Rainfall pattern variability as climate change impact in The Wallacea Region

I Pujiastuti\(^1\) and E Nurjani\(^1\)

\(^1\)Departement of Environmental Geography, Faculty of Geography, Universitas Gadjah Mada

isnapujiastuti@gmail.com

Abstract. The objective of the study is to observe the characteristic variability of rainfall pattern in the city located in every rainfall type, local (Kendari), monsoon (Manado), and equatorial (Palu). The result will be compared to determine which has the most significantly precipitation changing due to climate change impact. Rainfall variability in Indonesia illustrates precipitation variation thus the important variability is the variability of monthly rainfall. Monthly precipitation data for the period of 1961-2010 are collected from Indonesian Agency for Meteorological, Climatological, and Geophysical Agency. This data is calculated with the normal test statistical method to analyze rainfall variability. The result showed the pattern of trend and variability of rainfall in every city with the own characteristic which determines the rainfall type. Moreover, there is comparison of rainfall pattern changing between every rainfall type. This information is useful for climate change mitigation and adaptation strategies especially in water resource management form precipitation as well as the occurrence of meteorological disasters.

1. Introduction
Climate change is one of the important issues nowadays. Climate change resulted in various impact on human life. The most often studied impact regarding the climate change is increasing in global temperature. The temperature is studied very detailed in the term of climate change. In a tropical area like Indonesia, precipitation had a more significant impact on climate change rather than the changing temperature. Rainfall can indicate climate change [6] because precipitation has a direct impact on nature environment that implicate economical sector. The most common precipitation in Indonesia is rainfall. Rainfall plays a core role in every agricultural activity in Indonesia. Moreover, as the basics need for the human with such huge number of population in Indonesia made the detailed rainfall variability and trend study important.

Rainfall variability may cause some problems such as the flood and drought. Wallace city, the cities in Indonesia between Wallace Line and Weber Line, was one of the vulnerable areas with this problem. Manado suffered in may severe flood with periodically in 2000, 2006, 2012, 2013, and 2014, while the biggest at 15 November 2014, 58 households affected their houses were flooded as high as 50-100 cm. Flood often occurred in Kendari, there are 19 floods recorded from 1999 until 2016. The recent flood in Kendari in 2017 caused 25 people evacuated. Hydro-meteorological hazard’s priorities in Kendari are a flood and extreme weather. Palu is often flooded, one of them on 25 August 2012 affected two people died, four people washed away, and 32 household or 101 people evacuated. Another loss 9 house washed away, 3 houses heavily damaged, 200 houses lightly damaged, and 25 meters river embankment perforated [4].

The Wallace Region, region between Wallace line and Weber line is chosen because there we can found the complete rainfall type in Indonesia. Rainfall type in Indonesia is: equatorial type with two peaks of rainfall, the monsoonal type that influenced by the Southeast Hindia Monsoon, and local type.
with very high local influence. Palu station was chosen as the representative of equatorial rainfall type, whereas Manado was chosen as the representative of monsoonal rainfall type, and Kendari was chosen as the representative of local rainfall type. The reason for choosing these station was the station is located in same island, Sulawesi or Celebes Island. The detailed knowledge of rainfall regimes on time series data are important prerequisites for enhancing the water management, planning, and design the buildings and facilities also mitigate the negative impact of drought and floods [1].

Average change of annual and seasonal rainfall data represented the modification of climatic variability in future climate change. Annual rainfall data depicted each year data of rainfall in accumulative. The annual rainfall data were chosen as the fundamental of scientific thought that annual variability is better (than mean value) and one of the most important indicators of reliability of rainfall [5] Monthly rainfall data depicted the availability water in a month that is very important to determine the season and agricultural commodities.

This study aims to analyze the variability of monthly and annual rainfall in 40 years from each rainfall type in Indonesia. The data used as a tool to characterize which rainfall type have most variability due to climate change issue. This study expected as the reference of detailed rainfall study and basic study of climate change impact on the specific rainfall type for further research in rainfall and climate change.

2. The Method

2.1. Study Area
Wallace line is imaginary the faunal boundary in Indonesia separates the Indo-Malaya or Asian-Like ecology and Australian ecology. This line lied in between the Sulawesi Island (figure 1). This island is special because we can find the all the rainfall type in one island. The other reason is that the three selected area had suffered from hydro-meteorological disaster, drought, and flood.

![Wallacea Region and Study Area](image)

**Figure 1. Wallacea Region and Study Area.**
Manado is the capital city of North Sulawesi Province which has the monsoonal rainfall type. Manado city is located in 10°30'-10°40' north and 1240°40'-1260°50' west. Palu is the capital city of Central Sulawesi. Palu located in 0°36'-0°56' South and 119°45'-121°1' East. This city lies in the equator line; the rainfall type is equatorial rainfall type. Kendari Municipality is the capital city of Southeast Sulawesi. Kendari lied in 3°58'2.96″ north 122°35'40.92″ south. Kendari had the local rainfall type.

2.2. **Material and Method**

Data was collecting from Indonesian Agency for Meteorological, Climatological, and Geophysical Agency [3]. The data used is monthly rainfall data for 41 years (1960-2010) in three cities that have their own type of rainfall. The city was picked up because the Wallace area is the border of the two ecological zone of Indonesia, near the Wallace line. Besides, the city was suffered from hydro-meteorological disaster. Moreover, the area located in common island and the rainfall type is represented all the rainfall type in Indonesia. The rainfall type is equatorial rainfall type, monsoonal rainfall type, and local rainfall type. The island mentioned before is the Sulawesi Island. Manado was chosen as the data representative of monsoonal rainfall. Palu was chosen as the data representative of equatorial rainfall type rather than Gorontalo because the data is more complete. Kendari was chosen as the data representative of local rainfall type.

The data is categorized as the monthly rainfall data and annual data. The annual data was chosen as the variability of annual rainfall while the monthly data depicted how the season and weather changing over the years. The variability for every rainfall type showed which type of rainfall has the most variability during the climate change issue. The data is presented in the monthly rainfall data in a year. The data showed the rainfall pattern in a year.

2.3. **Analysis**

The rainfall variability calculated with statistical method, to analyze rainfall variability. The basic statistical analysis used in this study is measure of central tendencies (mean and mediation), measure the dispersion (standard deviation), and the degree of symmetry in the distribution (Skewness, SK), the degree to peak of data (Kurtosis/KT), and coefficient of variation (CV). The rainfall trend also applied using the moving average 3, 5, and 10 years and used the simple regression equation. The regression using time as independent variable and monthly rainfall as the dependent variable [8]. The result of the calculation showed with graph and table to describe better the founding.

| Nr. | Station | Coordinate | Rainfall Type | Data length |
|-----|---------|------------|---------------|-------------|
| 1   | Palu    | 00°41' S - 119°44' E | Equatorial     | 1960-2010   |
| 2   | Manado  | 01°32’ N - 124°55’ E | Monsoonal     | 1960-2010   |
| 3   | Kendari | 04°06’ S - 122°26’ E | Local         | 1960-2010   |

3. **Result and Discussion**

3.1. **Rainfall Pattern**

The research result showed the pattern of trend and variability of rainfall in every city with the own characteristic which determines the rainfall type. The rainfall type is characterized by the monthly rainfall pattern of peak rainfall. Sun radiation controlled these pattern showed in figure 2.

Palu has the equatorial rainfall type which has two peaks of rainfall that occurred after the equinox. This is manifestation as Palu located close to the equator. The peaks occurred after the sun across the equator line which happened on 21 March and 23 September [2]. However, in this case, Palu has fluctuated pattern. There is only one peak was distinct which form a hill from April until October. The fact that the peak on June-July which the sun in Summer Solstice. The rest monthly rainfall has the fluctuate such as increasing in November, decreasing in December, and the interesting
thing is in January the first two decades was increasing but much decreasing in last three decade. In January in the third decade was the less rainfall in these time series (figure 2a).

The fourth decade (1991-2000) showed that the rainfall much more than the other decade in the peak of the season, May, June, and July, also in the low rainfall still the highest in October and December. Other than that, this decade is the most fluctuating monthly rainfall. The only reason was the occurrence of severe El Nino hit Indonesia around 1997. The maximum monthly rainfall recorded in 51 years was 286 mm/month and the minimum was 0 mm/month. The average range is 32-96 mm/month.

Manado monthly rainfall presented in figure 2b. has the monsoonal rainfall type. The monsoonal rainfall type has the V monthly rainfall pattern [2]. The peaks are in January and the minimum in June, July, and August. This data was shifted a little bit to July, August, and September. The second decade showed less rainfall than another decade. The maximum monthly rainfall recorded in 51 years was

![Monthly Rainfall Data of Palu 1960-2010](image1)

![Monthly Rainfall Data of Manado 1960-2010](image2)

![Monthly Rainfall Data of Kendari 1960-2010](image3)

**Figure 2.** Average Monthly Rainfall in (a) Palu, (b) Manado, (c) Kendari.
1552 mm/month occurred in August 2005 and the minimum was 0. The average range is 123-456 mm/month.

Kendari has local rainfall type which means the local condition control more than other. The pattern is seen as monsoonal rainfall type. But, the difference is the sharp graph resulted in local type. The rainfall drastically decreases in August and increasing in November. The maximum monthly rainfall recorded in 51 years was 755 mm/month and the minimum was 0. The average range is 68-232 mm/month (figure 2c).

The place with highest monthly rainfall is Manado and the lowest is Palu. Monsoon wind gives more influence than the effect of location and condition such as equator and topography (local rainfall type). All of the rainfall types showed that third decade (1991-2000) is the most fluctuating monthly rainfall. Annual rainfall data from 51 years showed the fluctuation data with no certain pattern (figure 3). In general, from the individual year looks like there are increasing and decreasing pattern of annual in one cycle occurred in four years.

The monsoonal and local rainfall type has the likely specific pattern. The significant decreasing for the first time occurred in 1972, then in 1987, 1997 and 2003. The significant increase occurred in 1975, then 1989, 1995, 2000, and 2005. The pattern showed that the occurrence of extreme peak and base annual rainfall repeated in shorter time. The data showed the extreme peak and base graph extreme cycle first in 28 years and then the extreme reoccurred again only in 16 years. The most extreme are from 1996-2010.

![Annual Rainfall Data of Palu, Manado, and Kendari from 1960-2010](image)

**Figure 3.** Annual Rainfall Data 1960-2010.

The monsoonal and local rainfall type has the likely specific pattern. The significant decreasing for the first time occurred in 1972, then in 1987, 1997 and 2003. The significant increase occurred in 1975, then 1989, 1995, 2000, and 2005. The pattern showed that the occurrence of extreme peak and base annual rainfall repeated in shorter time. The data showed the extreme peak and base graph extreme cycle first in 28 years and then the extreme reoccurred again only in 16 years. The most extreme are from 1996-2010.

| No | Location | Min (mm) | Max (mm) | \(\bar{x}\) | \(\sigma\) | CV | Skewness | Kurtosis |
|----|----------|----------|----------|----------|----------|----|-----------|-----------|
| 1  | Palu     | 352      | 1081     | 713,1    | 188,0217 | 0,263683 | -0,1368   | -0,84545  |
| 2  | Manado   | 1920     | 5010     | 3228     | 743,9887 | 0,230472 | 0,374267  | -0,42651  |
| 3  | Kendari  | 709      | 2778     | 1931     | 497,6049 | 0,257753 | -0,36147  | -0,47134  |
3.2. Rainfall Variability
The result of the basic statistical analysis for the parameters annual rainfall presented in table 2. Manado has the highest number of rainfall average and Palu has the lowest number of rainfall average. The standard deviation shows the heterogeneity of data compared to mean. The coefficient of variation showed the similar value from every rainfall type around 0.23-0.26 which small variability. The greater the coefficient value the rainfall variation more fluctuates [7]. Monsoonal rainfall type has the highest variability compared to Palu and Kendari.

The skewness parameter showed the positive and negative value. This means the distribution of the data is positively skewed in Manado means the tendency of rainfall above the average and negatively skewed in Palu and Kendari which mean the tendency of rainfall distribution below the average. The kurtosis showed a negative value for all the rainfall type which means flatter than normal peak distribution. The value ranges between -0.42 to -0.84. Manado and Kendari have the similar value, 0.42; 0.47 and Palu have the -0.84 kurtosis which means the peak flattest than the average.

![Standard of deviation monthly rainfall pattern for 1960-2010](image)

![Coefficient of variation monthly rainfall pattern for 1960-2010](image)

**Figure 4** (a) Standard Deviation and (b) Coefficient of Variation of Monthly Rainfall Data 1960-2010.
The monthly rainfall variability is more complicated than the annual rainfall. Monthly rainfall data is extracted by making average every month in the 51 years of data. The standard of deviation monthly rainfall showed the extreme value in the Manado mean that Manado has the most heterogenic data (figure 4a). The most fluctuating data is September. On September occurred the extreme rainfall event in the fifth decade for the exactly in 2005. The data extreme standard of deviation value recorded because September is the originally dry season but in 2005 the number of rainfall as much as the wet season. January also high number but the original month is the wet season so that no many impacts.

Kendari as the local rainfall type representative showed the standard deviation extreme in June and October, where in June is the peak of value and October is the base value. The highest number of rainfall on June occurred in the fourth decade for exactly in 2000. While in October is the lowest rainfall amount. The monsoonal rainfall type has the most distributed data with the highest standard deviation of 238.1078.

The coefficient of variation showed local monsoonal type has the greatest value means the local rainfall type has the most variability (figure 4b). The fluctuation pattern for every rainfall is similar, except for December in Kendari (local rainfall type). The coefficient variation value is less than one except for July with 1.78, September 4.86, and October 3.28 in Monsoonal rainfall type. In monsoonal rainfall type and Augustus, September, and October with value 1.00-1.27. Palu and Manado have the increasing pattern in December while in Kendari is decreasing and reach the lowest coefficient of variation mean rainfall in Kendari on December is less variation. The most variability is monsoonal rainfall type in September and October. The greatest variability caused by the Sun after across the equator and strive to the south (Kendari latitude 40S). This cause greater Sun radiation makes the rainfall number greater.

The skewness and kurtosis data are presented in the graph below (figure 5). The skewness presented the positive skewed means the tendency of rainfall above the mean. The monthly rainfall pretends to increase since the skewness showed the positive value. The most increasing value is in monsoonal rainfall type in September and local rainfall type in November. Because the relative position of the sun, resulted in more precipitation in September. The anomaly of negative skewness found in Manado on December means the data was below the average. The data found in the last decade of the study period with decreasing number of rainfall in 2002 to 2004 with 110mm/month while the average is 353 mm/month. The greatest number found in Manado in September and in Kendari in October. The highest number of rainfall recorded in Kendari in November 2001 with 668 mm/month while the average is 106.7 mm/month.

The kurtosis value ranged between -0.926 to 21,434 which very extreme (Fig.5). The highest range of kurtosis value is Manado ranged between -0.926 - 21.434. Kurtosis parameter represented the peak distribution. Positive kurtosis value indicates the distribution sharper than normal peak and negative kurtosis value indicates the distribution flatter than normal peak distribution. Palu has the positive value more than negative value. The negative kurtosis value only found three months i.e. February, July, and October. These months indicate the average of data flatter than the average data. The positive kurtosis ranged between 0,150 -7.996. The highest value occurred in December means December has the sharpest peak compared the average peak.

Manado has the extreme sharp distribution in September with the highest kurtosis value 21.434. This extreme value supposes of the Sun radiation which across the equator and Manado is close to equator then the rainfall is more simulated. The negative value is dominated this rainfall type means the peak is flatter than the average. Kendari also has the extreme range from -0.471 to 15,041. The highest value indicates the sharpest peak of data occurred in November. This is because there is extreme rainfall in 2001 on October with the amount rainfall 668 mm/month while the average is 107 mm/month.
3.3. Rainfall Trend

The rainfall variability can be investigated by the trend. The trend analysis for the data is applicable for the annual rainfall data and presented by 9 years of moving average. The moving average presented for each location in graph figure 6, 7 and 8. The moving average of 9 years used because the three and five years showed the similarity for each data while the ten years of moving average showed the inverse of the trend. This is because of the quality of data which cause the longer trend investigation less reliable than the shorter one. The most extreme trend is Manado which means the most variability data.

Figure 5. Skewness and Kurtosis Value of Monthly Rainfall Data 1960-2010.
Figure 6. Annual rainfall pattern in Kendari for 1960-2010 period.

Figure 7. Annual rainfall pattern in Manado for 1960-2010 period.
Kendari showed no significant trend in the first two decades. The decreasing trend showed from 1980 to 1994 and increasing trend from 1995-2005. A full cycle of decreasing and increasing (one wave) is completed from 1975-2005. Manado has the most fluctuating trend. A cycle of increasing and decreasing always completed two decades since 1960. The amplitude of wave around 3000-3500 mm per year except for the lowest trough in 1999 and highest crest more than 3500 mm per year in 2008. These found means that Manado has the most variability. Palu has only one full cycle from 1980-2005 and before these years was no significant fluctuation.

**Table 3.** The standard deviation and coefficient variation (Palu).

| No | Month   | Max (mm) | Median (mm) | CV  | SK  | KT  |
|----|---------|----------|-------------|-----|-----|-----|
| 1  | January | 196      | 52          | 57.55 | 40.56 | 0.70 | 1.28 | 2.42 |
| 2  | February| 110      | 41          | 45.53 | 28.03 | 0.62 | 0.38 | -0.81 |
| 3  | March   | 286      | 53          | 63.24 | 53.06 | 0.84 | 2.07 | 6.09 |
| 4  | April   | 161      | 41          | 49.41 | 38.47 | 0.78 | 1.24 | 1.35 |
| 5  | May     | 224      | 57          | 67.71 | 44.79 | 0.66 | 1.05 | 1.50 |
| 6  | June    | 265      | 63          | 74.24 | 53.48 | 0.72 | 1.21 | 2.10 |
| 7  | July    | 204      | 62          | 77.73 | 53.53 | 0.69 | 0.84 | -0.05 |
| 8  | August  | 233      | 51          | 67.27 | 59.32 | 0.88 | 0.91 | 0.15 |
| 9  | September| 181      | 48          | 52.65 | 40.94 | 0.78 | 0.78 | 0.50 |
| 10 | October | 143      | 45          | 50.33 | 39.90 | 0.79 | 0.74 | -0.23 |
| 11 | November| 153      | 50          | 55.94 | 37.72 | 0.67 | 0.94 | 0.31 |
| 12 | December| 252      | 37          | 51.47 | 46.88 | 0.91 | 2.53 | 8.00 |

**Figure 8.** Annual rainfall pattern in Palu for 1960-2010 period.
Standard deviation as well as the coefficient of variation 0.22
Moreover, the moving average test also showed Manado has the most extreme fluctuation trend. The monthly rainfall data presented that Manado as the representative of monsoonal rainfall type has the highest variability of monthly and annual rainfall is 4.86, the extreme range of skewness -3.95, and kurtosis -0.93 – 21.43 parameter. Moreover, the moving average test also showed Manado has the most extreme fluctuation trend. The summary of this study is described that the highest variability of monthly and annual rainfall is founded in Manado as the monsoonal rainfall type representative.

Table 4. The Deviation Standard and Variation Coefficient (Manado).

| No | Month   | Max (mm) | Median (mm) | \( \bar{x} \) | CV  | SK  | KT  |
|----|---------|----------|-------------|----------------|-----|-----|-----|
| 1  | January | 904      | 469         | 456.49         | 183.51 | 0.22 | 0.41 | 0.16 |
| 2  | February| 915      | 364         | 366.14         | 181.72 | 0.38 | 0.66 | 0.91 |
| 3  | March   | 772      | 339         | 332.49         | 171.67 | 0.40 | 0.33 | -0.08|
| 4  | April   | 533      | 240         | 267.71         | 117.35 | 0.60 | 0.68 | -0.32|
| 5  | May     | 469      | 248         | 252.41         | 100.61 | 0.40 | 0.20 | -0.52|
| 6  | June    | 558      | 243         | 236.92         | 109.00 | 0.98 | 0.36 | 0.37 |
| 7  | July    | 419      | 143         | 153.84         | 105.27 | 1.78 | 0.56 | -0.18|
| 8  | August  | 378      | 105         | 122.69         | 95.66  | 0.55 | 0.72 | -0.17|
| 9  | September| 1552    | 131        | 187.36         | 238.11 | 4.86 | 3.95 | 21.43|
| 10 | October | 614      | 176         | 200.82         | 134.60 | 3.28 | 0.95 | 0.83 |
| 11 | November| 629      | 294         | 298.07         | 141.21 | 0.76 | 0.54 | -0.10|
| 12 | December| 581      | 337         | 353.17         | 132.90 | 0.82 | -0.06| -0.93|

Table 5. The Deviation Standard and Variation Coefficient of Kendari.

| No | Month   | Max (mm) | Median (mm) | \( \bar{x} \) | CV  | SK  | KT  |
|----|---------|----------|-------------|----------------|-----|-----|-----|
| 1  | January | 430      | 183         | 184.24         | 84.10 | 0.46 | 0.61 | 0.33 |
| 2  | February| 447      | 213         | 206.25         | 84.12 | 0.41 | 0.24 | -0.03|
| 3  | March   | 514      | 222         | 231.53         | 108.43 | 0.47 | 0.53 | 0.23 |
| 4  | April   | 461      | 222         | 215.92         | 87.50  | 0.41 | 0.12 | 0.32 |
| 5  | May     | 425      | 203         | 203.94         | 93.07  | 0.46 | 0.02 | -0.07|
| 6  | June    | 755      | 201         | 213.24         | 139.08 | 0.65 | 1.24 | 3.07 |
| 7  | July    | 396      | 138         | 154.00         | 105.03 | 0.68 | 0.70 | -0.32|
| 8  | August  | 416      | 55          | 80.49          | 88.04  | 1.09 | 1.72 | 3.54 |
| 9  | September| 362     | 33          | 75.37          | 96.16  | 1.28 | 1.68 | 2.07 |
| 10 | October | 271      | 48          | 67.82          | 69.13  | 1.02 | 1.04 | 0.45 |
| 11 | November| 668      | 88          | 106.71         | 106.52 | 1.00 | 3.21 | 15.04|
| 12 | December| 434      | 170         | 191.04         | 91.79  | 0.48 | 0.76 | 0.29 |

4. Conclusion
The result showed local rainfall type has the most variability of annual rainfall which the local condition influenced more by the climate change issues. The annual rainfall value showed that Palu as the representative of equatorial rainfall type has the lowest variability rainfall with the highest value of the coefficient of variation and highest (negative) kurtosis values while the skewness is the lowest. While Manado as the representative of monsoonal rainfall type has the increasing trend and highest variability and Kendari as the representative of local rainfall type has the decreasing trend. The monthly rainfall data presented that Manado as the representative of monsoonal rainfall type has the highest variability with the highest extreme trend of standard deviation as well as the coefficient of variation 0.22-4.86, the extreme range of skewness -0.06 – 3.95, and kurtosis -0.93 – 21.43 parameter. Moreover, the moving average test also showed Manado has the most extreme fluctuation trend. The summary of this study is described that the highest variability of monthly and annual rainfall is founded in Manado as the monsoonal rainfall type representative.
References
[1] Al-Houri Z 2014 Detecting Variability and Trends in Daily Rainfall Characteristics in Amman-Zarqa Basin, Jordan. *International Journal of Applied Science and Technology*. Vol. 4, No. 6; November 2014.
[2] Tjasyono B 2004 *Climatology Bandung* ITB Press.
[3] BMKG 2005-2010 *Rainfall Data*. bmkg.go.id.
[4] BNPB (Indonesia National Disaster Management Agency) 2017 *Indonesia Disaster Data and Information* (in Bahasa Indonesia). Accessed from http://dibi.bnpb.go.id/.
[5] Chakraborty S Pandey P Chaube U C and Mishra S K 2013 Trend and variability analysis of rainfall series at Seonath River Basin, Chhattisgarh (India). *Int. Journal of Applied Sciences and Engineering Research*, Vol. 2, Issue 4, 2013.
[6] Hanaki K 2008 Global Climate Change and Cities *Urban Environmental Management and Technology*. London: Springer.
[7] Juaeni I 2006 Analisis Variabilitas Curah Hujan Wilayah Indonesia Berdasarkan Pengamatan Tahun 1975-2004. *Journal of Mathematics UNDIP*, 9, No. 2, 2006.
[8] Setiawan O 2012 Rainfall and Temperature Variability Analysis in Bali. *Jurnal Analisis Kebijakan Kehutanan*. Vol. 9 No. 1, April 2012 : 66 – 79.