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EXTREME RAINFALL PROFILE IN WEST JAVA PROVINCE AS AN INDICATION OF GLOBAL WARMING IMPACT

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ABSTRACT

This study was conducted to determine the profile of extreme rainfall in West Java province as an indication of the impact of global warming. The data used was sourced from Kertajati Meteorological Station from the period 1981 to 2023, which was obtained officially from the BMKG online website. This research was conducted in the Physics Education laboratory of FKIP Sriwijaya University. The research method used is secondary data research with a quantitative approach. Data analysis was used using the RClimDex application with Expert Team on Climate Change Detection and Indices (ETCCDI) rules related to rainfall indicators. Trend analysis was carried out with the Man-Kendall and Sens test non-parametric statistical tests. The results of the analysis show that the extreme rainfall index has experienced significantly varying trends over the past 43 years, indicating the impact of climate change as a result of global warming.

Keywords : Climate change; ETCCDI; West Java; Extreme rainfall.

I. INTRODUCTION

Indonesia has high rainfall and strong solar lighting every year because it is in the tropics. This is combined with a high risk of climate disasters such as floods and droughts [1]Climate change is a term that refers to changes in temperature and weather patterns that occur over a long period of time. While this shift may be natural, human activities since the 1800s have played a major role in climate change, especially with the burning of fossil fuels (gas, oil, coal, and so on) producing heat-trapping gases. Rainfall behavior in the Indonesian region can be accurately analyzed by using climate data from meteorological stations to show the characteristics of climate change. [2]

In recent years, the study of climate change issues has become a major focus of researchers in the field of atmospheric science. The worldwide average air temperature has increased by 0.74°C over the last hundred years (1906-2005), according to the fourth evaluation report of the Intergovernmental Panel on Climate Change. The increase in air temperature will lead to an increased risk of disasters and more frequent events in the future [3]. To observe extreme climate events, it is necessary to define a climate index that can be used in extreme climate analysis. The Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) clearly indicates that climate change affects climate extremes around the world. Several factors contribute to the occurrence of climate extremes, including atmospheric circulation, topography and human activities [4]. Climate change has intensified in recent decades and is projected to further intensify in the future, resulting in the occurrence of more frequent and long-lasting extreme events that in turn lead to extreme ecological responses. For example, the global average surface air temperature was warmer by about 0.85◦C from 1880 to 2012. In addition to increasing temperatures, a significant trend of increasing precipitation has also been observed globally (1-2% per decade) between 1951 and 2010. The Intergovernmental Panel on Climate Change (IPCC) says that within 15 years, namely in 1990-2005, there has been an increase in global temperature on earth around between 0.15℃-0.3℃[5].

A warmer climate will result in increased atmospheric moisture, which will result in more frequent and more intense extreme rainfall events in the future. As a result of climate change, more severe climate-related events, such as floods, droughts, heat waves, and cold waves, are occurring and have received much attention[6]. Climate change brings extreme weather and climate events in a significant way and small changes in climate variables can result in significant changes in extreme weather and climate events [4]

Meteorological disasters are one of the most important types of natural disasters. According to the statistics of the World Meteorological Organization, more than 90% of natural disasters are directly or indirectly caused by meteorological conditions. Because meteorological disasters include various types of events, wide regional occurrence, and obvious seasonal characteristics, they have a serious impact on the ecological environment, economic development, social stability and national security, and higher requirements for rapid and effective prevention and control of the emergency management sector [7]. Disasters are a general term for objects that have a destructive effect on humans and the environment on which humans depend for their [8]. As one type of disaster, meteorological disasters refer to disasters caused by weather changes. Different meteorological disasters are closely related to different weather phenomena, and their impacts and hazards are also different. However, the occurrence of meteorological disasters is not only related to weather phenomena but also closely related to people and the surrounding environment. For example, a rainstorm of the same scale in a densely populated city may result in disasters such as urban inundation; if it occurs in an unpopulated sea, it is only a weather phenomenon. [7]

Climate change has entered a pivotal phase. The target of keeping global temperatures below 1.5°C is unlikely to be achieved. According to an analysis by the United Nations Environment Program (UNEP), the Earth's temperature continues to rise to 2.7°C [9]. Climate change has many negative impacts, so mitigation (in the form of greenhouse gas reduction) and adaptation (in the form of development strategies that can reduce the negative impacts of climate change) are needed. Cities are also facing and will face many problems related to carrying capacity and damage [1]

Alexander, et al. [10] conducted research on climate extremes around the world. The results show that there is a significant correlation between the increase in air temperature from 1951 to 2003. In addition, [11]conducted research in the Southeast Asia, Asia Pacific, South America, and South Pacific regions. The results are comparable to previous studies. Most of the analyses related to extreme climate events are conducted in developing country regions that are vulnerable to disasters caused by extreme climate [12]. Indonesia is among them. Due to its tropical location, Indonesia has high rainfall and strong sunshine every year. This condition is also accompanied by a high risk of disasters due to extreme climate events such as floods and droughts.

Based on previous studies that have been conducted on several islands, namely Sumatra and Kalimantan Java, this study will examine climate change in West Java Province which has never been done before, especially at the Kertajati Meteorological Station so that this research is a new study that aims to determine the dynamics of climate change in West Java Province using the Men-kendall test. The data used are monthly data on rainfall, maximum temperature, minimum temperature and average temperature from the Meteorology, Climatology and Geophysics Agency (BMKG) at Kertajati Meteorological Station in a 43-year period.

II. METHOD

The first step taken is to collect data, namely rainfall data (RR), maximum temperature data (Tx), and minimum temperature (Tn) starting from 1981 to 2022 taken from the BMKG observation station precisely at the Kertajati Meteorological Station on the sites https://dataonline.bmkg.go.id and http://www.meteomanz.com/ . After that, the data that has been downloaded from the official BMKG online data page is compiled by month, then compiled by year and then merged into one as a whole for a period of 43 years. Furthermore, data quality testing (QC) was carried out using the filter component in Microsoft excel and data processing was carried out manually and will be continued with analysis using RClimDex. The last stage is the non-parametric Man Kendall test with the results in the form of trends in changes in extreme temperature rainfall indices from year to year.

1) *Location and Research Subjects*
   Research was conducted in the Province of Bangka Belitung Islands to analyze the dynamics of climate change by utilizing rainfall, minimum temperature, maximum temperature, and average temperature measuring instruments on the BMKG system at Kertajati meteorological station. The tool can record rainfall data, minimum temperature, maximum temperature in the Bangka Belitung Islands with the following map details:

Fig. 2. Kertajati Meteorological Station Observation Location

2) *Data Download and Compilation*
The data used in this study are rainfall data, minimum temperature and maximum temperature recorded from BMKG stations in West Java Province, namely Kertajati Meteorological Station during the period 1981-2023. This research uses descriptive analytical research, which is an activity that describes an activity by referring to sources and data obtained while in the field (Sugiyono, 2009). The data used can be downloaded through the official website https://dataonline.bmkg.go.id/ in the form of daily data. For missing or even empty data, we can complete the data from the http://www.meteomanz.com/ site. The complete data is then compiled from 1981-2023 with the data arrangement in accordance with the data format in RClimDex.
3) *Data Analysis*
Quality Control (QC) and Test of Homogeneity
The quality control (QC) analysis conducted in this study uses a manual method by operating the filter feature in Microsoft Excel one by one to see some data irregularities such as letter-shaped data, extra-normal data, maximum temperature above 36 °C, minimum temperature below 18 °C and relatively the same Tx-Tn data. Data is said to be complete if in one year there is only a maximum of 10% missing daily data (Mulyanti et al., 2020).
4) *RClimDex Calculation Index*
In this study only pay attention to several elements including rainfall and temperature with respect to the ETCCDI climate index because there are several indices that are not relevant for use in the Indonesian region such as growing season length (GSL), frost days (FDO), summer days (SU25), cold spell duration indicator (CSDI). Based on some indices that do not exist in Indonesia, only a few indices were selected as shown in Table 1:

Table 1. Rainfall Index used in the study

No.	Index	Indicator Name	Indicator Definition	Unit
1.	CDD	*Consecutive dry day*	Maximum number of days without rain occurring in a year	*days*
2.	CWD	*Consecutive wet day*	Maximum number of consecutive rainy days	*days*
3.	PRCPTOT	*Annual total wet day precipitation*	The amount of rainfall that occurs in one year	mm
4.	R_{10mm}	*Number of heavy precipition days*	Annual number of days when PRCP ≥ 10	*days*
5.	R_{20mm}	*Number of very heavy precipitation days*	Annual number of days when PRCP ≥ 20	*days*
6.	R_{95P}	*Very wet day*	Total annual rainfall when RR>95th percentile	mm
7.	R_{99p}	*Extremely wet day*	Total annual rainfall when RR>99th percentile	mm

5) *Trend Analysis and Magnitude of Change*

The Mann-Kendall (MK) test belongs to non-parametric statistics, so no data with a normal distribution is required. The MK test is used to calculate and determine the trends of various indicators at weather stations. MK statistics provide the final conclusion in the form of the direction of change (positive or negative) and the degree of significance. The basic hypothesis used is that there is no change (H0 accepted) or the alternative hypothesis is H0 rejected, which means there is a significant change in the data (Marzuki Sinambela, 2013). The MK test has been widely used to analyze changes in climatological elements such as rain and temperature. The Mann-Kendall test is a test to determine the significance of whether there is a positive or negative change in the data. Trends are significant (i.e. rejection of the null hypothesis) at the 5% significance level if the Z value is greater than ±1.96. A positive Z value indicates that there is an increasing trend, while a negative Z indicates a decreasing trend (Tan et al., 2021). The MK test is performed using the following equation:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn\,(x_j - x_k), \quad (1)$$

$$sgn(x_j - x_k) = \begin{cases} +1, if\ (x_j - x_k) > 0 \\ 0, if\ (x_j - x_k) = 0 \\ -1, if\ (x_j - x_k) < 0 \end{cases}, \quad (2)$$

where xj and xk are consecutive data values. The variance S can be calculated using the following equation:

$$var\,(S) = \frac{n(n-1)(2n+5)}{18}, \quad (3)$$

where statistically S approaches the normal distribution if n is greater than 8. Statistical tests are carried out using the normal distribution approach and the standard test statistic Z is calculated as follows:

$$z = \begin{cases} \frac{S-1}{\sqrt{var(S)}}, if\ S > 0 \\ 0, if\ S = 0 \\ \frac{S+1}{\sqrt{var(S)}}, if\ S < 0 \end{cases}, \quad (4)$$

The Sen slope provides information on how much rainfall and temperature extremes change on average from year to year. The Sen slope is calculated as follows:

$$\beta = med \frac{x_j - x_k}{j-k}, j > k, \quad (5)$$

where β is the slope of Sen with positive values indicating an increasing trend, while negative values indicate a decreasing trend in a time series.

III. RESULTS AND DISCUSSION

Data from 1981-2023 is a compilation of annual data which is the result of compiling monthly data at Kertajati station. During the 43-year period there are some blank data such as in 1993 in August, 1995 in month 12, 1998 in months 4, 6, and month 7, and in month 4 of 2015. Empty data can be completed by using data from the site http://www.meteomanz.com/ and if the meteomanz site does not get the desired data, justification is done by looking at the data on the previous and following days if there are only a few days of emptiness [13]. However, if there is still relatively long empty data, it can consider months with the same seasonal pattern or have the same characteristics as the area being studied such as the Banten area.

The quality control (QC) analysis carried out in this study uses a manual method by operating the filter feature in Microsoft excel one by one to see some data deviations such as letter-shaped data, extra-normal data, maximum temperatures above 36 ℃, minimum temperatures below 18 ℃ and relatively the same Tx - Tn data [14]. The results of data analysis at Kertajati Meteorological Station show that there are some data that are still categorized as abnormal data where there are some data whose Tx and Tn are relatively the same or even minus (-) in several months in the 1981-2022 period. There are still some data errors and must be corrected so that we can operate in the RClimDex application.

Data that has been analyzed manually with the filter feature in Microsoft excel is arranged in the same order as the data format in the RClimDex application. After the data has been compiled and is in accordance with the rules of the RClimdex application, then the complete data is saved in txt format so that it can be operated in the RClimdex application whose outputs are indices, logs, outputs, plots, and trends. The results of RClimDex are included in the MK test.

There are 27 climate indices in the ETCCDI [15]. The ETCCDI indices used in this study are only a few indices because they are relevant to the climate in Indonesia which does not have an index of freezing days and ice days. This study uses several indices, namely 7 rainfall indices. For rainfall, the indices used include CDD, CWD, PRCPTOT, R10mm, R20mm, R95p, and R99p. Based on research that has been conducted at Kertajati meteorological station from 1981 to 2023 shows that the CDD trend of y = 0.3801x - 699.93 y indicates that days without rain increase every decade by 38.01 days meaning that in 100 years the number of days without rain will increase 38 days longer than now. With the increase in CDD, there is a decrease in CWD with the equation y = -0.0421x + 96 which means that there is a reduction in days for 0.04 days per decade so that in the next 100 years wet days occur 4 days shorter than now. PRCPTOT (Total rainfall) will decrease with the equation y = -2.9937x + 8661.6 which means that there is a decrease of 2.99 mm / decade so that in the next 100 years rainfall will

reduced by 0.57 days, medium rain which has a shorter time of 0.56 days, and heavy rain (R95p and R99p) which is reduced by 402 mm and 252 mm in the next 100 years than now. The following are the results of the analysis of each indicator:

1) CDD

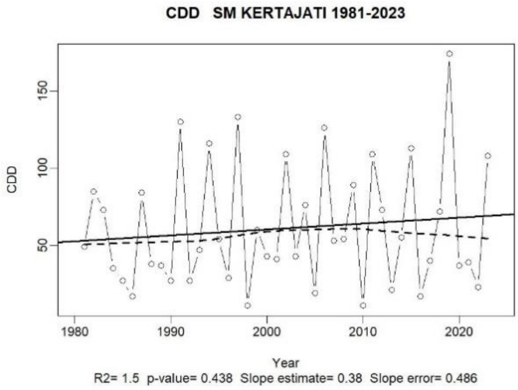

Fig. 2. CDD Graph of Kertajati Meteorological Station on RClimDex

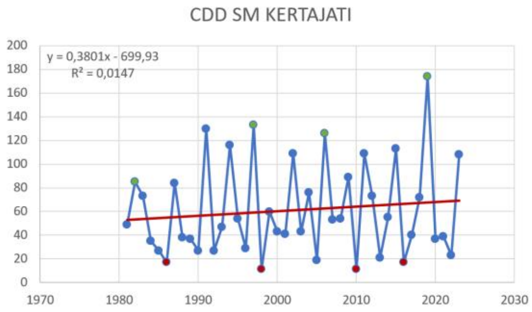

Fig. 3. Results of CDD Trend Analysis for West Java Province

CDD is an index that states the maximum number of days without rain that occurs in one year, usually this can also be referred to as the dry season. The results of the analysis at the Kertajati station show that the longest dry days occurred with the number of days> 50 days for four decades starting from 1981-2023, namely the first decade occurred in 1982 for 85 days, in the second decade occurred in 1997 for 133 days, in the third decade the longest day without rain occurred in 2006 for 126 days, and in the last decade the highest number was in 2019 for 174 days without rain in a row. While the shortest days occurred in 1986 for 17 days, 1998 for 11 days, 2010 for 11 days and 2026 for 17 days. Based on the CDD trend analysis with the equation y = 0.3801x - 699.93 which means that the number of dry days or series of days without rain will increase in the next 100 years the number of days will increase 38.01 days longer than now.

2) CWD

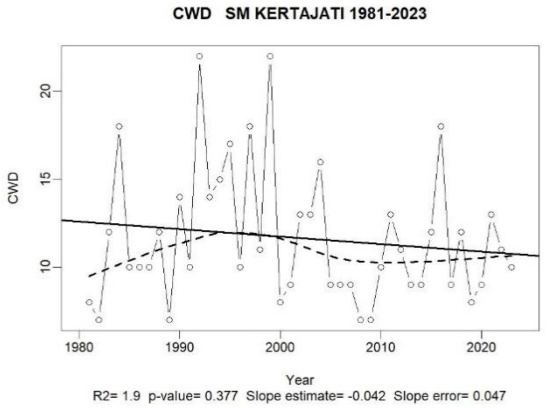

Fig. 4. CWD Graph of Kertajati Meteorological Station on RClimDex

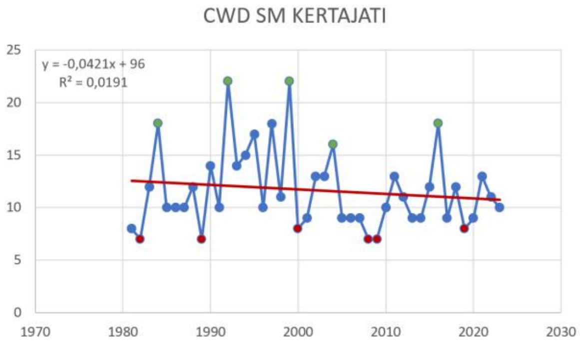

Fig. 5. Results of CWD Trend Analysis for West Java Province

CWD is an index that states the maximum number of consecutive rainy days in one year. The results of the analysis at Kertajati station conducted over a period of 4 decades starting from 1981 to 2023 showed that the longest wet days with a number of days > 13 days occurred in 1984 for 18 days, in 1992 and 1999 occurred for 22 days, in 2004 occurred for 16 days, and in the last decade occurred in 2016 for 18 days. While the shortest wet days occurred in 1982 and 1989 for 7 days and in 2000 for 8 days and in 2008 and 2009 for 7 days and in 2019 for 8 days. Based on the results of the trend analysis shows a decrease in the number of wet days with the equation y =-0.0421x + 96 which means that in the next 100 years the number of wet days will be 4.2 days shorter than now.

3) PRCPTOT

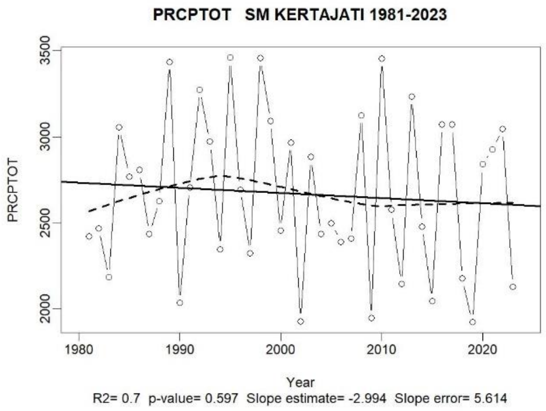

Fig. 6. PRCPTOT Graph of Kertajati Meteorological Station on RClimDex

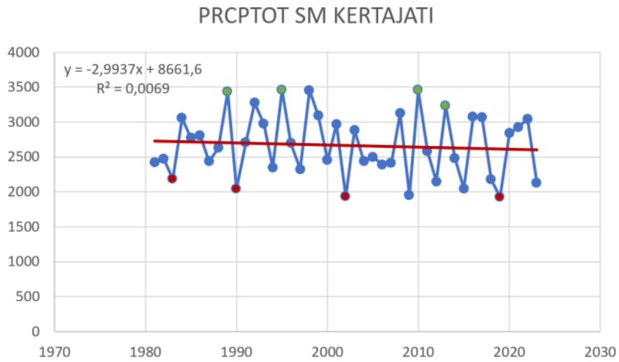

Fig. 7. Results of PRCPTOT Trend Analysis for West Java Province

PRCPTOT is an index that shows the amount of rainfall that occurs during one year. Measurement results at Kertajati Meteorological Station from 1981-2023 show that the annual total rainfall index in wet years and dry years. Wet years with rainfall >3200 mm/year occurred in the first decade in 1989, in the second decade in 1995, in the third decade occurred in 2010, and in the last decade occurred in 2013. Meanwhile, the results for dry years with RR < 1800 mm/year occurred in 1983 in the first decade, in the second decade occurred in 1990, in the third decade occurred in 2002, and in 2019 during the last decade. Based on the results of the trend analysis carried out, it shows a decrease in the total amount of rainfall in one year which means that in the next 100 years the rainfall will decrease by 299.3 mm from now.

4) *R_{10mm}*

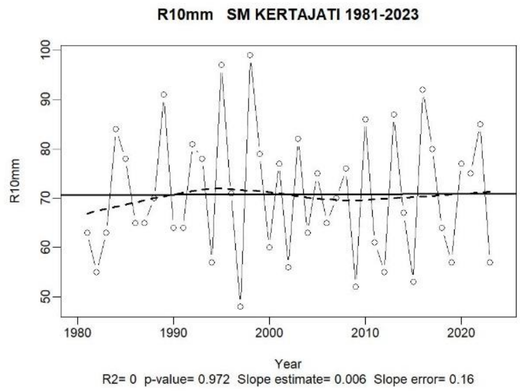

Fig. 8. R_{10mm} Graph of Kertajati Meteorological Station on RClimDex

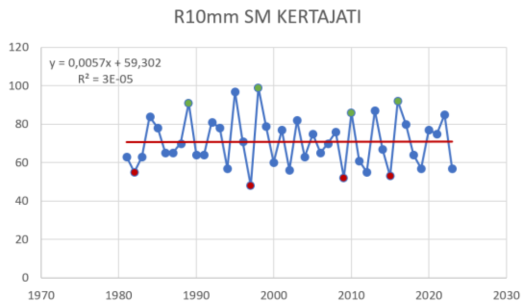

Fig. 9. Results of R_{10mm} Trend Analysis for West Java Province

R10mm is the number of annual days when PRCP (rainfall) ≥ 10mm, can be said to be a day with light rain. The results of data analysis at Kertajati station for 43 years starting from 1981 to 2023 with the number of days > 70 days occurred in the first decade with the longest number of days occurring in 1989, in the second decade occurred in 1998, in the third decade there was in 2010, and in the last decade occurred in 2016. While for the number of days < 60 days occurred in the first decade occurred in 1982, in the second decade occurred in 1997, in the third decade occurred in 2009, and in the last decade occurred in 2015. Based on the results of the trend analysis, it shows that rainy days with light intensity in the next 100 years will be 0.57 days longer than now.

5) R_{20mm}

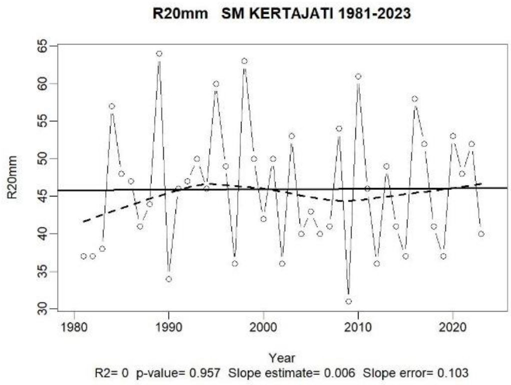

Fig. 10. R_{20mm} Graph of Kertajati Meteorological Station on RClimDex

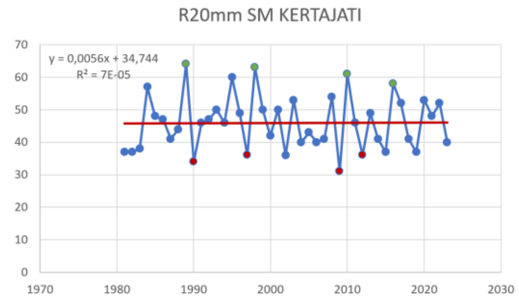

Fig. 11. Results of R_{20mm} Trend Analysis for West Java Province

$R20_{mm}$ is the number of annual days when PRCP (rainfall) ≥ 20mm, it can be said that days with rain in the medium category. The results of data analysis at Kertajati station for 43 years starting from 1981 to 2023 with the number of days > 45 days occurred in the first decade with the longest number of days occurring in 1989, in the second decade occurred in 1998, in the third decade located in 2010, and in the last decade occurred in 2016. Meanwhile, for the number of days < 35 days occurred in the first decade occurred in 1990, during the second decade occurred in 1997, in the third decade occurred in 2009, and in the last decade occurred in 2012. Based on the results of the trend analysis carried out, it shows that in 100 years the wet days with moderate intensity will be 0.56 days longer than now.

6) R_{95p}

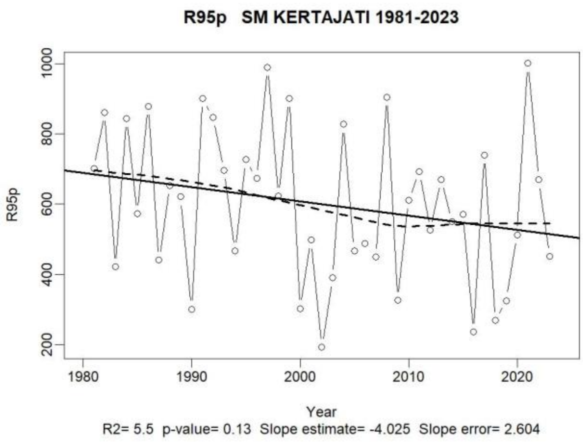

Fig. 12. R_{95p} Graph of Kertajati Meteorological Station on RClimDex

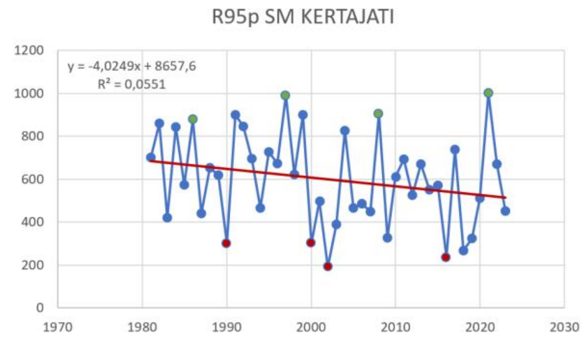

Fig. 13. Results of R_{95p} Trend Analysis for West Java Province

R95p is the total annual rainfall when RR > 95p. The results of the analysis of the Kertajati meteorological station for 43 years starting from 1981 to 2023 show that wet years > 800 mm/year occurred in the first decade in 1986, during the second decade wet years occurred in 1997, in the third decade occurred in 2008, and finally in the fourth decade occurred in 2021. For dry years 95p shows that in the next 100 years rainfall will experience a reduction of 402.49 mm from now.

7) R_{99p}

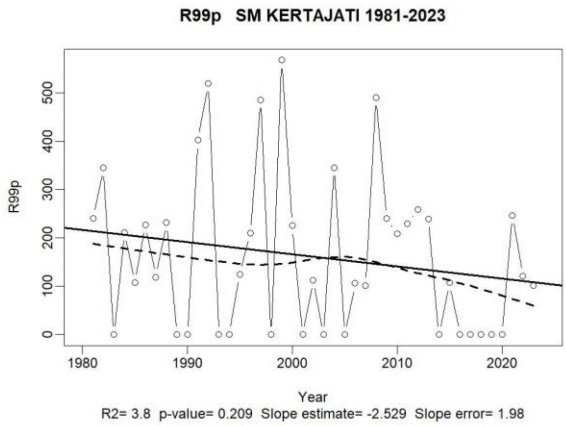

Fig. 15. R_{99p} Graph of Kertajati Meteorological Station on RClimDex

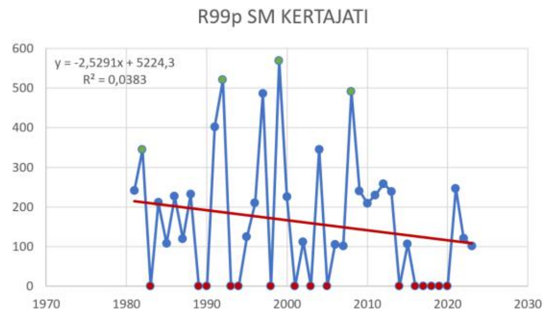

Fig. 13. Results of R_{99p} Trend Analysis for West Java Province

R99p is the total annual rainfall with RR > 99p. The results of the analysis of the Kertajati meteorological station for 4 decades starting from 1981 to 2023 show that wet years that have RR> 300 mm / year in the first decade period occurred in 1982, during the second decade occurred in 1992 and 1999, in the third decade in 2008. While for dry years with RR = 0 occurred in 1983, 1989, 1990, 1993, 1994, 1998, 2001, 2003, 2005, 2014, 2016, 2017, 2018, 2019, 2020. Based on the results of the trend analysis conducted on annual rainfall with RR> 99p shows that in the next 100 years rainfall will experience a reduction of 252.91 mm from now.

Trend Estimation of the Non- Man-Kendall Test Parametric

Kendall's Man Test or can be abbreviated as the This non-parametric MK test is also combined with the penny slope estimator in terms of determining significance trend index and penny slope is used to detect the magnitude of the trend that occurs [13]MK test based on Suryanto & Krisbiyantoro [15] was used to see the significance level of a trend. The significance range is denoted through percent 99% confidence (very high), 97.5% (high), 95% (moderate), and 90% (low) and is given a 4-star designationmarked in the form of 4 stars (****), 3 stars (***), 2 stars (**), and 1 star (*).

The MK test is used to see the trend of each indicator present at the station and can be used to predict how the state of the climate in the next few years. The indices are averaged where the results are obtained from the application results we get from the application RClimDex [16]. Man-Kendall test test was conducted on all climate variables The results are shown in the following table:

Table 2. Man-Kendall Test Results West Java Province 1981-2023

Indicator	First Year	Last Year	N	Test Z	Sig.	Q
CDD	1981	2023	43	0,44		0,182
CWD	1981	2023	43	-0,61		0,000
PRCPTOT	1981	2023	43	-0,54		-38,517
R_{10mm}	1981	2023	43	0,05		0,000
R_{20mm}	1981	2023	43	0,26		0,000
R_{95P}	1981	2023	43	-1,13		-41.563
R_{99p}	1981	2023	43	-1,21		-0.870

Based on the estimation trend for the rainfall index, it can be concluded that there is an insignificant downward trend due to the very high spatial and temporal variation of measurements and parameter properties [17], [18]. The results of the analysis of each indicator have decreased except for CDD so that without any significant countermeasures in the next 100 years the West Java region will experience drought. Then for medium and light intensity rainfall only experienced a very slight increase, which is respectively longer than 0.57 and 0.56 days in a century. The results are described as follows: rainfall > 99p decreased by 252.91 mm, rainfall > 95p decreased by 402.49 mm, moderate intensity rainfall increased by 0.56 days, light intensity rainfall increased by 0.57 days. The decrease in R99p, R95p affects the total amount of rainfall in one year (PRCPTOT) which will decrease by 299.3 mm/century. CWD or wet days series will also be affected because R20mm and R10mm also decreased so that the wet days series will decrease by 4.2 days/century. The decrease in CWD will result in an increase in CDD or a sequence of days without rain for 38 days longer than now.

IV. CONCLUSION

Climate data at Kertajati meteorological station 1981-2023 are: (a) Rainfall > 99p (R99p) decreases by 252.91 mm (b) R95p (rainfall > 95p) decreases by 402.49 mm (c) Moderate intensity rainfall (R20mm) is longer by 0.56 days/century (d) R10mm (light intensity rainfall) also increases for 0.57 days (e) Total rainfall amount in one year (PRCPTOT) will decrease by 299. 3 mm/century (f) CWD or wet days series will also be affected due to R20mm and R10mm so that the wet days series will be reduced by 4.2 days/century (g) The decrease in CWD will result in an increase in CDD or rainless days series for 38 days longer than now.

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