Effect of rain characteristics on rain erosivity in Banggai Regency, Central Sulawesi, Indonesia

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Abstract. Rain characteristics are important characteristics to know and predict their response to overall climate change. The purpose of this study is to determine the characteristics of rain and its effect on the erosivity of rain and to make a relationship between rain erosivity and rain. The method used is the rain pattern, the nature of rain, rain erosivity, and double linear lines. The analysis was carried out using rain data at Singkoyo and Waru Stations with observation periods from 1997-2017 (21 years). The calculation results show that the rain characteristic is patterned C or opposite of A pattern; rain characteristics greatly affect the size of the rain erosivity; BN, N, and AN values are not the same for the two rain stations because they are strongly influenced by the statistical parameters of the rain; multiple regression equations for Singkoyo Station, \( \text{ET0} = 8.890 + 18.681 R_{\text{month}} - 21.594 N + 5.574 R_{\text{max}} \) and for Waru Station, \( \text{ET0} = -29.163 + 10.581 R_{\text{month}} - 6.150 N + 13.156 R_{\text{max}} \).

1. Introduction
Indonesia is located in a tropical climate, which has two seasons, namely the rainy season and the dry season. In general, the rainy season occurs from October to April, while the dry season occurs from April to October. However, the season patterns in these months can no longer be used as a reference. Global climate change caused by the effects of global warming has influenced the climate and weather in Indonesia. Some of the impacts that occur include, the season in Indonesia has changed to become erratic, the intensity of rain has increased, and increased flooding in areas that have been known to have rarely been flooded. These various impacts greatly affect the planning and design of various buildings that require hydrological data in their implementation [1].

Simply put, the hydrological process in a watershed can be described as the relationship between the input elements namely rain, process, and output in the form of flow. The existence of certain rain will produce a certain flow as well. This flow is also influenced by the characteristics of the watershed and the characteristics of falling rain. Rainfall characteristics include rainfall thickness, intensity, and duration of rain, while watershed characteristics include topography, geology, geomorphology, soil, land cover, and land management and watershed morphometry [2].

The threat of drought in the dry season and the danger of flooding in the rainy season are classic problems that continue to recur every year, even lately with increasing frequency and intensity and are difficult to predict. Responding to the impact of global climate change in its relation to flood disaster risk control, it is deemed necessary to study a characteristic of rainfall as one of the factors that are considered to have a significant influence on the phenomenon of flooding [3]. Brown stated that rain characteristics are important characteristics to know and predict their response to overall climate change.
change. Information on the amount and distribution of rain is very useful in making policies concerning the use of rainwater so that planting can be carried out optimally [4]. Hutomo stated that the ability of rain to cause erosion is called rain erosivity. Erosion occurs due to rainwater blows and surface runoff erosion [5]. This study aims to determine the characteristics of rain and its effect on rain erosivity and to make a relationship between rain erosivity and rain.

2. Material and Methods

2.1. Description of study

The data used in this study were obtained from two rainfall stations in Central Sulawesi (table 1 and figure 1). The material used in this analysis is secondary data in the form of monthly average rainfall, monthly maximum rainfall and the number of rainfalls per month. While the equipment used includes calculators, stationery, and personal computers.

Table 1. Rainfall station names and positions

| No. | Station | Location | Period (year) | Position |
|-----|---------|----------|--------------|----------|
| 1   | Singkoyo Watershed | 1997 - 2017 | 01° 26' 51" South Latitude (21 years) 122° 20' 09" East Longitude |
| 2   | Waru Watershed | 1997 - 2017 | 0° 49' 25,1" South Latitude (21 years) 123° 10' 16" East Longitude |

Figure 1. Location of research

2.2. Literature study

2.2.1 Rainfall characteristics. Tjasyono states that in general there are three rainfall patterns in Indonesia [6], namely:
1. Pattern A or Monsoon Pattern, influenced by monsoon winds with the characteristic of monthly distribution forming the letter (V).
2. Pattern B or Equatorial Pattern, the distribution of rainfall with two maximums, around April and October, is not always clear of the difference in the distribution of monthly rainfall.
3. Pattern C or Local Pattern, where the distribution of monthly rainfall is opposite to pattern A.
2.2.2 The nature of rain
The evaluation of rain properties can be calculated using the standard deviation formula. Rainfall by standard deviation method is classified into five characteristics of rain [7], namely:

1. Far below Normal (JBN)
   \[ JBN = x \leq X - 1.5 \text{ SD} \]  

2. Under Normal (BN)
   \[ BN = X - 1.5 \text{ SD} < x \leq X - 0.5 \text{ SD} \]  

3. Normal (N)
   \[ N = X - 0.5 \text{ SD} < x \leq X + 0.5 \text{ SD} \]  

4. Above Normal (AN)
   \[ AN = X + 0.5 \text{ SD} < x \leq X + 1.5 \text{ SD} \]  

5. Far above Normal (JAN)
   \[ JAN = x > X + 1.5 \text{ SD} \]  

Standard deviations are calculated using the formula [8-11]:

\[ SD = \sqrt{\frac{\sum_{i=1}^{n} X_i^2 - (\sum X_i)^2}{n-1}} \]  

2.2.3 Rain erosivity
To calculate the value of rain erosivity used the Bols formula, 1978 [12]. The rainfall data needed is the average monthly rainfall, the number of rainy days and the maximum daily rainfall per month.

\[ E_{30} = 6.119 \ (RAIN)^{1.21} \times (DAYS)^{0.47} \times (M_{max})^{0.53} \]  

2.2.4 Equation of multiple linear regression
The relationship between rain erosivity and rainfall characteristics that influence it is analyzed using the multiple linear regression equation [13]:

\[ Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 \]  

2.3 Research method
Several stages carried out in this study, including:

2.3.1 Data collection. Rain data were obtained from the Cipta Karya and Water Resources Office, Central Sulawesi Province, taken from the Singkoyo and Waru Rain Stations for 1997-2017 (21 years).

2.3.2 Data processing. The stages of data processing in this study start from create a monthly rain pattern profile, analyzing the nature of rain, analyzing rain erosivity, analyzing the effect of rain characteristics on erosivity, and make a regression line equation the relationship between rain characteristics and erosivity.
3. Results and Discussion

3.1 Rainfall pattern
Based on figure 2 and figure 3, it can be seen that the monthly rainfall patterns at the Singkoyo and Waru rain stations are almost the same, where the peak of rain occurs in July, subsequently lowering towards before and after July. Thus, it can be categorized by both rain stations patterned C or Pattern inverted V.

![Figure 2](image-url)  
**Figure 2.** Rainfall pattern at Singkoyo station (1997-2017)

![Figure 3](image-url)  
**Figure 3.** Rainfall pattern at Waru station (1997-2017)
Table 2. The rainy nature of Singkoyo station

| No. | Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Yearly | JBN | BN | N | AN | JAN |
|-----|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|--------|-----|-----|---|----|-----|
| 1   | 1997 | BN   | BN   | BN   | BN   | BN   | N    | N   | N   | N   | N   | N   | BN   | BN   | BN   | BN   | N   | N   | AN    |
| 2   | 1998 | BN   | BN   | BN   | BN   | BN   | N    | N   | N   | N   | N   | N   | BN   | BN   | BN   | BN   | N   | N   | AN    |
| 3   | 1999 | BN   | BN   | BN   | BN   | BN   | N    | N   | N   | N   | N   | AN   | JAN  | BN   | BN   | BN   | BN   | N   | N   | AN    |
| 4   | 2000 | BN   | AN   | BN   | N    | AN   | N    | AN  | AN  | BN   | BN   | AN   | BN   | AN   | BN   | BN   | BN   | N   | N   | AN    |
| 5   | 2001 | BN   | BN   | BN   | N    | N    | N    | N   | N   | N   | N   | AN   | BN   | BN   | BN   | BN   | N   | N   | AN    |
| 6   | 2002 | N    | N    | N    | N    | N    | JAN  | BN   | BN   | BN   | BN   | N    | AN   | BN   | BN   | BN   | BN   | N   | N   | AN    |
| 7   | 2003 | N    | N    | BN   | JAN  | BN   | N    | BN   | BN   | BN   | BN   | N    | AN   | BN   | BN   | BN   | BN   | N   | N   | AN    |
| 8   | 2004 | BN   | AN   | BN   | N    | JAN  | BN   | AN   | BN   | N    | AN   | BN   | N    | AN   | BN   | BN   | BN   | N   | N   | AN    |
| 9   | 2005 | N    | AN   | BN   | AN   | JAN  | BN   | AN   | BN   | BN   |BN   | N    | AN   | BN   | BN   | BN   | BN   | N   | N   | AN    |
| 10  | 2006 | BN   | AN   | BN   | N    | AN   | BN   | N    | BN   | BN   | BN   | N    | AN   | BN   | BN   | BN   | BN   | N   | N   | AN    |
| 11  | 2007 | BN   | N    | N    | BN   | AN   | BN   | AN   | N    | AN   | AN   | AN   | AN   | AN   | AN   | AN   | AN   | N   | N   | AN    |
| 12  | 2008 | N    | AN   | N    | JAN  | N    | JAN  | AN   | AN   | AN   | AN   | AN   | AN   | AN   | AN   | AN   | AN   | N   | N   | AN    |
| 13  | 2009 | N    | AN   | JAN  | N    | JAN  | AN   | AN   | AN   | AN   | AN   | AN   | AN   | AN   | AN   | AN   | AN   | N   | N   | AN    |
| 14  | 2010 | AN   | N    | AN   | N    | BN   | N    | N   | AN   | BN   | BN   | N    | AN   | BN   | BN   | BN   | BN   | N   | N   | AN    |
| 15  | 2011 | N    | AN   | AN   | N    | AN   | N    | N   | AN   | BN   | BN   | N    | AN   | BN   | BN   | BN   | BN   | N   | N   | AN    |
| 16  | 2012 | N    | AN   | AN   | N    | AN   | N    | N   | N    | BN   | BN   | N    | AN   | BN   | BN   | BN   | BN   | N   | N   | AN    |
| 17  | 2013 | AN   | N    | AN   | N    | BN   | N    | BN   | BN   | BN   | BN   | N    | AN   | BN   | BN   | BN   | BN   | N   | N   | AN    |
| 18  | 2014 | N    | AN   | AN   | N    | JAN  | BN   | N    | BN   | BN   | BN   | N    | AN   | BN   | BN   | BN   | BN   | N   | N   | AN    |
| 19  | 2015 | N    | AN   | AN   | N    | JAN  | BN   | N    | BN   | BN   | BN   | N    | AN   | BN   | BN   | BN   | BN   | N   | N   | AN    |
| 20  | 2016 | AN   | JAN  | N    | BN   | N    | BN   | N    | AN   | AN   | AN   | AN   | AN   | AN   | AN   | AN   | AN   | N   | N   | AN    |
| 21  | 2017 | AN   | N    | N    | JAN  | AN   | AN   | AN   | AN   | AN   | AN   | AN   | AN   | AN   | AN   | AN   | AN   | N   | N   | AN    |

Where: JBN = Far Below Normal; BN = Below Normal; N = Normal; AN = Above Normal; JAN = Far Above Normal

Based on the evaluation of the nature of rain during the period 1997-2017 at the Singkoyo rain station (table 2), some rain properties were obtained as follows: far below normal (JBN), the largest = 16.67% in 1997, below the normal (BN), the largest = 58.33% year 1997, normal (N) biggest = 58.33% in 2011, above normal (AN) biggest = 59.0% in 2017, and far above normal (JAN) biggest = 25% in 2008.

Table 3. The rainy nature of Waru station

Based on the evaluation of the nature of rain during the period 1997-2017 at the Waru Rain Station (table 3), some rain properties were obtained as follows: far below normal (JBN), the largest occurred in 2000 with a percentage of 8.3%, below normal (BN), the largest occurred in the year 1997 with the percentage of 91.7%, the highest normal rainfall (N) occurred in 2006 with the percentage of 75.0%, the highest than normal rainfall (AN) occurred in 2017 with a percentage of 41.7% and far above the normal (JAN) the biggest occurred in 10 with a percentage of 41.7%.

3.2 Rain erosivity

From table 4 and figure 4 the erosivity calculation results can be explained that the erosivity value of rainfall from 1997-2017 fluctuates from year to year. Starting in 1997, the erosivity value increased and reached its peak in 2000. After that, the value fluctuated until it reached its peak in 2008. Then it fell
again in 2009 and was almost flat until 2017. The biggest rain erosion occurred in 2008 and the smallest in 2009.

Table 4. Rain erosivity at Singkoyo station

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Yearly |
|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|--------|
| 1997 | 186.844 | 27.911 | 65.749 | 86.040 | 120.067 | 489.734 | 379.704 | 5.096 | - | - | - | - | 1361.146 |
| 1998 | 2.895 | - | 44.172 | 72.536 | 116.302 | 889.009 | 273.882 | - | - | 155.942 | 81.593 | 60.861 | 60.976 | 1778.168 |
| 1999 | 221.260 | 60.499 | 90.280 | 262.706 | 301.012 | 650.317 | 526.329 | 336.591 | 402.899 | 250.982 | 98.640 | 64.528 | 3274.042 |
| 2000 | - | 125.912 | 109.364 | 64.359 | 226.965 | 1375.246 | 829.984 | 2504.988 | 993.717 | 241.296 | 27.997 | - | - | 6569.836 |
| 2001 | 100.182 | 37.647 | 112.136 | 259.297 | 434.251 | 737.770 | 2331.991 | 921.906 | 195.175 | 131.592 | 153.387 | - | 167.647 | 5581.988 |
| 2002 | 127.714 | 73.607 | 96.428 | 304.672 | 280.158 | 1602.903 | 653.438 | 242.684 | 6.333 | - | 12.429 | 319.998 | - | 3720.355 |
| 2003 | 153.150 | 62.250 | - | 52.900 | 189.596 | 324.884 | 1008.491 | 325.428 | 78.136 | 5.221 | - | 43.071 | 145.945 | 3865.174 |
| 2004 | 20.721 | 152.112 | 24.904 | 108.451 | 333.604 | 1378.496 | 1464.814 | 19.746 | 548.010 | - | - | - | - | 4185.788 |
| 2005 | 20.828 | 133.877 | 29.281 | 169.231 | 774.788 | 279.433 | - | 939.960 | 56.063 | 30.911 | 81.455 | 97.515 | - | 2628.343 |
| 2006 | 13.023 | 136.258 | 60.576 | 141.381 | 234.597 | 879.188 | 265.677 | 498.077 | 60.696 | - | - | - | - | 2511.688 |
| 2007 | 19.083 | 82.680 | 48.044 | 65.913 | 338.383 | 478.035 | 284.462 | 802.768 | 486.830 | 108.762 | 68.479 | - | - | 5395.892 |
| 2008 | 87.260 | 105.298 | 60.035 | 653.600 | 276.605 | 900.397 | 379.851 | 1483.380 | 394.496 | 427.902 | - | - | 63.166 | 3884.242 |
| 2009 | 49.971 | 92.180 | 79.599 | 48.504 | 258.437 | 299.729 | 139.278 | - | - | - | - | - | - | 1471.647 |
| 2010 | 51.293 | 19.312 | 123.257 | 48.284 | 250.487 | 1278.561 | 430.914 | 1011.745 | 88.735 | 120.351 | 144.752 | - | - | 3737.855 |
| 2011 | 64.700 | 53.814 | 80.715 | 210.606 | 244.853 | 1328.363 | 850.560 | 699.148 | 1430.418 | 12.716 | 34.676 | - | - | 5083.654 |
| 2012 | 107.972 | 53.287 | 34.544 | 268.720 | 906.072 | 447.420 | 1486.033 | 333.115 | 111.793 | - | - | - | - | 3929.137 |
| 2013 | 159.071 | 102.063 | 94.522 | 118.422 | 203.466 | 252.963 | 857.282 | 436.979 | 223.227 | 47.151 | - | - | - | 2529.077 |
| 2014 | 33.630 | 63.239 | 21.902 | 37.498 | 328.335 | 921.148 | 641.309 | 1917.931 | 17.603 | 23.508 | 84.388 | - | - | 179.293 | 4269.787 |
| 2015 | 68.092 | 181.803 | 99.311 | 137.685 | 1159.08 | 905.176 | 905.656 | 27.819 | 9.466 | 36.985 | 32.173 | - | - | 3662.372 |
| 2016 | 281.419 | 202.230 | 65.180 | 96.030 | 55.624 | 811.446 | 757.114 | 279.228 | 120.279 | 150.256 | 117.592 | 309.048 | - | 3345.446 |
| 2017 | 86.595 | 105.069 | 50.678 | 55.980 | 260.217 | 1127.093 | 771.092 | 1340.786 | 590.278 | 136.211 | 91.823 | 35.234 | - | 4651.055 |

Figure 4. Singkoyo Station rain erosivity graph
Table 5. Rain erosivity at Waru station

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Yearly |
|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|--------|
| 1997 | 3.624 | 3.675 | 27.61 | 12.743 | 64.655 | 33.587 | 158.710 | 3.251 | 0.513 | 10.453 | 25.577 | 344.403 |
| 1998 | 6.152 | 5.490 | 22.725 | 65.219 | 34.632 | 67.219 | 29.729 | 124.084 | 88.550 | 34.150 | 35.187 | 10.761 | 532.697 |
| 1999 | 21.938 | 14.176 | 47.520 | 29.016 | 236.881 | 187.814 | 64.307 | 35.865 | 32.646 | 30.388 | 74.063 | 3.169 | 767.762 |
| 2000 | 20.990 | 24.958 | 7.552 | 20.152 | 29.476 | 98.256 | 147.299 | 94.945 | 29.308 | 28.365 | 17.701 | 3.425 | 522.323 |
| 2001 | 46.702 | 4.548 | 21.167 | 68.386 | 95.169 | 127.969 | 86.866 | 14.834 | 50.280 | 6.522 | 4.678 | 7.030 | 534.151 |
| 2002 | 15.933 | 12.636 | 59.818 | 68.581 | 84.188 | 130.129 | 19.422 | 5.135 | 10.915 | 64.299 | 162.024 | 633.077 |
| 2003 | 46.435 | 24.322 | 84.304 | 215.530 | 346.263 | 256.288 | 676.699 | 793.699 | 39.758 | 35.036 | 11.430 | 77.146 | 2606.321 |
| 2004 | 57.617 | 59.637 | 73.323 | 7.680 | 47.120 | 379.030 | 415.942 | 9.854 | 78.644 | 6.660 | 52.806 | 8.000 | 1183.933 |
| 2005 | 8.946 | 88.751 | 159.630 | 68.587 | 448.932 | 163.651 | 783.896 | 366.549 | 73.204 | 21.817 | 136.149 | 245.100 | 2665.207 |
| 2006 | 38.128 | 38.267 | 78.264 | 92.285 | 324.544 | 119.383 | 171.910 | 94.764 | 67.487 | 64.725 | 85.431 | 43.816 | 2297.004 |
| 2007 | 58.314 | 165.252 | 263.832 | 155.183 | 124.019 | 309.778 | 440.954 | 441.782 | 170.180 | 250.725 | 15.370 | 51.769 | 2445.148 |
| 2008 | 300.648 | 21.866 | 241.049 | 285.300 | 360.598 | 332.627 | 1314.984 | 783.726 | 241.530 | 67.654 | 69.198 | 53.247 | 4112.248 |
| 2009 | 99.012 | 27.787 | 113.064 | 56.920 | 697.983 | 190.078 | 218.568 | 59.204 | 104.982 | 88.505 | 80.257 | 13.969 | 1726.727 |
| 2010 | 77.577 | 23.585 | 108.375 | 88.503 | 73.313 | 451.924 | 154.199 | 181.607 | 533.742 | 234.668 | 151.621 | 171.764 | 3600.878 |
| 2011 | 177.541 | 400.482 | 92.641 | 251.672 | 305.337 | 160.669 | 655.813 | 342.386 | 832.371 | 56.791 | 361.705 | 72.254 | 3699.571 |
| 2012 | 68.430 | 67.844 | 79.011 | 249.876 | 181.572 | 472.241 | 976.669 | 379.587 | 259.506 | 51.862 | 88.303 | 50.056 | 2924.957 |
| 2013 | 14.221 | 34.952 | 19.039 | 462.411 | 451.725 | 347.227 | 356.381 | 384.903 | 308.165 | 101.120 | 46.658 | 55.147 | 2582.244 |
| 2014 | 74.189 | 76.180 | 97.465 | 217.356 | 614.613 | 567.401 | 257.320 | 114.055 | 58.136 | 35.222 | 60.120 | 23.484 | 3232.904 |
| 2015 | 42.223 | 28.756 | 216.779 | 234.742 | 860.857 | 589.136 | 502.761 | 10.099 | 5.970 | 2.362 | 121.140 | 9.365 | 2623.269 |
| 2016 | 275.207 | 48.837 | 167.233 | 105.855 | 167.729 | 537.852 | 211.550 | 149.495 | 38.696 | 218.500 | 82.863 | 132.269 | 2156.269 |
| 2017 | 62.286 | 194.503 | 130.477 | 189.623 | 767.929 | 604.615 | 1421.490 | 414.388 | 755.351 | 100.143 | 71.163 | 14.212 | 4830.579 |

Figure 5. Waru station rain erosivity graph

From table 5 and figure 5, the erosivity calculation results can be explained that the erosivity value of rainfall from 1997-2017 varies from year to year. For the year 1997-2002, the value of erosivity is relatively small compared to other years. This happens because the value of the rain is relatively very small and the number of rainy days is quite large. The greatest rainfall erosion occurred in 2017 and the smallest erosion value in 1997. However, there is a very significant difference,
namely the erosivity value the rain at Singkoyo Station is far greater than in Waru Station. This indicates that the amount of rain at Singkoyo Station is far greater than the Waru Station.

3.1. Relationship between rain characteristics and rain erosivity

![Figure 6](image1.png)

**Figure 6.** Graph relationship between rain erosivity and rain characteristics (Singkoyo station)

![Figure 7](image2.png)

**Figure 7.** Graph relationship between rain erosivity and rain characteristics (Waru station)

From figure 6 and figure 7 it can be explained that the characteristics of rain greatly affect the erosivity value of rain. For the characteristics of rain far below normal (JBN) and below normal (BN) produce the smallest erosivity, the characteristics of normal rain (N) produce erosivity in the middle and the characteristics of rain far above normal (JAN) and above normal (AN) produce greatest erosivity value. It is also important to note that the effect of rain characteristics on the erosivity value of rain is that BN, N and AN values are not the same for the two rain stations. This is strongly influenced by the statistical parameters of the rain.

3.3 Multiple linear regression

Multiple regression equation for Singkoyo Station, \( ET_0 = 8.890 + 18.681 R_{\text{month}} - 21.594 N + 5.574 R_{\text{max}} \). For Waru Station, \( ET_0 = -29.163 + 10.581 R_{\text{month}} - 6.150 N + 13.156 R_{\text{max}} \). Based on the regression equation it can be said that the erosivity value (ET0) is influenced by monthly rainfall (\( R_{\text{month}} \), rainy
day (N) and maximum monthly daily rainfall (R$_{\text{max}}$). This means that if the monthly rainfall is high, the rainy day is small and the maximum daily rainfall is large, the erosivity value will be large, and vice versa.

4. Conclusions
The conclusions that can be obtained from this study was the rain characteristic is patterned C or opposite of A pattern; rain characteristics greatly affect the size of the rain erosivity; BN, N and AN values are not the same for the two rain stations because they are strongly influenced by the statistical parameters of the rain; multiple regression equations for Singkoyo Station, $\text{ET}_0 = 8,890 + 18,681 R_{\text{month}} - 21,594 N + 5,574 R_{\text{max}}$ and for Waru Station, $\text{ET}_0 = -29,163 + 10,581 R_{\text{month}} - 6,150 N + 13,156 R_{\text{max}}$.

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