# ANALYSIS OF INTENSITY, DURATION, AND FREQUENCY RAIN DAILY OF JAVA ISLAND USING MONONOBE METHOD

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# ANALYSIS OF INTENSITY, DURATION, AND FREQUENCY RAIN DAILY OF JAVA ISLAND USING MONONOBE METHOD

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**Abstract**

The importance of analyzing rainfall is expected to help in handling disaster-prone areas, so that the consequences can be minimized. This study aims to determine the intensity of rain in the short term. The data used in this study is the annual rainfall data in Java for 2005 - 2019 for each province. The method used in this study is the Mononobe Method to see the intensity of daily rain and its daily return period. The results of this study indicate that the intensity of rain during the duration of one hour to three hours decreases quite significantly, but at the duration of four to eight hours the decrease in rain intensity is not as big as the decrease in the duration of one hour to three hours. The highest rainfall intensity is in the one hour duration in West Java Province. However, the intensity for the five to eight hour duration tends to be the same for 6 provinces in Java. The rainfall threshold in Java is included in the category of heavy rain. High rainfall intensity lasts for a short duration, on the other hand, rainfall with low intensity tends to occur over a relatively long duration.

**Key words: Daily rain intensity, Rainfall, Java Island, Mononobe Method**

## 1. INTRODUCTION

The climate that has occurred in Indonesia in recent years has experienced a shift, both for the rainy season and the dry season. Changes in the rainy season which are quite extreme can result in drought or floods (Aryastana et al., 2012; Lisboa et al., 2020). The climate phenomenon that occurs is quite difficult to predict precisely, so it can have a negative impact on various sectors, particularly the agricultural sector. The worst impact that appears in the agricultural sector is crop failure (Faradiba, 2018; Hertel & de Lima, 2020).

Indonesia has about 270 million inhabitants and has been named an agricultural country. This condition is reflected in the livelihoods of most of the population, who mostly work as farmers. Agricultural production in Indonesia is dominated by Java Island, so that Java Island has an important role in meeting national food needs. Geographically, Java Island is bordered by the Java Sea on the northern side. The south is bordered by the Indian Ocean. To the east by the Bali Strait, and to the west by the Sunda Strait (Setyawan & Pamungkas,

2017). Based on information submitted by the Meteorology, Climatology and Geophysics Agency (BMKG), regarding early warning of extreme weather, where heavy rain and strong winds will occur on April 15-16, 2020. This is due to low pressure in the Indian Ocean (southwest Sumatra) , which gives the effect of increasing wind speed in low layers, up to more than 25 knots (BMKG, 2018). Meanwhile, Java Island, which is located in the south, will feel relatively hot temperatures, this is due to the position of the sun in the southern hemisphere of Indonesia.

lmost all parts of Indonesia have a tropical climate, as does Java Island. The annual average temperature in Java can reach 22-29 degrees Celsius, while the average humidity is around 75 percent (Gernowo & Sugianto, 2012). The temperature in Java varies widely, where during the day and during the dry season the temperature around the coast is higher, reaching 34 degrees Celsius.

The position of the coastal plains also greatly affects temperature variations (Hernando et al., 2020; Li et al., 2020), where areas on the north coast have temperatures that tend to be higher (hotter) than areas on the south coast (Munandar et al., 2016; Soon & Legates, 2013). Meanwhile, in mountainous areas, the temperature is lower or cooler than lowland areas or coastal areas (Konishi et al., 2020; Reddy et al., 2020).

Java Island is located in the equatorial rain belt. This results in a typical tropical climate characterized by high levels of rainfall, temperature and humidity (Susanto et al., 2020). Java Island experiences 2 types of seasons, namely the rainy season which normally occurs from December to March (the following year), and the dry season from May to October.

The temperature in the rainy season ranges from 21 °C (70 °F) to 33 °C (90 °F), except in high elevation areas (mountains), where the temperature is much cooler. The lowest temperature ever recorded on the island is 18 °C (65 °F). Frequent seasonal changes in wind direction (monsoons) from the Indian Ocean and Pacific Ocean, resulting in more varied climatic conditions on the island (Jung & Schindler, 2019; Roshan et al., 2020).

Temperature in an area tends to correlate with rainfall intensity (Iwata et al., 2011). In the dry season with temperatures higher than average, tend to have relatively low rainfall intensity, and vice versa. So that through the measurement of rainfall intensity, it can be seen that the start of the dry or rainy season (Schollaen et al., 2013; Wu et al., 2020).

Rain intensity is the amount of rain expressed in the height of rain or the volume of rain per unit time. The amount of intensity varies, depending on the length of rainfall and the

frequency of its occurrence (Roy et al., 2020). Rain intensity is obtained by analyzing rainfall data, both statistically and empirically.

Rain intensity is associated with short-term rain duration, for example 5 minutes, 30 minutes, 60 minutes and hours. This short-term rainfall data can only be obtained by using an automatic rain recorder. In Indonesia, there are not many of these tools, so in their measurements more common rain recording devices are used, which measure 24-hour rain or called daily rain (Sofia & Nursila, 2019).

In diversifying rain into streams, there are several characteristics of rain that are important to note, including rain intensity (I), length of time of rain (t), rain depth (d), frequency (f), and area of influence of rain (A). Analysis of the relationship between two important rain parameters in the form of intensity and duration can be statistically related to a frequency of occurrence. The graphical presentation of this relationship is in the form of an Intesity-Duration-Frequency (IDF) curve. (Yulius, 2014). This curve can be used for the calculation of runoff and peak discharge at concentration time. Through this curve, it will also be known the probability of rainfall intensity occurring for the duration of indiscriminate rainfall.

Several studies on rainfall intensity analysis and IDF Curve have been done before (Agilan & Umamahesh, 2016; Lima et al., 2018). IDF curve depiction based on the results of rain intensity analysis using the Van Breen and Hasper der Weduwen method with the Talbot, Sherman and Ishiguro equation approach has been carried out. The IDF curve of daily rainfall is depicted based on rainfall intensity using the Mononobe formula. IDF curves were also created for the Mount Merapi slopes using several intensity formulas, such as the Sherman, Kimijima, Haspers and Mononobe formulas. (Laksana, 2015). Apart from that, another study also analyzed the IDF curve for the Surakarta City (Fauziyah et al., 2013). IDF curves are created using several approach formulas, such as Talbot, Sherman, Ishiguro and SDR-IDF.

The question is, what if we only have the accumulated daily (monthly) rain data? Of course this is not an obstacle for us to calculate the intensity of rain for a short time duration (minutes or hours), because the rain intensity for a short duration can be estimated using the Mononobe formula. The choice of this formula is due to the available daily rainfall data. Generally the IDF curve is formed using short duration rain data. However, if short period rainfall data is not available, then the IDF curve can still be created using daily rainfall data using the approach formula, namely the Mononobe and Haspers Formulas. So that the

purpose of this study is to determine and analyze the intensity of rainfall for various periods in Java.

## 2. DATA AND METHODOLOGY

In this study, the object of research was the island of Java, which consists of six provinces: DKI Jakarta, West Java, Central Java, DI Yogyakarta, East Java, and Banten. The variables used in this study are rainfall data from 2005 - 2019 which were taken from the Indonesian Statistical Publication published by the Central Statistics Agency.

The data collection and processing stages include (i) data collection by year for each province; (ii) Data entry and tabulation; (iii) Calculating the required statistical parameters. The required statistical parameters include: average, standard deviation, coefficient of variation, inclination coefficient, kurtosis coefficient and type of data distribution; (iv) Determination of the coefficient of Reduce Mean (Yn), Reduce variation (Yt) and Reduce standard deviation (Sn); (v) Calculation of daily rainfall (24 hours) for each province (Wesli, 2008).

The calculation of rainfall for a 24 hour period uses the Gumbel formula (Harris, 1996).

$$R_{24} = \bar{X} + \frac{S_X}{S_n}(Y_t - Y_n) \quad \text{..... [1]}$$

where:

$R_{24}$ = The amount of daily rainfall maximum 24 hours (mm / 24 hours)

$X$ = Average rainfall (mm)

$S_x$ = Standard deviation

$Y_n$ = Reduced mean

$S_n$ = Reduced standard deviation

$Y_t$ = Reduced variation as the return period

Data analysis using the Mononobe method (Fang & Chen, 1995).

$$I = \frac{R_{24}}{24}\left(\frac{24}{t}\right)^{\frac{2}{3}} \quad \text{..... [2]}$$

where:

I = Rainfall intensity in mm / hour.

$R_{24}$ = Maximum rainfall in 24 hours in mm

T = The amount of rain is in hours

## 3. RESULTS AND DISCUSSION

Rainfall data from 2005 - 2019 were obtained from certain measurement stations, where each province was selected so that it could represent the condition of the province as a whole. On average, West Java Province has high rainfall compared to other provinces in Java Island. This is supported by land elevation conditions. Meanwhile, Banten Province is the province with the lowest rainfall, this is because many of these provinces are located in coastal areas.

**Table 1.** Java Island Annual Rainfall, 2005 - 2019

| Year | Jakarta | West Java | Central Java | SR Yogyakarta | East Java | Banten |
|---|---|---|---|---|---|---|
| Station | Kemayoran | Bandung | Semarang | Yogyakarta | Juanda | Serang |
| **2005** | 1,433.50 | 1,796.30 | 1,132.10 | 1,886.00 | 2,260.80 | 1,192.00 |
| **2006** | 1,527.10 | 1,368.00 | 1,142.00 | 1,824.50 | 1,446.20 | 1,563.00 |
| **2007** | 2,353.90 | 2,219.00 | 1,868.00 | 1,919.00 | 1,515.20 | 1,735.00 |
| **2008** | 1,779.10 | 2,001.00 | 2,690.30 | 1,870.80 | 1,502.90 | 1,476.00 |
| **2009** | 1,973.00 | 2,098.00 | 2,807.00 | 1,584.00 | 1,987.00 | 1,414.00 |
| **2010** | 2,405.00 | 3,868.40 | 3,228.00 | 1,390.00 | 2,895.00 | 2,136.00 |
| **2011** | 1,274.00 | 1,789.00 | 1,879.00 | 2,285.00 | 1,790.00 | 1,141.00 |
| **2012** | 1,570.00 | 2,510.00 | 2,248.00 | 2,014.00 | 1,389.00 | 1,197.00 |
| **2013** | 2,524.60 | 2,682.00 | 2,628.00 | 2,309.00 | 2,270.00 | 3,573.00 |
| **2014** | 2,908.00 | 2,388.00 | 2,628.00 | 2,025.90 | 1,980.20 | 1,521.00 |
| **2015** | 2,169.50 | 2,199.30 | 1,620.70 | 2,045.50 | 2,024.70 | 1,310.10 |
| **2016** | 2,711.50 | 3,549.10 | 2,590.00 | 3,030.10 | 2,976.80 | 1,807.70 |
| **2017** | 2,152.10 | 2,297.30 | 2,657.00 | 2,596.00 | 2,123.80 | 1,762.30 |
| **2018** | 1,501.60 | 2,982.80 | 1,995.60 | 2,488.30 | 1,772.50 | 1,634.70 |
| **2019** | 1,560.00 | 3,555.90 | 1,249.40 | 2,121.40 | 1,884.80 | 1,606.90 |

The results of calculating the rainfall for a 24 hour period using the Gumbel Distribution formula, obtained a coefficient $Y_n$, $S_n$, and $Y_t$. From Table 2, information is obtained that the average for a longer period will produce a greater value, using data from 6 provinces over a 15 years period.

**Table 2.** 24 hour Rainfall Calculation

| | $Y_n$ | $S_n$ | $Y_t$ | | | |
|---|---|---|---|---|---|---|
| | | | 5 Years | 10 Years | 25 Years | 50 Years |
| N = 15 | 0.5128 | 1.0206 | 1.4999 | 2.2562 | 3.1985 | 3.9019 |

Table 3 is the result of the analysis of the frequency of daily rain which is processed through Table 2. The calculation results show that the largest increase occurred in the period 10 to 25 years.

**Table 3.** Results of Daily Rain Frequency Analysis

| Province | Daily Rainfall Return Period (mm) | | | |
|---|---|---|---|---|
| | 5 Years | 10 Years | 25 Years | 50 Years |
| Jakarta | 2,562.38 | 3,103.45 | 3,777.58 | 4,280.80 |
| West Java | 3,183.79 | 3,717.70 | 4,382.91 | 4,879.48 |
| Central Java | 2,797.12 | 3,287.16 | 3,897.72 | 4,353.48 |
| SR Yogyakarta | 2,517.31 | 2,893.78 | 3,362.83 | 3,712.96 |
| East Java | 2,510.62 | 2,962.17 | 3,524.78 | 3,944.76 |
| Banten | 2,216.99 | 2,788.31 | 3,500.14 | 4,031.50 |

Then, the rain intensity obtained from the results of the approach with the Mononobe formula is shown in Table 4 and in Table Appendix 1 to Table Appendix 6. Furthermore, analysis of rain intensity is carried out in different time durations or less than 24 hours (daily).

**Table 4.** Daily Rain Intensity For Several Return Rain Periods

| Rainy Return Period | Rain Intensity (mm / 24 hours) | | | | | |
|---|---|---|---|---|---|---|
| | Jakarta | West Java | Central Java | SR Yogyakarta | East Java | Banten |
| 5 Years | 106.77 | 132.66 | 116.55 | 104.89 | 104.61 | 92.37 |
| 10 Years | 129.31 | 154.90 | 136.97 | 120.57 | 123.42 | 116.18 |
| 25 Years | 157.40 | 182.62 | 162.40 | 140.12 | 146.87 | 145.84 |
| 50 Years | 178.37 | 203.31 | 181.39 | 154.71 | 164.36 | 167.98 |

The daily rainfall threshold (24 hours) based on the Meteorology, Climatology and Geophysics Agency (BMKG) is divided into several categories, namely:

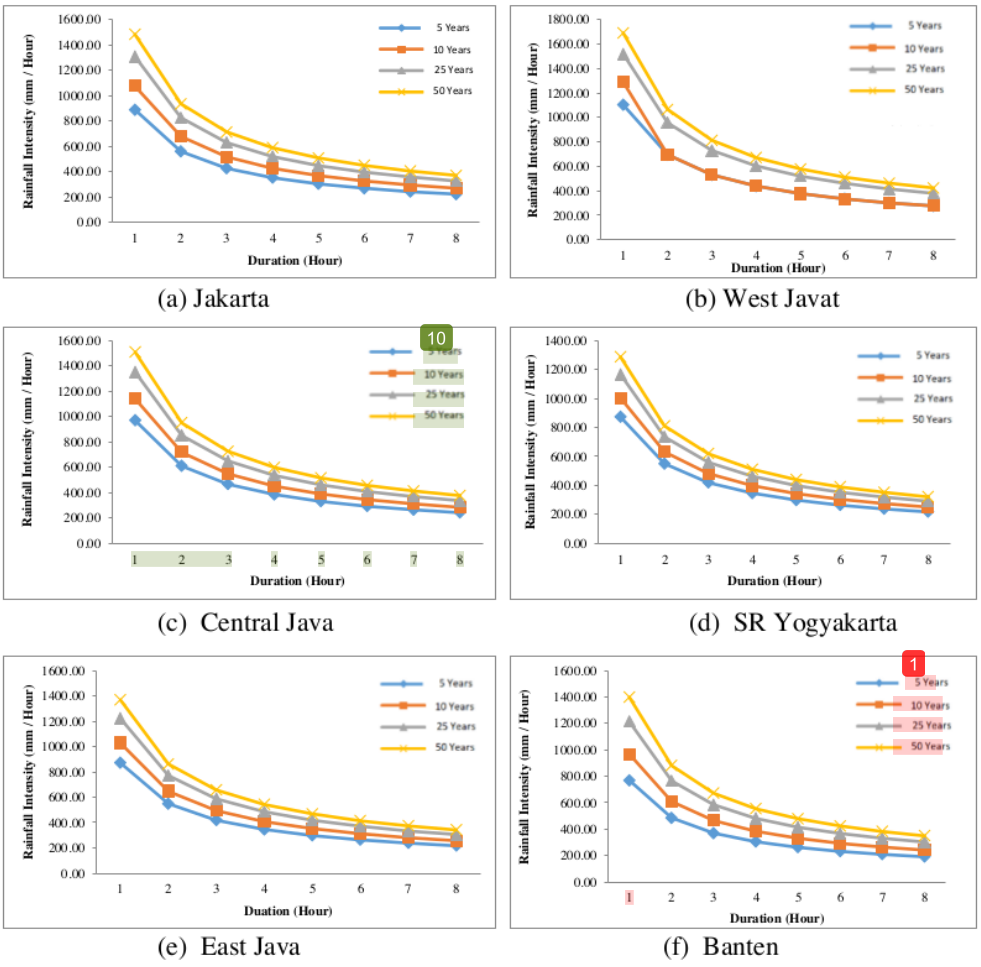
**Table 5.** Category of Daily Rainfall Intensity

| **Rainfall Range** | **Category** |
|---|---|
| 0 mm/day | Cloudy |
| 0,5 – 20 mm/day | Light rain |
| 20 – 50 mm/day | Moderate rain |
| 50 – 100 mm/day | Heavy rain |
| 100 – 150 mm/day | Very Heavy Rain |
| >150 mm/day | Extreme Rain |

The daily rainfall intensity for six provinces is in the range of around 100-200 mm / day. Based on the daily rainfall threshold according to the Meteorology, Climatology and Geophysics Agency (BMKG), the intensity of rain in Java is in the category of very heavy rain and extreme rain. The return period of rain in Java for 5 years and 10 years is included in the very heavy rain category, and for the return period of rain in Java for 25 years and 50 years, it is included in the extreme rain category.

The decrease in rain intensity can be seen using the IDF curve analysis. The IDF curve is a curve that presents the relationship between the frequency, intensity and duration of rain which is expressed in terms of curved rain intensity with a certain return period. IDF curve creation can be done from the results of the automatic rain data frequency analysis (duration minutes and hours). If automatic data is not available, IDF can be derived based on daily data analysis using an approximate formula.

The duration and results of rainfall intensity analysis for each return period use the Mononobe formula approach, which is then depicted in Cartesian coordinates. The abscissa axis (X) represents duration, while the ordinate axis (Y) represents intensity. The results of the depiction of the data, hereinafter referred to as the IDF Curve.




(a) Jakarta (b) West Javat

(c) Central Java (d) SR Yogyakarta

(e) East Java (f) Banten

**Figure 1**. Intensity-Duration-Frequency (IDF) Curve

Rain and high rain intensity generally lasts for a short duration and covers a small area. Rain covering a large area, rarely with high intensity, but can last quite a long duration. The combination of high rainfall intensity with long duration is rare. The amount of rainfall intensity is not the same for each province. It can be seen from the IDF curve that West Java Province has a fairly high rain intensity for one hour duration compared to the other 5 provinces. Rain intensity with a duration of five to eight hours from six provinces in Java Island tends to have almost the same rain intensity. The difference in rainfall intensity in the six provinces is influenced by the topography, duration and frequency of the place or location concerned.

In this study, the formula for the best empirical approach has not been determined to calculate the intensity of rainfall in each province in Java. This is due to the unavailability of hourly rain data to validate the calculated rainfall intensity.

## 4. CONCLUSION

Rain intensity and IDF curve depiction in Java with the Mononobe method have been successfully analyzed in this study. Analysis was carried out on the intensity, duration and frequency of rain events from 2005-2019. The results of this study indicate that high intensity rain occurs in a short duration. There are differences in the value of rain intensity between provinces in Java Island. However, this study has not been able to decide whether this method is suitable for use in Java. This is due to the limited available rain data. Further research can validate the results of rainfall intensity calculations with other approaches, through hourly rainfall record data, so that we can determine whether the rainfall intensity approach formula used for an area is appropriate.

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## APPENDIX

**Table A1.** Results of Rainfall Intensity Analysis in Jakarta

| Duration (Hour) | Rain Intensity with Repeat Period (mm / Hour) | | | |
|---|---|---|---|---|
| | 5 Years | 10 Years | 25 Years | 50 Years |
| 1 | 888.33 | 1,75.90 | 1,309.61 | 1,484.07 |
| 2 | 559.61 | 677.78 | 825.01 | 934.91 |
| 3 | 427.06 | 517.24 | 629.60 | 713.47 |
| 4 | 352.53 | 426.97 | 519.72 | 588.95 |
| 5 | 303.80 | 367.95 | 447.88 | 507.55 |
| 6 | 269.03 | 325.84 | 396.62 | 449.46 |
| 7 | 242.76 | 294.02 | 357.89 | 405.56 |
| 8 | 222.08 | 268.98 | 327.40 | 371.02 |

**Table A2.** Results of Rainfall Intensity Analysis in West Java

| Duration (Hour) | Rain Intensity with Repeat Period (mm / Hour) | | | |
|---|---|---|---|---|
| | 5 Years | 10 Years | 25 Years | 50 Years |
| 1 | 1,103.76 | 1,288.85 | 1,519.47 | 1,691.62 |
| 2 | 695.32 | 695.32 | 957.21 | 1,065.65 |
| 3 | 530.63 | 530.63 | 730.49 | 813.25 |
| 4 | 438.03 | 438.03 | 603.00 | 671.32 |
| 5 | 377.48 | 377.48 | 519.65 | 578.53 |
| 6 | 334.28 | 334.28 | 460.18 | 512.31 |
| 7 | 301.63 | 301.63 | 415.23 | 462.28 |
| 8 | 275.94 | 275.94 | 379.87 | 422.91 |

**Table A3.** Results of Rainfall Intensity Analysis in Central Java

| Duration (Hour) | Rain Intensity with Repeat Period (mm / Hour) | | | |
|---|---|---|---|---|
| | 5 Years | 10 Years | 25 Years | 50 Years |
| 1 | 969.70 | 1,139.59 | 1,351.26 | 1,509.26 |
| 2 | 610.87 | 717.90 | 851.24 | 950.77 |
| 3 | 466.18 | 547.86 | 649.62 | 725.58 |
| 4 | 384.82 | 452.24 | 536.24 | 598.95 |
| 5 | 331.63 | 389.73 | 462.12 | 516.16 |
| 6 | 293.68 | 345.13 | 409.23 | 457.08 |
| 7 | 264.99 | 311.42 | 369.26 | 412.44 |
| 8 | 242.427 | 284.899 | 337.816 | 377.317 |

**Table A4.** Results of Rainfall Intensity Analysis in SR Yogyakarta

| Duration (Hour) | Rain Intensity with Repeat Period (mm / Hour) | | | |
|---|---|---|---|---|
| | 5 Years | 10 Years | 25 Years | 50 Years |
| 1 | 872.70 | 1,003.21 | 1,165.82 | 1,287.21 |
| 2 | 549.76 | 631.98 | 734.42 | 810.89 |
| 3 | 419.55 | 482.29 | 560.47 | 618.82 |
| 4 | 346.33 | 398.12 | 462.65 | 510.83 |
| 5 | 298.46 | 343.09 | 398.70 | 440.22 |
| 6 | 264.30 | 303.82 | 353.07 | 389.83 |
| 7 | 238.48 | 274.15 | 318.59 | 351.76 |
| 8 | 218.17 | 250.80 | 291.45 | 321.80 |

**Table A5.** Results of Rainfall Intensity Analysis in East Java

| Duration (Hour) | Rain Intensity with Repeat Period (mm / Hour) | | | |
|---|---|---|---|---|
| | 5 Years | 10 Years | 25 Years | 50 Years |
| 1 | 870.38 | 1,026.93 | 1,221.97 | 1,367.57 |
| 2 | 548.31 | 646.92 | 769.80 | 861.52 |
| 3 | 418.44 | 493.70 | 587.46 | 657.46 |
| 4 | 345.41 | 407.54 | 484.94 | 542.72 |
| 5 | 297.67 | 351.20 | 417.91 | 467.70 |
| 6 | 263.60 | 311.01 | 370.08 | 414.17 |
| 7 | 237.85 | 280.63 | 333.94 | 373.72 |
| 8 | 217.60 | 256.73 | 305.49 | 341.89 |

**Table A6.** Results of Rainfall Intensity Analysis in Banten

| Duration (Hour) | Rain Intensity with Repeat Period (mm / Hour) | | | |
|---|---|---|---|---|
| | 5 Years | 10 Years | 25 Years | 50 Years |
| 1 | 768.58 | 966.65 | 1,213.43 | 1,397.64 |
| 2 | 484.17 | 608.95 | 764.41 | 880.46 |
| 3 | 369.49 | 464.71 | 583.35 | 671.91 |
| 4 | 305.01 | 383.61 | 481.55 | 554.65 |
| 5 | 262.85 | 330.59 | 414.98 | 477.98 |
| 6 | 232.76 | 292.75 | 367.49 | 423.28 |
| 7 | 210.03 | 264.16 | 331.60 | 381.94 |
| 8 | 192.14 | 241.66 | 303.35 | 349.41 |

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