Comparing erosion levels on slope classes below 40% and above 40% on pine stands in Hasanuddin University education forest

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Abstract. This study aimed to compare erosion rates on land with slope classes of <40% with those of slope classes> 40%, under pine stands and to determine the relationship between rainfall and erosion. The study was conducted during September 2016 until March 2017 and recorded 36 rain events. Measurement of rainfall using an observatory type rainfall. The amount of erosion is known through direct measurements in the field on the plot measuring 22 x 4 m and followed by the analysis of sediment samples in the laboratory. The measurement results in the field obtained the highest rainfall of 95.6 mm and the lowest of 2.7 mm with a total of 770.50 mm. Erosion is obtained from times result of the sediment concentration with the volume of samples accommodated in the container per thousand. The calculation result is known that the average of erosion on slope class> 40% is in the amount of 278.94 kg / ha and on slope class <40% is 94.93 kg / ha. The relationship of rainfall to erosion is obtained through a simple regression analysis

Y = -3.723 + 0.448x (R² 0.94), Y = -3.502 + 0.645x (R² 0.93), Y = -4.482 + 0.540x (R²0.95),
Y = -1.644 + 0.269x (R²20.91), Y = 0.006 + 0.008x (R² 0.84), and Y = -1.497 + 0.239x (R² 0.90).

1. Introduction
Erosion is the process of removing or eroding soil particles caused by water or wind. Especially in Indonesia which has a wet tropical climate, the process of soil erosion is mostly caused by water. There are several factors that influence erosion, those are rainfall, soil, topography and slopes, vegetation, and humans. Among these factors, rainfall is a factor determined by nature so that it cannot be intervened. Meanwhile, soil, topography, vegetation and human factors are factors that can be intervened.

There are three aspects of slopes that affect erosion, consist of shape, length and slope. Among these slope aspects, the most important aspects affecting erosion are the length and slope itself. If the slope of the soil surface is twice as steep, the amount of erosion per unit area is 2.0 to 2.5 times as much. As for the length of the slopes, the increase was 2 times, only causing the highest erosion 2 times [1]. Based on that the slope aspect is closely related to erosion, the slope aspect needs more serious attention.

Regarding the slope, according to the Regulation of the Director General of Watershed Management and those are flat/no slope (0-8%), gentle (8-15%), moderate (16-25%), steep (26-40%), and very steep
Meanwhile, the standard classification of slopes from 40% and above still needs to be reviewed because the slope classification system established by the Ministry of Forestry assumes that starting slopes of 40% and above will produce the same erosion [2]. This is not in line with what is expressed by Sitanala in his book which states that if the slope is 2 times steeper, the erosion will increase by 2.0 or even 2.5 times greater. In connection with this description, it is necessary to have data and information on how significant the difference is between the level of erosion on lands with slopes of less than 40% and lands with slopes of more than 40%. Apart from the slope factor, the type of vegetation cover also has a big influence on the number of the erosion. Therefore, it is necessary to have further information about the significance of the difference in erosion levels in the two categories of slope slopes with the identified vegetation cover type.

One type of forest cover that should be considered for the above purposes is Pinus merkusii. This is based on the consideration that this species has been widely developed as a reforestation plant since the Dutch colonial era. In the early 70's, Pinus merkusii began to be developed in Hasanuddin University Educational Forest through reforestation activities. Hasanuddin University Educational Forest Area is located in the Maros Regency, Cenrana District, Limampocco village with an altitude between 300-800 meters above sea level [3].

Pine is used as a reforestation plant because it can grow on land with low fertility where other commercial crops cannot grow well [4]. In addition, pine can also function to maintain natural conditions properly [5]. The pine leaves that form the stand canopy can play a role in reducing the kinetic energy of the rainwater, which in turn reduces rain erosivity, reduces and slows down runoff.

In general, the lower layer of pine stands is covered with leaf drop which is known to decompose slowly so that it can protect the soil surface from direct hit by rainwater or surface runoff so that the erosion that occurs will also be smaller [6]. Until now, the portion of the Hasanuddin University Educational Forest which is covered with pine stands which was the result of reforestation plants in 1970 is 291.13 ha. This stand is generally found in the northern part which spreads over lands with topographic conditions that vary from wavy to steep slopes.

In connection with the description above, it is considered necessary to conduct a study whose results can be the basis for explaining the role of pine species in reducing erosion rates and rates in several different slope classes. This study aims to compare the level of erosion on land with slope class <40% with that occurring in slope class> 40%, under pine stands and to determine the relationship between rainfall and erosion. The results of this study are expected to be useful as a basis for consideration by various parties in the context of RHL efforts by planting pine.

2. Research method
2.1. Tool and materials
The tools and materials used in the study consisted of equipment used in the field, those are observatory type rainfall gauge, hagameter, roll meter, machete, crowbar, hoe, bamboo, rubber gutter, pipe, compass, GPS, rapiah rope, sediment collection device, plastic cover for container, measuring cup, meter tape, 600 ml aqua bottle, sample ring, label paper, tally sheet, writing instruments. Furthermore, the tools and materials used in the laboratory are small funnels, measuring cups, filter paper, digital scales, ovens, petri dishes, desiccators, and pliers.

2.2. Implementation method
This research was conducted through the following stages: (1) Primary Data Collection (2) Secondary Data Collection and (3) Analysis.

2.3. Primary data collection
Primary data in this research consists of main data and supporting data.

2.3.1 Main Data. The main data is in the form of measurement of rainfall and erosion.
a. Rainfall
Rainfall is measured using an observatory-type rainfall gauge. Positioned close to the plot on a flat and open ground where the distance between the gauge and the surrounding barrier is 2 times the height of the nearest barrier. Observations are made every time it rains. Rainfall stored on a rain gauge is calculated using the formula:

\[
\text{Rainfall (mm)} = \frac{\text{Rainwater volume that is stored (cm3)}}{\text{Area of the top of gauge (cm2)}} \times 10
\]

b. Erosion
Erosion data were obtained by making erosion plots measuring 22 mx 4 m with three plots of <40% slope class and 3 plots of >40% slope class. Erosion plot images can be seen in Figure 1.

To prevent the possibility of water inflow entering or leaving the erosion plot, a boundary plot is made on the outside of each plot and the erosion plot boundary is immersed into the ground 5cm deep. During the plotting, efforts should be made to the extent possible as not to destroy the original conditions in the erosion plots. At the bottom of the plot, 3 collection tools were placed. The collecting device is placed in such a way that it allows all erosion for each rain event to be accommodated in the storage device. This observation is made whenever it rains.

The amount of erosion that occurs every time it rains can be determined through sediment analysis in a storage tank. Sampling was done by stirring the contents of the tub until the sediment was mixed. Then the sample is put into a 600 ml plastic bottle and labeled. After that, the tub is cleaned from the remains of mud and water. Furthermore, laboratory analysis is carried out to determine the sediment concentration. From each sample, 20 ml was taken and then filtered using filter paper until the water ran out. Then oven at 105°C to obtain dry soil weight. The dried sample is then weighed.

2.3.2 Supporting data. Supporting data in this study are environmental conditions in which to grow including biotic and abiotic conditions.

1. Biotic conditions
Identification of biotic factors at the research location was carried out through stand inventory activities which included seedlings, saplings, poles and trees to determine the diversity of species and stand density around the erosion test plots, making canopy projections to determine the crown density.

a. Stand inventory
Inventory of stands around the test plot was carried out on a plot of 20 mx 20 m in size to determine diversity of species and stand density around the erosion test plot. The scheme of making inventory plots is presented in Figure 2.
After that, an analysis of stand density around the plot was carried out using the formula:

\[
\text{Stand Density} = \frac{\text{number of individual trees (on the measuring plot)}}{\text{Area of plot observation (m}^2\text{)}}
\]

1) Plot 2 mx 2 m for inventory of seedlings <1.5 m.
2) Plot 5 mx 5 m to inventory stakes > 1.5 m high and <10 cm in diameter.
3) Plot 10 mx 10 m to inventory poles with a diameter of 10 cm-20 cm.
4) Plot 20 mx 20 m to inventory trees with a diameter > 20 cm.

b. Canopy closure
Canopy closure on test plots known through making tree canopy projections on millimeter paper blocks with a scale of 1: 100.

2. Abiotic conditions
Identification of abiotic factors was carried out to determine the texture, organic matter content, soil permeability, and slope aspects of the erosion plots at the research location.

a. Soil sampling
To take texture, organic matter content and soil permeability, soil samples were taken from each plot. Soil samples were taken using a ring sample with a diameter of 5.3cm and a height of 5cm, then the soil samples obtained in the field were then analysed in the laboratory to obtain texture data (sand, fine sand, and dust), permeability and soil organic matter content. Laboratory observations were made at the Laboratory of Soil Science, Faculty of Agriculture, Hasanuddin University. The stages of the activities are as follows:

1) Determining the texture of the hydrometer way
In a 100 ml glass beaker weighed 25.00 g of fine soil sample <2mm, 10ml of sodium pyrophosphate dispersing solution was added. Transfer to a metal cup and dilute with ion-free water to the contents of 200 ml. Stir with a high-speed mixer for 5 minutes. After that, everything is transferred to a 500 ml measuring cup (do rinsing), diluted with ion-free water to 500 ml, stirred with a special stirrer and left overnight. In the same way, but without an example, a blank assignment is made.

Measurement of the content of the dust fraction was measured the next day, each soil suspension in a measuring cup was stirred for 30 seconds with a stirrer. After that the stopwatch was prepared for the measurement of the dust fraction. The suspension is shaken homogeneously with a stirrer (just 20 seconds) after which the soil hydrometer is immediately inserted into the suspend slowly and carefully. Exactly 40 seconds after shaking, the hydrometer scale figure coinciding with the surface of the suspension is recorded (reading 1). The figure shows the number of g fraction of dust per litre of suspension. The blank solution was also measured to correct the temperature of the dust fraction.

2) C-Organic assignment
The C-Organc content is known by weighing 0.500 g of soil sample size <0.5 mm, then put into a 100 ml volumetric flask. Add 5 ml of K2Cr2O7 1 N, then shake it. Add 7.5 ml of H2SO4 concentrated, shake then let stand for 30 minutes. Diluted with ion-free water, let it cool and squeeze. The next day, the absorbance of the clear solution was measured with a spectrophotometer at a wavelength of 561 nm. As a comparison, 0 and 250 ppm standards were made, by piping 0 and 5 ml of the 5,000-ppm standard solution into a 100 ml volumetric flask with the same treatment as the sample work. Note: If the sample reading exceeds the highest standard, repeat the determination by weighing fewer samples. Change the factor according to the calculation according to the sample weight you are weighing.

3) Determination of permeability
   a) Cover one end of the sample ring with a barrier to hold the soil in the ring, using two strands of cloth that are quite porous tied with a rubber band.
   b) After that, place the sample (part of the barrier covered in the soil) put into a tray filled with water with a depth of approximately ½ the height of the ring. After the entire soil surface is wet, raise the water level in the tray so that it is level with the ground. Let it soak for 24 hours.
   c) The submerged sample ring is connected to another sample ring using a rubber tire (the joint must be 100% waterproof).
   d) The ring is placed on the funnel, then the water is flowed into the siphon and reservoir. After the water level is constant above the soil sample, percolates are accommodated into a barrier or flask.
   e) Measurement of the water volume (Q) that passes through the sample during (t).
   f) Permeability calculation with the equation

\[ K = \frac{Q}{T} \times \frac{L}{H} \times \frac{1}{A} \]

Where:
K = Permeability (cm/hour)
Q = How much water flows per measurement (mL)
t = Time of measurement (hours)
L = Thickness of soil sample
H = Height of water surface from soil sample surface (cm)
A = The surface area of the soil sample (cm²)

Based on the above field data and laboratory analysis, the K value (erodibility) can be calculated using a nomograph. The use of a nomograph is carried out through the following stages:
   a) The percentages of dust and very fine sand are determined at the corresponding point on the vertical axis to the left of the nomograph.
   b) The horizontal line is drawn to cut the line showing the percentage of sand.
   c) Then from this point of intersection a vertical line is drawn to cut the percentage of organic matter.
   d) From this point of intersection, a horizontal line is drawn to the right to intersect the soil structure class.
   e) After that from this point of intersection a vertical line is drawn to cut the soil permeability class.
   f) From this point of intersection, drag a horizontal line to the left until it intersects the erodibility index scale (K).

b. Measurement of Land Slope Aspects
   Slope aspects in this study is the slope of the erosion plot which is measured using a meter.

2.4. Secondary data collection
Secondary data collected are supporting data that are not obtained from direct observation data at the research location. These data include annual rainfall data, slope, literature studies and information that is relevant to this research. Secondary data collection is carried out through agencies and other related sources. Annual rainfall data is sourced from the Regional BMKG Maros Regency.

2.5. Analysis method
2.5.1. The formula used to calculate the sediment concentration is:

\[ C = \frac{(b-a)}{v} \]

Where:
- \( C \) = Sediment concentration (g/m\(^3\))
- \( b \) = Weight of the filter paper containing erosion (g)
- \( a \) = Weight of empty filter paper (g)
- \( v \) = volume of erosion sample (m\(^3\))

2.5.2. The formula used to calculate the rate of erosion is:

\[ E = \frac{K \times V}{1000} \]

Where:
- \( E \) = Erosion in kg
- \( K \) = Concentration of sediment in g/m\(^3\)
- \( V \) = Volume in m\(^3\)

Furthermore, to determine the relationship between rainfall erosion then used a simple regression analysis with the formula \( y = a + bx \) where \( y \) is erosion, \( x \) is rainfall \( a \) and \( b \) is a parameter estimator [7].

3. Result and discussion
Based on observations made for ± 2 months in the field, it is known that there were 36 rainfall events with a total rainfall of 770.50 mm. The highest rainfall of 95.6 mm occurred in the 13th rainy event on 26 January 2017 and the lowest rainfall occurred in the 15th rainy event on 27 January 2017 of 2.7 mm. The highest rainfall intensity occurred on February 8, 2017 at 25.56 mm / hour and the lowest was 1.71 mm / hour which occurred on January 12, 2017. The value of rainfall varies each time it rains, causing the erosion value to also vary. Rainfall data in Annex 1 shows the variance of each rain event. From these data and is filed under very mild rain to rain cats and dogs based Sosrodarsono and Takeda (1999) [8], the results can be seen in Table 1.

| Rainfall Classification | Rainfall Intensity (mm/hour) | Rain Events | Percentage of Rainfall (%) |
|-------------------------|-----------------------------|-------------|---------------------------|
| Very light              | ≤ 1                         | 0           | 0.00                      |
| Light                   | 1 – 5                       | 13          | 36.11                     |
| Moderate                | 5 – 10                      | 11          | 30.55                     |
| Heavy                   | 10 – 20                     | 10          | 27.77                     |
| Very heavy              | > 20                       | 2           | 5.55                      |
| **Total**               | **36**                     | **100**     |                           |

Table 1. Percentage of rain events during the research
Tables 4 shows that the rainfall found during the study (36 times of rain events) is light rainfall as much as 13 times of rain events or 36.11% of the total rain events, moderate rain is 11 times of rain events or 30.55% of the total rain events, 10 times heavy rain or 27.77% of the total rainfall, and 2 times very heavy rain or 5.55% of the total rainfall. Very light rain was not found during the study. Light rainfall is rainfall with the highest percentage of rain events, 36.11% of the total rainfall events. In light rainfall the average time duration is 171 minutes, in normal rainfall the average occurs for a duration of 230 minutes, in average heavy rainfall occurs for a duration of 137 minutes, and in very heavy rainfall occurs on average over a duration of 36 minutes, causing different erosion results. The variation in rainfall during the study can be seen in Figure 3.

![Figure 3. Graph of Rainfall (mm)](image)

Although rainfall is closely related to erosion, sometimes the role of rain intensity is not clear. Rain with high intensity but only for a short time will cause little erosion. Conversely, rain with light or moderate intensity, but lasting for a long time will cause greater erosion. As happened in this study, in the slope class > 40%, very heavy rain occurred on February 8, 2017 with the highest intensity of 25.57 mm/hour in 23 minutes, which only resulted in erosion of 0.65 kg/ha. Light rain occurred on 29 January 2017 with an intensity of 4.8 mm/hour for 495 minutes resulting in an erosion of 21.33 kg/ha. Heavy rain occurred on 26 January 2017 with an intensity of 15.26 mm/hour for 376 minutes resulting in an erosion of 42.18 kg/ha.

### 3.1. Erosion

The erosion value is obtained from the analysis of sediment concentration in the laboratory. The erosion results obtained differ between slopes <40% and > 40% slopes. The value of erosion that occurs in both of these classes is completely listed in Appendix 2, while the recapitulation of erosion values can be seen in Table 2.

| Slope Class | Plot (Slope) | Amount of rainfall (mm) | Amount of Erosion (kg/ha) | Amount of Erosion (ton/ha) |
|-------------|--------------|--------------------------|---------------------------|---------------------------|
| >40%        | 1 (58%)      | 770.50                   | 211.03                    | 0.21                      |
|             | 2 (61%)      | 770.50                   | 370.98                    | 0.37                      |
|             | 3 (72%)      | 770.50                   | 254.83                    | 0.25                      |
|             | **Total**    | **836.84**               | **0.83**                  |                           |
|             | **Average**  | **278.95**               | **0.28**                  |                           |
| <40%        | 4 (25%)      | 770.50                   | 148.42                    | 0.15                      |
|             | 5 (27%)      | 770.50                   | 6.29                      | 0.01                      |
|             | 6 (29%)      | 770.50                   | 130.09                    | 0.13                      |
|             | **Total**    | **284.8**                | **0.29**                  |                           |
|             | **Average**  | **94.93**                | **0.10**                  |                           |
Table 2 shows the differ between the amount of erosion on slope <40% with an average of 94.93 kg/ha or equivalent to 0.10 tonnes/ha while on the slope class >40% with an average of 278.95 kg/ha or equivalent with 0.28 tonnes/ha. This data further confirms that each increase in slope also causes the erosion value to increase. Arsyad S (2010) states that the amount of erosion that occurs can be influenced by the interaction of several factors such as rainfall, slope, vegetation, and litter [1].

Rainfall is very influential on the occurrence of erosion, but in this study, the rainfall that occurs is the same, both at a slope of <40% or >40% so that the slope has a large effect on the amount of erosion that occurs. As in this study, the erosion that occurred in the slope class was <40% (94.93 kg/ha) while in the slope class >40% (278.95 kg/ha) the erosion occurred was greater. Arsyad U (2010) found the same thing in research in the Upper Jeneberang watershed where the average value of the smallest amount of erosion occurred in the slope class <45% and increased with increasing slope class which are on slope class 20-45% erosion occurred at 48.41 tons/ha/year, on slopes >45-65% is 117.45 tons/ha/year, on slopes >65-85% is 178.48 tonnes/ha/year, and >85% is 225.59 tons/ha/year [9].

In the erosion observation plots, both on the <40% and >40% slope class, each of them has three plots with different slopes. Slope class <40%, the highest erosion occurs in plot 4 (148.42 kg/ha) with a slope of 25%. This is because the canopy cover conditions in plot 4 are more open than the vegetation conditions in plots 5 (27%) and 6 (29%) as shown in Appendices 10, 11 and 12. Apart from the condition of canopy cover, the thickness of the litter on the plot 4 is lower than plot 5 and 6 and plot 5. This research is in line with what Arsyad U (2010) expressed that although the slope is high but the vegetation cover is dense, the amount of erosion is smaller than the low slopes but open [9].

Slope class >40% also occurs the same thing where the highest erosion actually occurs in plot 2 (370.98 kg/ha) with a slope of 61% then followed by plot 3 (254.84 kg/ha) with a slope 72% and plot 1 (211.03 kg/ha) with a slope of 58%. The difference in the results of erosion in each plot is due to the different conditions of vegetation and litter in each plot.

Plot 2, with a 61% slope, the canopy closure condition is more open compared to plots 1 and 3 as shown in appendices 7, 8, and 9. This statement is in line with Gunawan and Kusminingrum (2018) who state that the erosion rate will decrease with increasing levels [10], plant cover and cover crop cover> 70% of the soil that is eroded is close to zero. Apart from the canopy closure, the litter condition in plot 2 is thinner compared to plots 1 and 3. This is in line with the results of research conducted by Ispriyanto et.al, (2001) where plots with thick litter produce less erosion than plots that have thick litter. high litter thickness [11].

The litter layer protects the soil surface from direct hit by raindrops which can destroy the soil aggregate. The role of the litter layer in protecting the soil surface is greatly influenced by its resistance to weathering. Litter in the form of leaves, twigs and so on that have not experienced weathering functions to cover the surface of the soil and is a protector of the soil against the strength of falling raindrops. Kohnke and Bertrand (1959) in Ispriyanto et.al, (2001) stated that plant residues as mulch from vegetation greatly affect soil physical, chemical and biological properties [11]. Mulch or litter can minimize the occurrence of splash erosion on the soil surface caused by rainwater. To clarify the ratio of erosion results on slope classes below 40% and above 40%, it can be seen in Figure 4.
Figure 4. Graphic comparison of erosion results on slope classes below 40% and above 40%

Litter layer serves to protect ground surface from direct hit by raindrops that can crush soil aggregates. The role of the litter layer in protecting the soil surface is greatly influenced by its resistance to weathering. Litter in the form of leaves, twigs and so on that have not experienced weathering functions to cover the surface of the soil and is a protector of the soil against the strength of falling raindrops. Kohnke and Bertrand (1959) in Ispriyanto et.al, (2001) stated that plant residues as mulch greatly affect soil physical, chemical and biological properties [11]. Mulch or litter can minimize the occurrence of splash erosion on the soil surface caused by rainwater.

3.2. Relationship between rainfall and erosion
To determine the relationship between rainfall and erosion, a simple regression analysis was carried out. The results of analysis of variance and estimation of regression parameters can be seen in Appendix 3 and Appendix 4 showing that rainfall has a large effect on erosion. The regression equation for the relationship between rainfall and erosion at slopes above 40% (plot 1, plot 2, plot 3) and below 40% (plot 4, plot 5, plot 6) is presented in Table 3.

Table 3. Relationship between rainfall and erosion

| Slope Classes | Plot | Regression Equations | $R^2$ | $R^2(\%)$ |
|---------------|------|----------------------|-------|-----------|
|               | 1    | $\hat{y} = -3.723 + 0.448x$ | 0.935 | 93.50%    |
| >40%          | 2    | $\hat{y} = -3.502 + 0.645x$ | 0.929 | 92.90%    |
|               | 3    | $\hat{y} = -4.482 + 0.540x$ | 0.947 | 94.70%    |
| <40%          | 4    | $\hat{y} = -1.644 + 0.269x$ | 0.909 | 90.90%    |
|               | 5    | $\hat{y} = 0.006 + 0.008x$ | 0.838 | 83.80%    |
|               | 6    | $\hat{y} = -1.497 + 0.239x$ | 0.903 | 90.30%    |

Table 6 shows that the highest erosion occurred in the slope class >40%, which are in plot 2 then followed by plot 3 and plot 1. Plot 2 with the regression equation $\hat{y} = -3.502 + 0.645x$ means that in plot 2 erosion begins to occur during the bulk time rain reaches 6 mm, the value of erosion that occurs is 0.368 kg/ha. The coefficient of determination ($R^2$) a high of 92.90% indicates that rainfall is very involved in the process of erosion. In other words, 92.90% erosion is influenced by rainfall and 7.10% is influenced by other factors.

Plot 3 with a regression equation $\hat{y} = -4.482 + 0.540x$ means that in plot 1 erosion begins to occur when rainfall reaches 9 mm, the erosion value is 0.378 kg/ha. This is supported by the coefficient of determination ($R^2$) a high of 94.70%. In other words, 94.70% erosion is influenced by rainfall and 5.30% is influenced by other factors.
Plot 1 with a regression equation $\hat{y} = -3.723 + 0.448x$ means that in plot 1 erosion begins to occur when rainfall reaches about 9 mm with an erosion value of 0.309 kg/ha. The regression equation shows that there is a close relationship between rainfall and erosion. This is supported by the coefficient of determination ($R^2$) a high of 93.50%. In other words, 93.50% erosion that occurs in plot 1 is influenced by rainfall and 6.50% is influenced by other factors.

In the slope class <40%, the highest erosion occurs in plot 4 followed by plot 6 and plot 5. Plot 4 with the regression equation $\hat{y} = -1.644 + 0.269x$. The regression equation shows that there is a close relationship between rainfall and erosion. In plot 4, erosion begins to occur when the rainfall reaches 7 mm with an erosion value of 0.239 kg/ha. This is supported by the coefficient of determination ($R^2$) a high of 90.90%. In other words, 90.90% of erosion that occurs in plot 4 is influenced by rainfall and 9.10% is influenced by other factors.

Plot 6 with the regression equation $\hat{y} = -1.497 + 0.239x$. The regression equation shows that there is a close relationship between rainfall and erosion. In plot 6, erosion begins to occur when the rainfall reaches 7 mm with an erosion value of 0.176 kg/ha. This is supported by the coefficient of determination ($R^2$) a high of 90.30%. In other words, 90.30% erosion that occurs in plot 6 is influenced by rainfall and 9.70% is influenced by other factors.

Plot 5 with the regression equation $\hat{y} = 0.006 + 0.008x$. This equation explains that when the rainfall reaches 1 mm, the erosion is 0.002 kg/ha. By looking at the value of the coefficient of determination ($R^2$) is 83.80%, which is known that the erosion at plot 5 is influenced by rainfall and 16.20% influenced by other factors.

From these descriptions, it can be concluded that rainfall has a very strong influence on erosion. Climate is one of the factors that influence the occurrence of erosion in tropical climates such as Indonesia, which is rain. Rain that falls on the soil surface will cause the destruction of the soil aggregate due to the destructive power and decomposition power of the rainwater.

High intensity rain will have great energy in destroying soil aggregates. Rainfall that falls to the ground has different diameters so that it has different impact energies. The energy of this collision depends on the speed at which the water drops fall, the diameter of the raindrops and the intensity of the rain. This is also supported by Bafdal et al., (2011) who stated that rain parameters can be divided into: (i) the amount of rain; (ii) rain intensity; (iii) duration / duration of rain events); and (iv) rain distribution [12]. The lines of increasing erosion to rainfall are presented in Figure 5.

![Figure 5](image.png)

**Figure 5.** The lines of increasing erosion to rainfall

Figure 5 shows that the higher the rainfall value, the higher the erosion value. Based on the graph in Figure 3, it can be seen that in 1 mm of rainfall, erosion has occurred on the slope <40%, while in the
slope > 40% plot, erosion only occurs when the height of rainfall reaches the range of 6 mm. This is because the percentage of sand and dust content in the slope plot <40% is much greater than the content in the slope plot > 40% (Appendix 16). In line with that, Hardjowigeno S (2010) stated that soils with high content of fine sand and dust are soils with a high level of erosion sensitivity [13]. Bafdal et al., (2011) argues that in terms of soil texture, it can be said that the sand texture is more easily broken down by rain grains into soil particles than other textures [12]. This is because the binding power between soil particles from the sand texture is not strong or unstable due to the weak adhesive between the particles due to the lack of clay texture (which functions as cement between soil particles).

4. Conclusions

Based on the research results obtained, it can be concluded that:
1. The level of erosion on land with slope class > 40% has an erosion value that does not increase 2.0 to 2.5 times when compared to the erosion that occurs in slope class < 40%.
2. The relationship between rainfall and erosion during the research is linear as indicated by the coefficient of determination which is generally > 90% where the linear value tends to be higher on slopes > 40%.

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