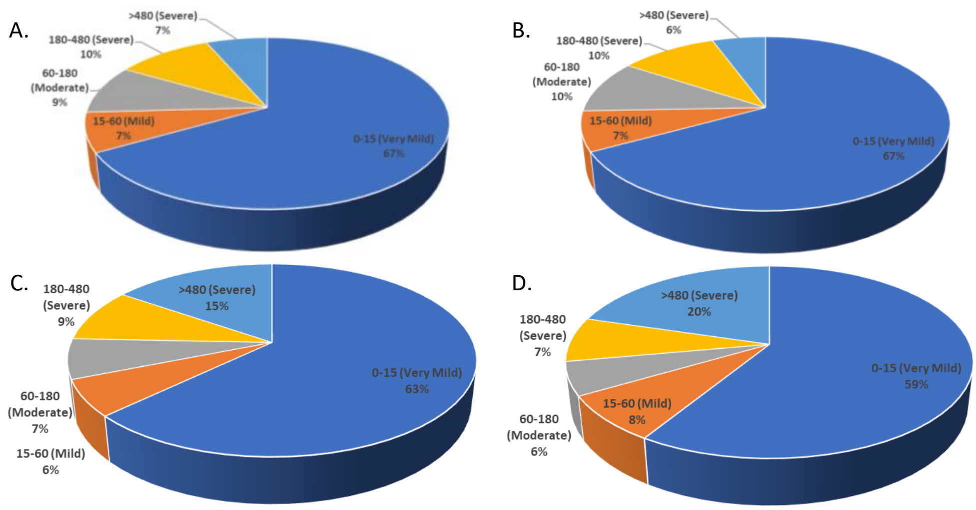


Figure 3. Erosion factors map of Mayang Watershed; a = factor R with Bols equation (monthly rainfall), b = factor R with Utomo equation (monthly rainfall), c = factor R with Bols equation (annual rainfall), d = factor R with Hurni equation (annual rainfall), e = factor K, f = factor LS, g = factor CP, h = erosion with Bols equation (monthly rainfall), i = erosion with Utomo equation (monthly rainfall), j = erosion with Bols equation (annual rainfall), k = erosion with Hurni equation (annual rainfall).



Remark:

A. Soil Erosion Estimation using Bols Equation (Monthly Rainfall)
B. Soil Erosion Estimation using Utomo Equation (Monthly Rainfall)
C. Soil Erosion Estimation Test using Bols Equation (Annual Rainfall)
D. Soil Erosion Estimation using Hurni Equation (Annual Rainfall)

Figure 4. Soil erosion values in Mayang Watershed; Source: own elaboration

Table 4. Results of Mann-Whitney test for each soil loss estimation

Soil Erosion	Mann-Whitney U	Z	p-value
Monthly rainfall	330.000	-0.146	0.884

Remarks: Monthly rainfall = A1 and A2; A1 = Bols equation (monthly rainfall), A2 = Utomo equation (monthly rainfall).

Table 5. Results of Independent T-test for each soil loss estimation

Soil Erosion		Levene's test p-value	T-test p-value
Annual rainfall	Equal variances not assumed	0.036	0.007

Remarks: Annual rainfall = A3 and A4; A3 = Bols equation (annual rainfall), A4 = Hurni equation (annual rainfall).

This is indicated by the significance probability value in both models (sig < α), specifically 0.003 < 0.05, and a positive regression coefficient. Thus, it can be concluded that the R factor variable positively influences the erosion yields A.

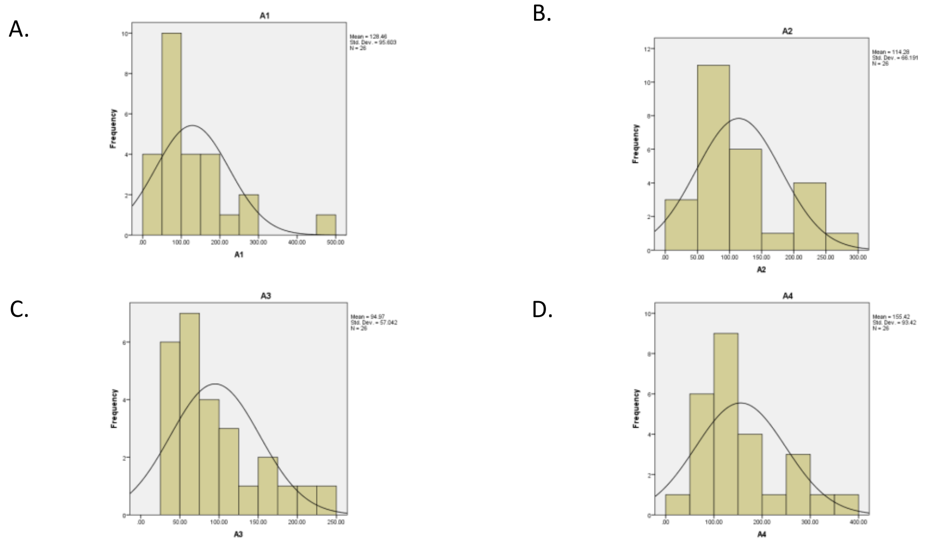
The amount of rainfall determines the destructiveness of rain on soil, the strength of surface runoff, and the level of erosion damage that occurs (Supriyono et al., 2021). Although rainfall erosivity contributes to erosion rates worldwide, other erosion factors also increase erosion rates in certain regions and scales (Renard et al., 1997). In line with this statement, Kartika et al. (2016) state that the high value of rainfall erosivity does not guarantee an increase in erosion yields when other factors are managed well. In this study, assuming other influencing factors are the same, erosion yields will depend on rainfall erosivity. In this sense, selecting appropriate rainfall data and formulas is important when using the USLE and RUSLE models.

4. DISCUSSION

In the USLE and RUSLE models, rainfall erosivity is the ability of rainfall to soil erosion expressed in units of annual rain erosion (Ban et al., 2016) it is influenced by intensity, velocity, grain size, and the spread of the grain size of rainfall (Karyati, 2016). In this sense, low rainfall intensity rarely causes erosion, but the potential for erosion is quite high if it occurs over a long duration. On the other hand, the variability of the rainfall data is very highly influenced by the rainfall pattern (Trinugroho et al., 2022). Therefore, it is necessary to select the best input data for the right input data for the existing equations in the models that affect erosion prediction (Luvai et al., 2022; Tiwari et al., 2000).

The study results show that the erosivity values calculated using monthly data in various equations in both models are not significantly different, which is in line with Supriyono et al. (2021). Contrary to the results when the annual rainfall data are used. This is because the models are designed for erosion yield per year (annual) (Andriyani et al., 2020; Renard et al., 1997; Rohman, 2018). Moreover, The different results are because these models are designed to provide predictive results for a year where the assumption used is that the erosion event and the factors that influence it are uniform or the same throughout the year (Luvai et al., 2022). On the other hand, the annual rainfall pattern was changing due to climate change in East Java during the study periods (Aldrian & Djamil, 2008), including in the study location besides that, the heterogeneity of annual data is getting bigger due to the position of the study area, which is located in a mountainous region which causes greater variation in annual rainfall data (Trinugroho et al., 2022).

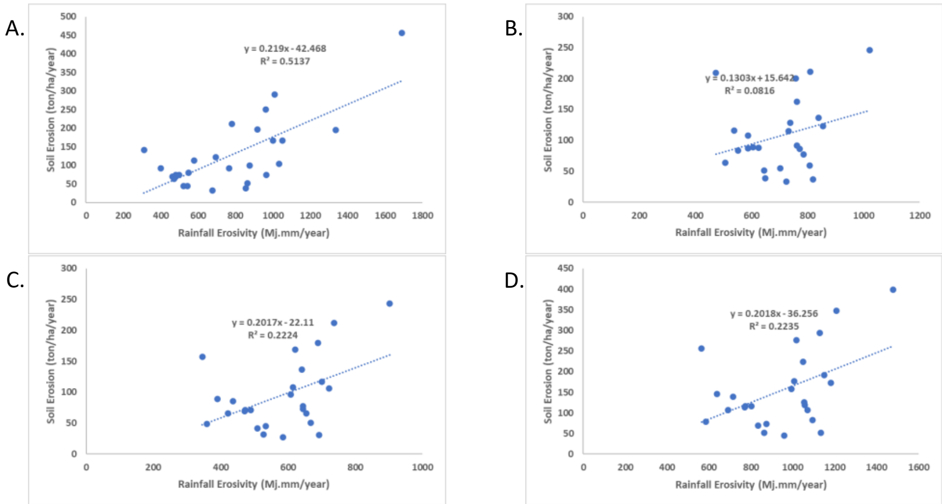
Another result is differences in the predicted value of the rate of erosion produced using USLE and RUSLE models. USLE produces an average erosion rate very heavy (>480 tons ha^{-1} $year^{-1}$) higher than RUSLE (7% versus 6%), while RUSLE produces erosion hazard rate (TBE) moderate (60-180 tons ha^{-1} $year^{-1}$) higher than USLE (10% versus 9%).



Remark:

A. Histogram of Normality Test using Bols Equation (Monthly Rainfall)
B. Histogram of Normality Test using Utomo Equation (Monthly Rainfall)
C. Histogram of Normality Test using Bols Equation (Annual Rainfall)
D. Histogram of Normality Test using Hurni Equation (Annual Rainfall)

Figure 5. Normality Test for each soil loss estimation; source: own elaboration



Remark:

A. Regression analysis using Bols Equation (Monthly Rainfall)
B. Regression analysis using Utomo Equation (Monthly Rainfall)
C. Regression analysis using Bols Equation (Annual Rainfall)
D. Regression analysis using Hurni Equation (Annual Rainfall)

Figure 6. Regression analysis for each soil loss estimation; Source: own elaboration

This is influenced by a reduction in the value of R on flat slopes with a high amount and intensity of rainfall (Andriyani et al., 2020; Renard et al., 1997; Rohman, 2018).

The erosivity calculated using monthly data is standardized into the equation for each model and then summed for one year. In this case, the results obtained from the two models do not show significant differences (Supriyono et al., 2021). In contrast, when the annual rainfall data is used, the data obtained from the summation of monthly rainfall will give more accurate results for the thickness of rainfall throughout the year. These two differences will give different results for erosivity calculations. The use of annual data will be more suitable for tropical countries such as Indonesia, where climate change can occur during the year during the rainy season and dry season (Djoukbala et al., 2019). In the case of there are no differences in annual rainfall data but the rainfall intensity is different hence the erosivity analysis will be a difference (Avia, 2019), because in the beginning, the erosivity value in the USLE model is determined based on the intensity of rainfall that occurs for at least 30 minutes I_{30} (Kinnell, 2007). Therefore, rainfall intensity variability will specifically affect the results of rainfall erosivity calculations, especially when the RUSLE model is used in tropical areas (Naipal et al., 2015).

However, based on the regression analysis (Fig. 6), the highest correlation between the rainfall erosivity factor and soil erosion is in the USLE model when rainfall erosivity is calculated using the Bols equation (Eq. 2). On this basis, the use of the Bols equation (Eq. 2) to calculate the erosivity is considered more suitable compared others. However, soil erosion prediction using annual rainfall data on the RUSLE model gives more accurate results prediction. These results also happened in studies in other watersheds in the Jember district (Andriyani et al., 2020; Rohman, 2018). In fact, both models have been widely used in Indonesia, and several researchers found that the RUSLE model provides more accurate results than the USLE model (Luvai et al., 2022; Mondal et al., 2018; Tiwari et al., 2000), especially when validated data from primary data in the field are used (Andriyani et al., 2017) more specific is the kinetic energy data generated by rain intensity (Nearing et al., 2017). However, for more accurate predictions, it is recommended to integrate machine learning in the RUSLE model to calculate rainfall erosivity values (Suhara KK et al., 2023).

5. CONCLUSION

The erosivity values calculated using monthly data in various equations in both models are not significantly different, contrary to the results when the annual rainfall data are used. This is because annual rainfall data is changing due to climate change (time) and the location of study areas. Moreover, the USLE model gives lower erosion yield predictions than the RUSLE model. The study recommends that the annual rainfall data be used to predict erosion yields using USLE and RUSLE models. However, regression analysis considers using the rainfall erosivity method with USLE and monthly rainfall data more suitable in east Java regions. The regional rainfall characteristics may influence the erosivity calculations. In this case, more studies are necessary to analyze the sensitivity of regional rainfall characteristics.

Declaration of Competing Interest

The authors declare that no competing financial or personal interests may appear and influence the work reported in this paper.

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