

Analysis of the Relationship Between Temperature and Extreme Rainfall with Drought and Flood Events in Lampung Province

Sudirman^{1*}, Hamdi Akhsan², Melly Ariska³, Mutia Eka Salsabilla⁴

^{1,2,3} Physics Education Department, Universitas Sriwijaya, Indonesia

^{1*} sudirman@fkip.unsri.ac.id

ARTICLE INFO

Article history:

Received 13 May 2025

Revised 18 June 2025

Accepted 08 July 2025

Available online 7 August 2025



This is an open access article under the [CC BY-NC 4.0](https://creativecommons.org/licenses/by-nc/4.0/) license. Copyright © 2025 by Author. Published by Physical Society Indonesia

ABSTRACT

The extreme temperature and rainfall studied in this study have a clear purpose, namely to identify recurring patterns that occur in a certain time span related to the level of rainfall in a certain region. By analyzing the data, it is hoped that it will be possible to better understand the weather and climate dynamics in the context of the region, as well as to enable the development of more effective adaptation and mitigation strategies against the impacts of climate change. This study uses RCLimDex to identify temperature and precipitation data to be observed in the year from 1981-2022. The results show extreme rainfall temperatures in the Lampung Province area if there are no optimal countermeasures, projections of climate conditions in the region in the next 100 years show a tendency to decrease rainfall and increase temperature. With increasingly rare rainfall and significantly rising air temperatures, this has the potential to

trigger droughts and fires. But the government also needs to pay attention to the threat of hydrometeorological disasters that can arise due to heavy rainfall.

Keywords: extreme, temperature, rainfall, climate, hydrometeorological

ABSTRAK

Suhu dan curah hujan ekstrem yang dikaji dalam penelitian ini memiliki tujuan yang jelas, yaitu untuk mengidentifikasi pola berulang yang terjadi dalam rentang waktu tertentu terkait dengan tingkat curah hujan di suatu wilayah tertentu. Dengan menganalisis data tersebut, diharapkan akan dapat lebih memahami dinamika cuaca dan iklim dalam konteks wilayah, serta memungkinkan pengembangan strategi adaptasi dan mitigasi yang lebih efektif terhadap dampak perubahan iklim. Penelitian ini menggunakan RCLimDex untuk mengidentifikasi data suhu dan curah hujan yang akan diamati pada tahun 1981-2022. Hasilnya menunjukkan suhu curah hujan ekstrem di wilayah Provinsi Lampung apabila tidak ada upaya penanggulangan yang optimal, proyeksi kondisi iklim di wilayah tersebut pada 100 tahun mendatang menunjukkan kecenderungan penurunan curah hujan dan peningkatan suhu. Dengan curah hujan yang semakin jarang dan suhu udara yang meningkat secara signifikan, hal ini berpotensi memicu kekeringan dan kebakaran. Namun pemerintah juga perlu memperhatikan ancaman bencana hidrometeorologi yang dapat muncul akibat curah hujan yang tinggi.

Kata kunci: ekstrem, suhu, curah hujan, iklim, hidrometeorologi

1. INTRODUCTION

Rising global temperatures to meet human needs have triggered the use of greenhouse gases such as nitrogen dioxide, carbon dioxide, methane, and various freons derived from industrial processes that continue to increase (Letcher, 2018). Extreme itself refers to weather situations outside the normal limits or standard rainfall standards that usually occur in a certain area and period of time. Rain is one of the common weather elements in Indonesia, especially in the tropics, where rain is very heavy in intensity and is often referred to as extreme rain (Hadiansyah et al., 2018). If the dry season is prolonged, it can result in a drought disaster. Meanwhile, if the rainy season is short but with high precipitation, the risk of floods and landslides can increase significantly (Hidayat et al., 2023).

Analysis of extreme climate change can be carried out using the ETCCDI index calculation method. (Chervenkov & Slavov, 2019) explains that ETCCDI is a software that provides a standard in the form of open source for performing calculations related to extreme climates. It contains 27 indices that can be used to evaluate extreme climate change, with 16 indices to measure extreme temperatures and 11 indices to calculate rainfall. The

Expert Team for Climate Change Detection and Index, which focuses on extreme changes in rainfall temperatures, has established 27 widely used indices based on observations obtained from stations (Yu et al., 2020). Climate can be described as an average condition that reflects variation over a long span of time, exceeding 10 years. The climate in an area is influenced by various characteristics of climate parameters, such as atmospheric pressure, temperature, air humidity, rainfall, cloud formation, wind direction, and other elements (Tjasyono. et al., 2012).

ENSO is a natural phenomenon that occurs involving variations in ocean temperatures in the central and eastern equatorial Pacific regions, which is also accompanied by changes in the atmosphere (Nur'utami and Hidayat, 2016). ENSO is a global climate phenomenon characterized by an increase in sea surface temperature in the eastern region of the Pacific Ocean, known as El Niño, which exceeds its normal level (Trenbeth et al., 2002).

IOD is a difference in sea surface temperature (SST) between the western part of the India Ocean and the eastern part (Behere & Yamagata, 2001). The positive IOD effect mainly occurs when the positive phase causes the upwelling process in the waters off the coast of South Java and west Sumatra (Saji et al., 1999). Disturbances in winds along this equator increase in line with the polarization of sea surface temperatures, which results in the accumulation of convective clouds around the east coast of the African Continent, causing high rainfall in the region. In the western region of the Maritime Continent of Indonesia, the conditions tend to lack rain or experience drought (Saji et al., 1999).

Based on the Expert Team on Climate Change Detection and Indices (ETCCDI), there are 27 extreme indices that represent extreme temperature and rainfall conditions as presented in the Table 1. (Zhang et al., 2011).

Table 1. ETCCDI Extreme Temperature and Rainfall Index

No.	ID	Indicator name	Indicator Definition	Unit
1.	Txmean	Mean Tmax	Annual mean of maximum temperatur	°C
2.	Tnmean	Mean Tmin	Annual mean of minimum Temperatur	°C
3.	TXx	Maximum Tmax	Monthly maximum value of daily max temperatur	°C
4.	TNx	Maximum Tmin	Monthly maximum value of daily min temperature	°C
5.	TXn	Minimum Tmax	Monthly minimum value of daily max temperature	°C
6.	TNn	Minimum Tmin	Monthly minimum value of daily min temperature	°C
7.	TN10p	Cool nights	Percentage of time when daily min temperature<10th percentile	%
8.	TX10p	Cool days	Percentage of time when daily max temperature< 10th percentile	%
8.	TN90p	Warm night	Percentage of time when daily min temperature> 90th percentile	%
10.	TX90p	Warm day	Percentage of time when daily max temperature> 90th percentile	%
11.	DTR	Diurnal temperaturerange	Monthly mean difference between daily max and min temperature	°C
12.	GSL	Growing season length	Annual (1st Jan to 31st Dec in NH, 1st July to 30th June in SH) count between first span of at least 6 days with TG >5°C and first span after July 1 (January 1 in SH) of 6 days with TG <5°C	Days
13.	FDO	Frost day	Annual count when daily minimum temperature< 0°C	Days
14.	SU25	Summer day	Annual count when daily max temperature> 25°C	Days
15.	TR20	Tropical night	Annual count when daily min temperature> 20°C	Days
16.	WSDI	Warm spell duration indicator	Annual count when at least six consecutive days of max temperature> 90th percentile	Days
17.	CSDI	Cold spell duration indicator	Annual count when at least six consecutive days of min temperature< 10th percentile	Days
No.	ID	Indicator Name	Indicator Definition	Unit
18.	RX1day	Max 1-day precipitation	Monthly maximum 1-day precipitation	Mm

No.	ID	Indicator name	Indicator Definition	Unit
		amount		
19.	RX5day	Max 5-day precipitation amount	Monthly maximum consecutive 5- day precipitation	Mm
20.	SDII	Simple daily intensity index	The ratio of annual total precipitation to the number of wet days (≥ 1 mm)	mm/day
21.	R10	Number of heavy precipitation days	Annual count when precipitation ≥ 10 mm	Days
22.	R20	Number of very heavy precipitation days	Annual count when precipitation ≥ 20 mm	Days
23.	CDD	Consecutive dry days	Maximum number of consecutive days when precipitation < 1 mm	Days
24.	CWD	Consecutive wet days	Maximum number of consecutive days when precipitation ≥ 1 mm	Days
25.	R95p	Very wet day	Annual total precipitation from days > 95 th percentile	Mm
26.	R99p	Extremely wet day	Annual total precipitation from days > 99 th percentile	Mm
27.	PRCPTOT	Annual total wet-day precipitation	Annual total precipitation from days ≥ 1 mm	Mm

2. METHOD

The type of research used is descriptive, quantitative and qualitative using Rclimadex software from Mann Kendall. The location of the research study in Lampung province, by utilizing the BMKG Raden Intan II station recordings from 1981-2022.

Quality Control (QC) procedures are used to identify and correct errors that may occur in various stages, such as recording, manipulation, formatting, transmission, and data storage. One of the QC steps is to ensure the accuracy of the analysis by using only data from observation stations that have a minimum of 80% full year. A full year is considered when the data lost in a year does not exceed 15 days and there is no month with more than 3 days of data not recorded (Aguilar, 2009).

Table 2. Extreme Rainfall Index Used in Research

No.	ID	Indicator Name	Indicator Definition	Unit
<i>Rainfall</i>				
1.	PRCPTOT	Annual total wet-day precipitation	Annual total precipitation from days ≥ 1 mm	Mm
2.	R50	Number of extremely heavy precipitation days	Annual count when precipitation ≥ 50 mm	Days
3.	CDD	Consecutive dry days	Maximum number of consecutive days when precipitation < 1 mm	Days
4.	CWD	Consecutive wet days	Maximum number of consecutive days when precipitation ≥ 1 mm	Days

Table 3. Extreme Temperature Index Used in Research

No.	ID	Indicator Name	Indicator Definition	Unit
<i>Temperature</i>				

1.	TXmean	Mean Tmax	Annual mean of maximum temperatur	°C
2.	TNmean	Mean Tmin	Annual mean of minimum temperatur	°C
3.	TXx	Maximum Tmax	Monthly maximum value of daily max temperatur	°C
4.	TNx	Maximum Tmin	Monthly maximum value of daily min temperatur	°C

2.1. Trend Analysis and the Magnitude of Change

Trends from various indicators have been calculated by applying a non-parametric Mann-Kendall (MK) test on weather station data. The MK test is one of the most important statistical methods commonly used to detect trends in hydroclimatic time series. In this study, the MK test was used to detect the trend of indicators of changes in rainfall and extreme temperatures. In the MK test, the null hypothesis indicates that there is no trend in the data. Instead, the alternative hypothesis suggests the data has a monotonous trend. A significant trend (i.e. zero hypothesis rejection) at a significance level of 5% if the Z value is greater than ± 1.96 . A positive Z value indicates an upward trend, while a negative Z value indicates a downward trend.

The initial value of the Mann-Kendall statistic (S) is assumed to be 0 (e.g. no propensity). If the data value of the subsequent time period is higher than the data value of the previous time period, S is added 1. Conversely, if the data value of the time period after that is lower than the data value of the previous period, S is subtracted by 1. The results of all stages produced the final score of S. (N. M. Hidayat et al., 2018).

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

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

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

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

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:

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

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:

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

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.

2.2. Correlation Analysis

At this stage, a correlation analysis will be carried out between rainfall indices and extreme temperatures in Lampung Province. The calculation of the value of the correlation coefficient uses the following equation (Thomson & Emery, 2004):

$$r_{xy} = \frac{1}{N-1} \sum_{i=1}^N \frac{(x_i - \bar{x})(y_i - \bar{y})}{s_x s_y} \quad (6)$$

where x_i and y_i are the time series data to be searched for the value of the correlation coefficient, and s_x and s_y are the standard deviations for each of the time series. The correlation coefficient r has a value in the range of -1 to $+1$. A negative value indicates that the two time series have a phase difference of 180° , while a positive value indicates that the two time series are one phase. The standard deviation value is expressed by the following equation:

$$s_x = \sqrt{\frac{1}{N} \sum_{i=1}^N (x_i - \bar{x})^2},$$

3. RESULTS AND DISCUSSION

In the initial stage of the research, what was carried out was to collect data, namely rainfall data (RR), maximum temperature data (Tx), and minimum temperature (Tn) data starting from 1981 to 2022 taken from the BMKG observation station, precisely at Radin Inten II Lampung Station through the <https://dataonline.bmkg.go.id> and <http://www.meteomanz.com/sites>. After that, the data that has been downloaded from the official BMKG online data page is compiled by month, then compiled by last year is combined into one as a whole for a period of 42 years. The next stage is to perform Quality Control (QC) manually using Microsoft Excel. This aims to find and identify problems that may arise during the process of data transfer, formatting, and completeness. Problems that can arise such as rainfall above 50 mm in a single day and the difference between Tmax and Tmin is negative. At this stage, observational data with a full year is defined as annual data that is lost for no more than 15 days. As a result of this stage, the data obtained has met the standards because there is no data missing, no rainfall data above 150 mm and the difference between Tmax and Tmin is positive and not zero.

Detailed information about the definitions and terms of each index can be found on http://etccdi.pacificclimate.org/list_27_indices.shtml website. The calculation of climate index values from this time series uses RClimDex. For monthly indexes, calculations cannot be performed if more than 3 days of data are lost. Meanwhile, the annual index cannot be calculated if more than 15 days of data are lost in a year. Annual indices are also not generated if the data does not meet the criteria for a monthly index. The resulting output is an annual data index value presented in Microsoft Excel format. The data obtained were then processed using the Mann-Kendall and Slope Sen non-parametric tests.

3.1. Rainfall

The results of the analysis are in the form of an extreme rainfall index that occurred in the data of Radin Inten II Station from 1981-2022.

1) CDD

CDD is an index that expresses the maximum number of days without rain that occurs in a year, usually this is also called the dry season. To explain more, the picture is presented below.

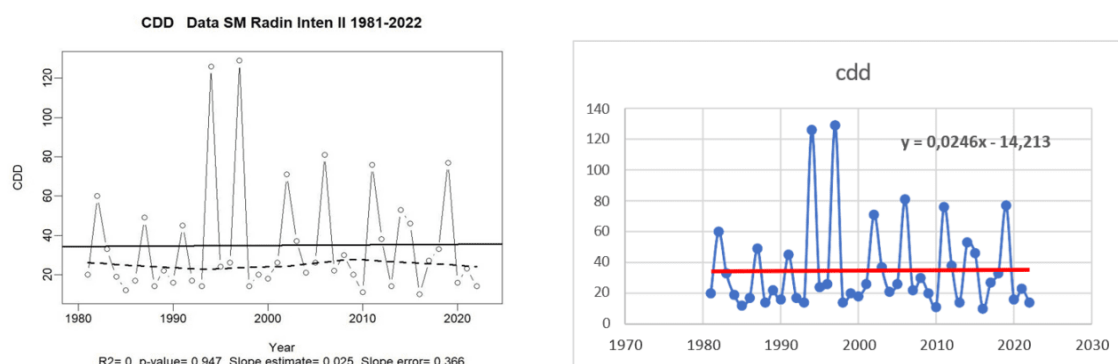


Figure 1. Graph and Results of CDD Trend Analysis

The results of the analysis at the Radin Inten II Meteorological Station showed that the longest dry days occurred with a total of >30 days for 4 decades starting from 1981-2022, namely the first decade occurred in 1982 for 60 days, the second decade occurred in 1997 for 129 days, the third decade occurred in 2006 for 81 days, the fourth decade occurred in 2019 for 77 consecutive days without rain. Meanwhile, the shortest days occurred in 1985 for 12 days, in 2010 for 11 days, and in 2016 for 10 days. Based on the analysis of the CDD trend with the equation $y = 0.0246x - 14.213$ which means that the number of days without rain will increase in the next 100 years, the number of days will increase by 2.5 days longer than now.

2) PRCPTOT

PRCPTOT is an index that shows the amount of rainfall that occurs during a year. The results of measurements at the Radin Inten II Meteorological Station from 1981-2022 show that the annual total rainfall index in wet years and dry years

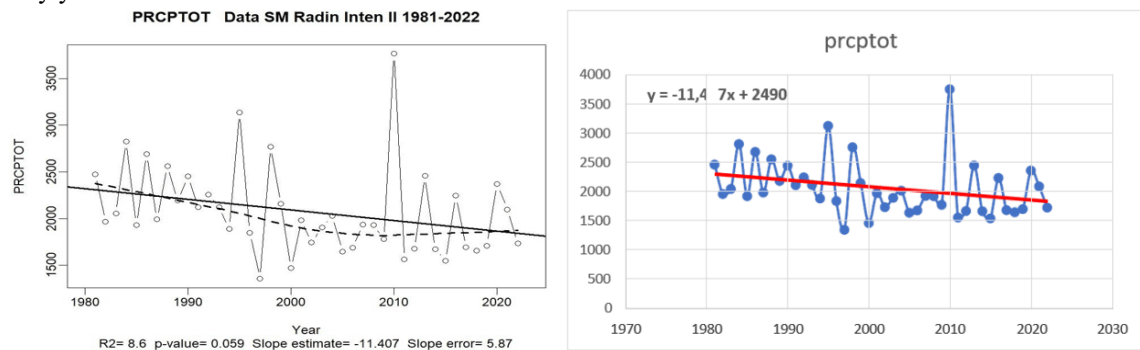


Figure 2. Graph and Results of PRCPTOT Trend Analysis

Based on figures 4.5 and 4.6 wet years with rainfall >2800 mm/year occurred in three decades, the first decade occurred in 1995, the second decade occurred in 1998, and the third decade in 2010. Meanwhile, the results for the driest years with $RR < 2400$ mm/year occurred in the first decade in 1985, the second decade in 1997, the third decade in 2005, and the fourth decade in 2011. 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, rainfall will decrease by 114.07 mm from now.

3) R50mm

R50mm is the number of annual days when PRCP (rainfall) ≥ 50 mm, it can be said that the days with very heavy rainfall. The results of data analysis at Radin Inten II Station for 42 years starting from 1981 to 2022.

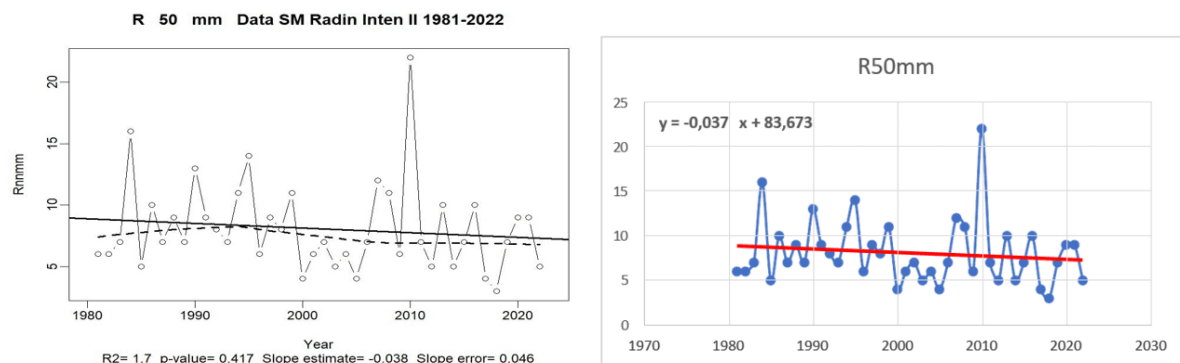


Figure 3. Graph and Results of R50mm Trend Analysis

Based on data obtained in 2010, it experienced very heavy rain for 22 days and in 2018 experienced heavy rain for only 3 days. Based on the results of trend analysis, it shows that high-intensity wet days in the next 100 years are 3.78 days shorter than now.

4) CWD

CWD is an index that states the maximum number of consecutive rainy days in a year. The results of the analysis at the Radin Inten II Station conducted during the period 1981-2022 produced the following:

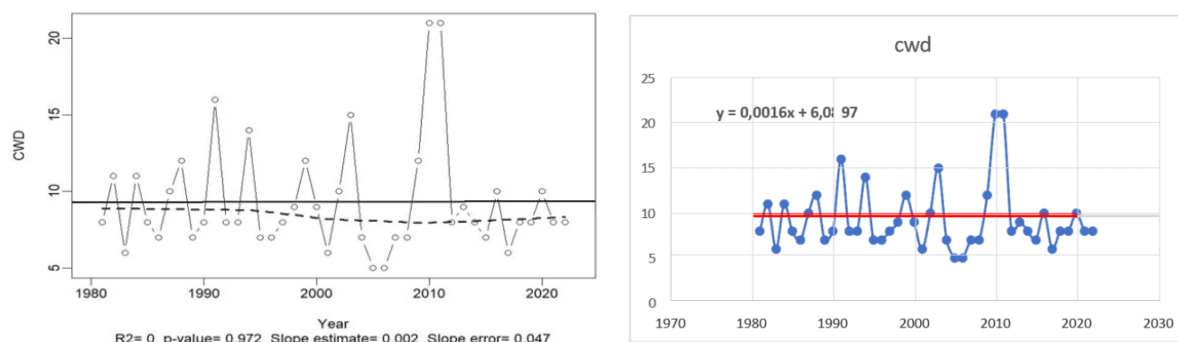


Figure 4. Graph and Results of CWD Trend Analysis

Based on the figure of the highest 4 decades which shows the longest wet days with the number of days >13 days occurred in 1988 for 12 days, in 1991 for 16 days, in 2003 for 15 days, and in 2010 for 21 days. While the shortest wet days ≤ 7 days occurred on in 1983 for 6 days, in 1996 for 7 days, in 2005 for 5 days and 2017 for 6 days. Based on the results of trend analysis, it shows a decrease in the number of wet days with the equation $y = 0.0016x + 6.0897$ which means that in the next 100 years the number of wet days is 0.16 shorter than now.

Based on research that has been conducted at the Radin Inten II meteorological station from 1981 to 2022, it shows that the CDD trend is $y = 0.0246x - 14.213$, which shows that the days without rain increase by 0.02 days, meaning that in 100 years the number of days without rain will increase by 2 days longer than now. With the increase in eating CDD, there is a decrease in CWD with $y = 0.0016x + 6.0897$ which means that there is a reduction in days by 0.001 days per decade so that in the next 100 days wet days occur 1 day shorter than usual. Therefore, PRCPTOT (Total Rainfall) will decrease with the equation $y = -11.407x + 24906$ which means that there will be a decrease of 11.4 mm/decade so that in the next 100 years rainfall will decrease by 114.07 mm from now, this is also was greatly influenced by the intensity of high/heavy rainfall (R50mm) which decreased by 3 days with the equation $y = -0.0378x + 83.673$.

3.2. Temperature

1) DTR

DTR is the temperature range or in other words as the monthly average difference between TX and TN.

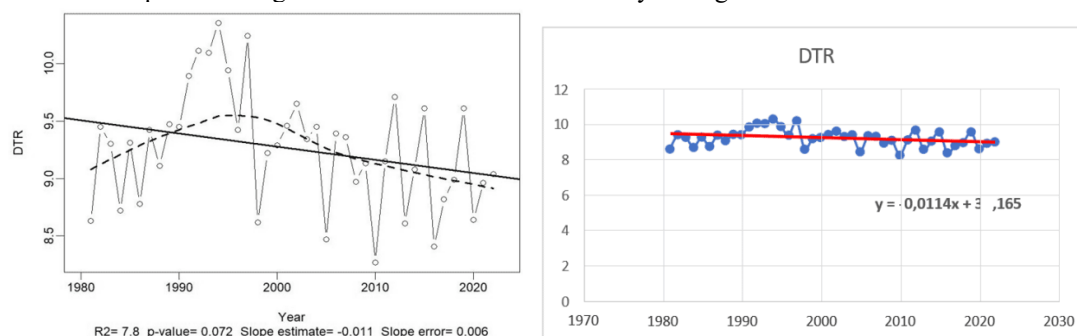


Figure 5. Graph and Results of DTR Trend Analysis

The results of the analysis of the Radin Inten II meteorological station showed that the slope estimate was -0.011 with the peak temperature in the range of 10.35°C with the lowest temperature of 8.27°C . Based on the results of the analysis on the DTR trend, there is a decrease of 1.1°C from now.

2) TMAXmean

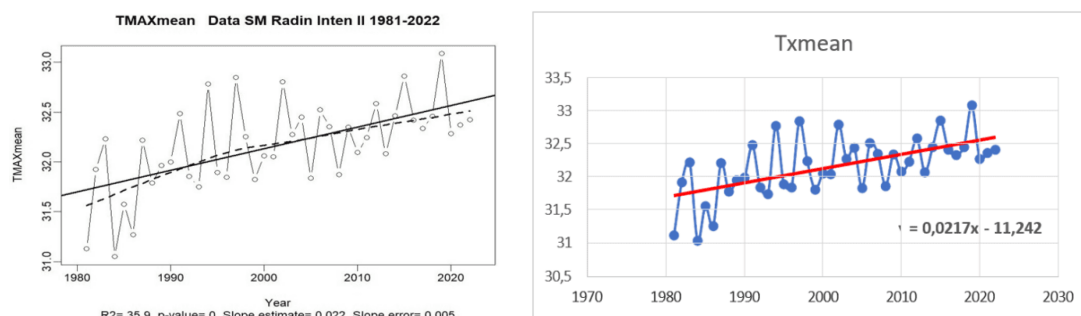


Figure 6. Graph and Results of TMAXmean Trend Analysis

The results of the analysis show that there was an increase during the period 1981-2022 with a slope estimate of 0.022 with a peak temperature of 33.09°C and a low temperature of 31.05°C. Based on trend analysis what is happening shows that in the next 100 years temperature will increase by 2.17°C hotter than now.

3) TMINmean

TMINmean is an index that shows the average temperature at night for one year. The results of the analysis at Radin Inten II Station from 1981 to 2022 show a very significant increase

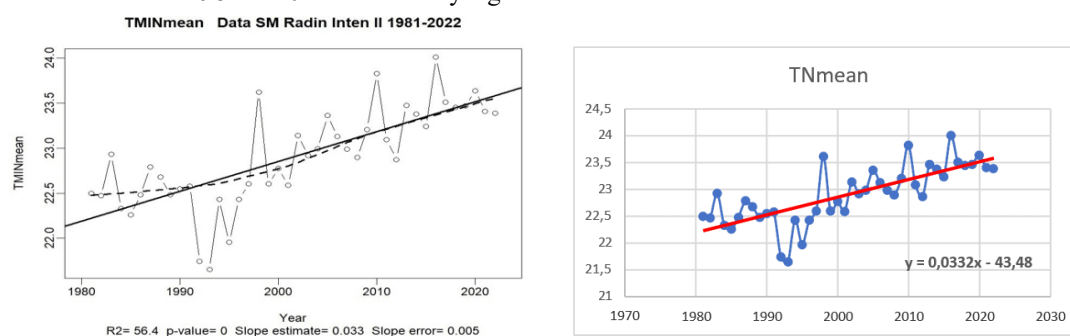


Figure 7. Graph and Result TMINmean Trend Analysis

Based on the data, every year with a slope estimate of 0.033 with a temperature between 21.65°C to the highest of 24.01°C. Based on trend analysis, it is shown that temperatures will increase in the next 100 years by 3.3°C Compared to now

4) TNn

TNn is the coldest temperature at night for one year. The results of the analysis from the Radin Inten II station are depicted in a fluctuating manner with a tendency to increase with a slope estimate value of 0.04.

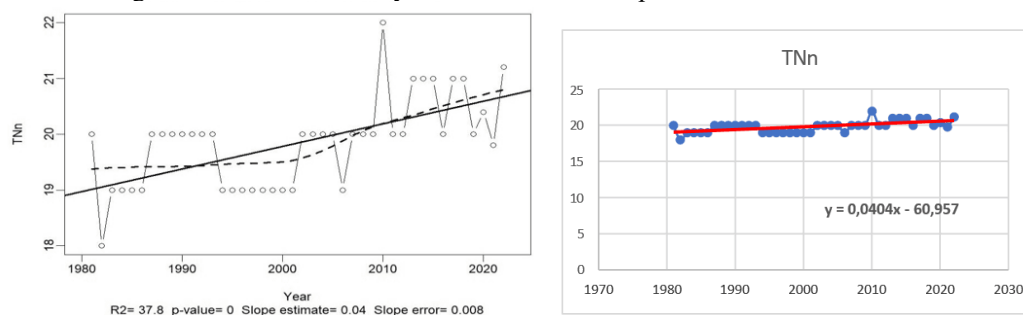


Figure 8. Graph and Results of TNn Trend Analysis in Lampung Province

Based on the data above, a significant increase occurs every year with a peak temperature of 22°C and a minimum temperature of 18°C. Based on the results of trend analysis, there is a temperature increase that will be experienced in the next 100 years by 4.0°C.

5) TNx

TNx is an index that shows the hottest temperature at night in a year.

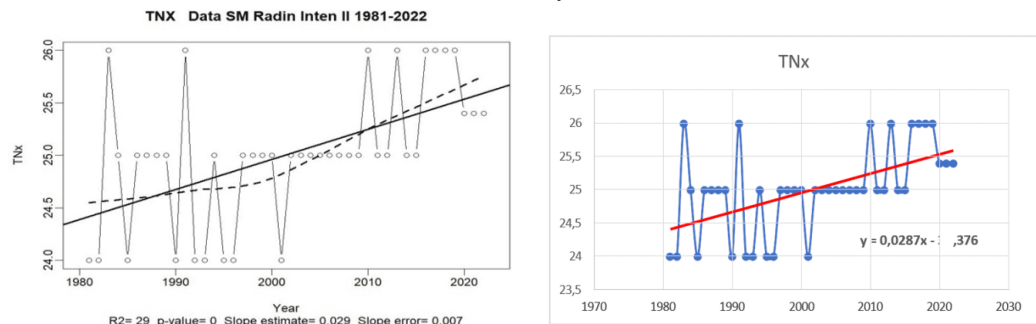


Figure 9. Graph and Results of TNx Trend Analysis

The results of the analysis from the Radin Inten II meteorological station are depicted in a fluctuating manner with a tendency to increase with a slope estimate value of 0.029 with a peak temperature of 28°C and a low temperature of 24°C. Based on the results of the analysis carried out, the trend shows that the trend is increasing, which means that in the next 100 years, the temperature will increase by 2.87°C hotter than now.

6) TXn

TXn is an index that shows the coldest temperature during the day in a year. The results of the analysis illustrate the occurrence of an increase.

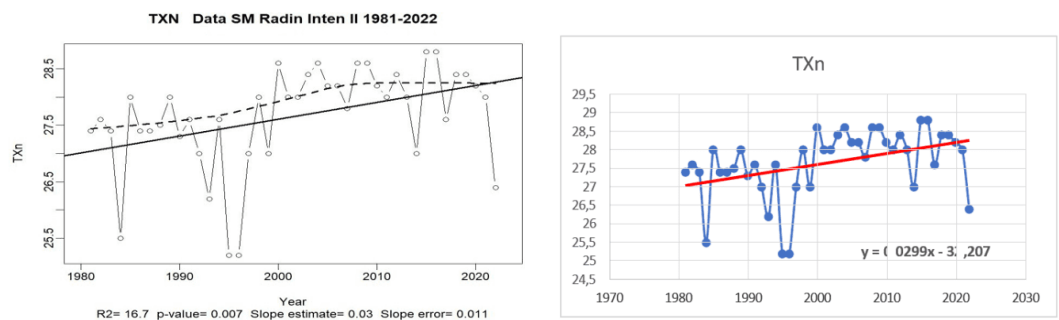


Figure 10. Graph and Results of TXn Trend Analysis

The slope estimate value of TXn Radin Inten II is 0.03 with a peak temperature of 28.8°C and a low temperature of 25.2°C. Based on the results of the trend analysis carried out, it shows that there is a increase every decade. So in the next 100 years the temperature will increase by 3°C hotter than now.

7) TXx

TXx is an index that describes the hottest daytime temperature conditions for a year

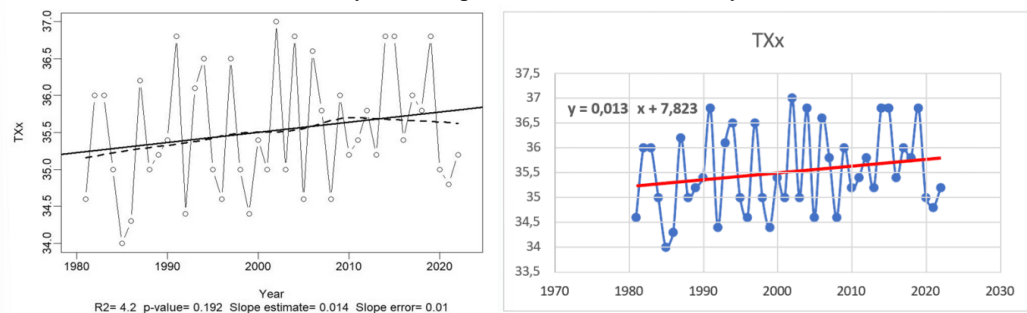


Figure 11. Graph and Results of TXx Trend Analysis

The results of the analysis showed a slope estimate value of 0.014 with a peak temperature of 37°C and the lowest temperature during the day when the hottest conditions were 34°C. Based on the results of the trend analysis, it shows that there is an increase in temperature by 1.4°C hotter than now.

Reduced rainfall will have an impact on the temperature in the surrounding environment. The results of the analysis at the Radin Inten II Meteorological Station from 1981-2022 have shown and described the situation that will occur in the future that days without rain will be longer than wet days. This is also proven through temperature analysis which is also carried out in the same place, namely by looking at several indicators such as DTR, TMAXMean, TMINMean, TXx, TNx, TXn and TNn. The similarity of the seven existing indicators shows significant events and correlates with the results of the rainfall analysis carried out previously. Of the seven indicators, only the DTR has decreased by 0.011°C/decade so that in 100 years it has decreased by 1.1°C. For TXx (the hottest temperature during the day) which has increased by 0.014°C/decade which means that in the next 100 years there will be an increase of 1.4°C hotter than now, followed by cold daytime temperatures will increase by 0.03°C/decade which means in 100 years will increase by 3°C. Likewise, hot temperatures at night will increase by 2.87°C/century, with cold temperatures at night also experiencing an increase of 4°C/century. So that it has an impact on the average temperature during the day which has increased by 2.17°C/century as well as the average temperature at night will increase by 3.3°C/century compared to now.

3.3. Non-parametric Man-Kendall Test trend estimation

The Man Kendall test or abbreviated as the Non-parametric MK test is also combined with the pen slope estimator in terms of determining the significance of the index trend and the pen slope is used to detect the magnitude of the trend that occurs (Supari, Tangang, Salimun, et al., 2017). The MK test is also used to see the level of significance of a trend. The trend is Significant (i.e. zero hypothesis rejection) at a significance level of 5% if the Z value is $> \pm 1.96$. The significance range is symbolized by the percent confidence of 99% (very high), 97.5% (high), 95% (moderate), and 90% (low) and is marked in the form of 4 stars (****), 3 stars (***), 2 stars (**), and 1 star (*). The Man-Kendall test was carried out on all climate variables used with the results as shown in the following table:

Table 4. Results of the Lampung Province Kendall Man Test

Indicator	First Year Last Year		n	Test Z	Signific.	Q
PRCPTOT	1981	2022	42	-2,64	**	-13,379
R50mm	1981	2022	42	-1,11		-0,038
CDD	1981	2022	42	0,46		0,071
CWD	1981	2022	42	-0,20		0,000
DTR	1981	2022	42	-1,70	+	-0,011
TMAXmean	1981	2022	42	3,99	***	0,020
TMINmean	1981	2022	42	5,45	***	0,032
TNn	1981	2022	42	3,94	***	0,033
TNx	1981	2022	42	3,85	***	0,013
TXn	1981	2022	42	3,06	**	0,026
TXx	1981	2022	42	1,37		0,014

The results of the MK test analysis for data at the Radin Inten II meteorological station from 1981-2022 show that trend data for extreme rainfall such as R50mm, CDD, and CWD are insignificant. Meanwhile, PRCPTOT is significant with a significance level of 95% (**). Meanwhile, in the temperature trend, the TXx trend is insignificant and for the DTR trend it is insignificant but the trend is positive, while TMAXmean, TMINmean, TNn, TNx, show a trend of 97.5% (***), and for TXn show a trend significance of 95% (**). The graph below shows the trend patterns as well as those that have occurred over 4 decades

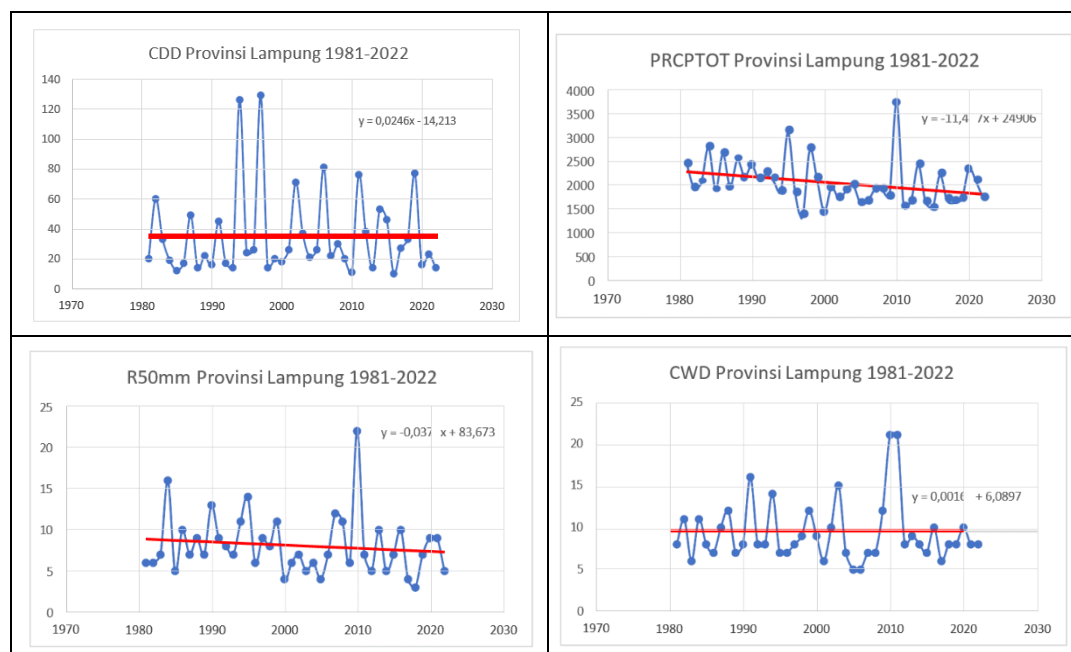


Figure 12. Rainfall Index Estimation Trend for 4 Decades

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 variation in measurements and parameters spatially and temporal (Collischonn et al., 2008). The results of the analysis All indicators showed a decline except for CDD, implying that without significant countermeasures in the next 100 years, Lampung Province is at risk of drought.

The results of the trend are increasing every year, this can have a significant impact if maximum countermeasures are not given, in the next 100 years there will be an increase in air temperature in Lampung Province. The results can be described as follows: the hot temperature during the day has increased by 1.4°C where the coldest temperature during the day also increases by 3°C . Not only during the day, this affects the hottest temperature at night days where the temperature increases by 2.87°C and cold temperatures at night also increase at the same value of 4°C . So that the average daytime temperature increases by 2.17°C and the average nighttime temperature also increases by 3.3°C , so the difference between the average daytime and nighttime temperature is 1.13°C .

Analysis conducted from weather data at the Radin Inten II meteorological station from 1981 to 2022 showed a less significant decrease in extreme rainfall patterns. Meanwhile, there is a more pronounced increase in extreme temperature values. This indicates that Lampung Province tends to experience a gradual increase in temperature over the next 100 years, while rainfall tends to decrease. From this analysis, it can be predicted that without serious preventive efforts, the region will become more vulnerable to drought as time goes on.

3.4. Correlation of Rainfall with IOD and ENSO

In an effort to find and understand the possible correlational relationship between the IOD and ENSO indices and the extreme rainfall index, the study involved two previously calculated multi-month average variations. The analysis aims to explore it by exploring the potential patterns and trends that can appear in the data, so that it can reveal how the correlation or relationship with the variation of extreme rainfall recorded. By utilizing this approach, it is hoped that the complex dynamics between IOD and ENSO climate factors and extreme rainfall events in the region under study can be further discovered and explained. From the average IOD and ENSO indices against the extreme rainfall index, the following values are obtained:

Table 5. Climate Index Correlation Table with IOD and ENSO

No.	Variable	IOD Index	ENSO Index
1.	CDD	R= 0,663869 ****	R= 0,571889 ****
2.	PRCPTOT	R= 0,008229 Insignificant	R= 0,18497 Insignificant
3.	R50mm	R= 0,181931 Insignificant	R= 0,087165 Insignificant
4.	CWD	R= 0,35789 ***	R= 0,024915 Insignificant

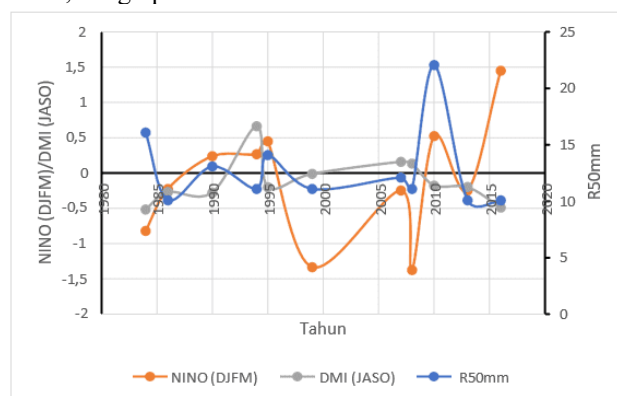
From table 5 with the results of the Pearson correlation one tile test, it can be concluded that the correlation between IOD and the number of consecutive days without rain (CDD) shows a very significant correlation level for observation data. Meanwhile, the correlation between IOD and total rainfall over a year (PRCPTOT) also showed a level of insignificant correlation for the data studied. Something similar occurred in the correlation between IOD and the Extreme Rainfall Index (R50mm), which also showed an insignificant degree of correlation. However, it should be noted that the correlation between IOD and the number of days with consecutive rainfall (CWD) shows a high level of correlation for observation data at the Radin Inten Lampung II meteorological station.

From the data in table 5, it can be concluded that the correlation generated from the Pearson correlation one tile test between ENSO and the number of CDD shows a high level of significance for the observation data. Similarly, the correlation between ENSO and total rainfall over a year (PRCPTOT) shows no significance for the data studied. A similar situation is also seen in the correlation between ENSO and the Extreme Rainfall Index (R50mm) which also does not show a level of significance. Similarly, the correlation between ENSO and the number of CWD showed a non-significant correlation level for observation data at the Radin Inten Lampung II meteorological station.

3.5. Hydrometeorological Disasters

Floods can cause inundation in areas that are not normally flooded, such as farmland, residential areas, or city centers. Problems arise when overflowing water causes losses, accidents, or if puddles persist for a long time and often interfere with daily life by soaking settlements and interfering with human activities.

From the data from the Radin Inten II meteorological station, the annual very heavy rainfall data index (R50mm) that has been obtained, the graph results are obtained as follows:

**Figure 13.** R50mm analysis results with Nino Index 3.4 and IOD

Based on figure 4.17, showing the days with heavy rain (R50mm) from 1981-2022 which has a number of days ≥ 10 days, it is obtained that the highest peak of very heavy rainfall is in the year 2010 which reached 22 days. The data above shows that when Nino and IOD are negative, heavy rainfall is also high, this can be said to be consistent. As we know, one of the causes of flooding is natural factors where the intensity of rain and high and long duration of rain can cause the river to be unable to accommodate water anymore so that it overflows and inundates the surrounding area.

In line with research (Situngkir, 2022), this is what happened during the floods in 2004, 2013, and 2016. The major flood that occurred in 2004 has caused several villages such as Suka Banjar, Sukaraja, Bagelen, Sukadadi, Kesugihan, Gedongtataan and Penengahan villages to be flooded for 3 (three) days with an altitude of 0.3 m-1.0 m. In 2010, there was also a flash flood in Lampung Province as written in an article written on the Kompas page

(Flash Flood Damaged Lampung Residents' Houses (kompas.com)) flooding caused by heavy rain so that the river that crossed the village overflowed due to not being able to accommodate the sudden increase in water discharge.

3.6. Drought disaster

The combined trends detected for the two indicators CDD and PRCPTOT will be discussed below:

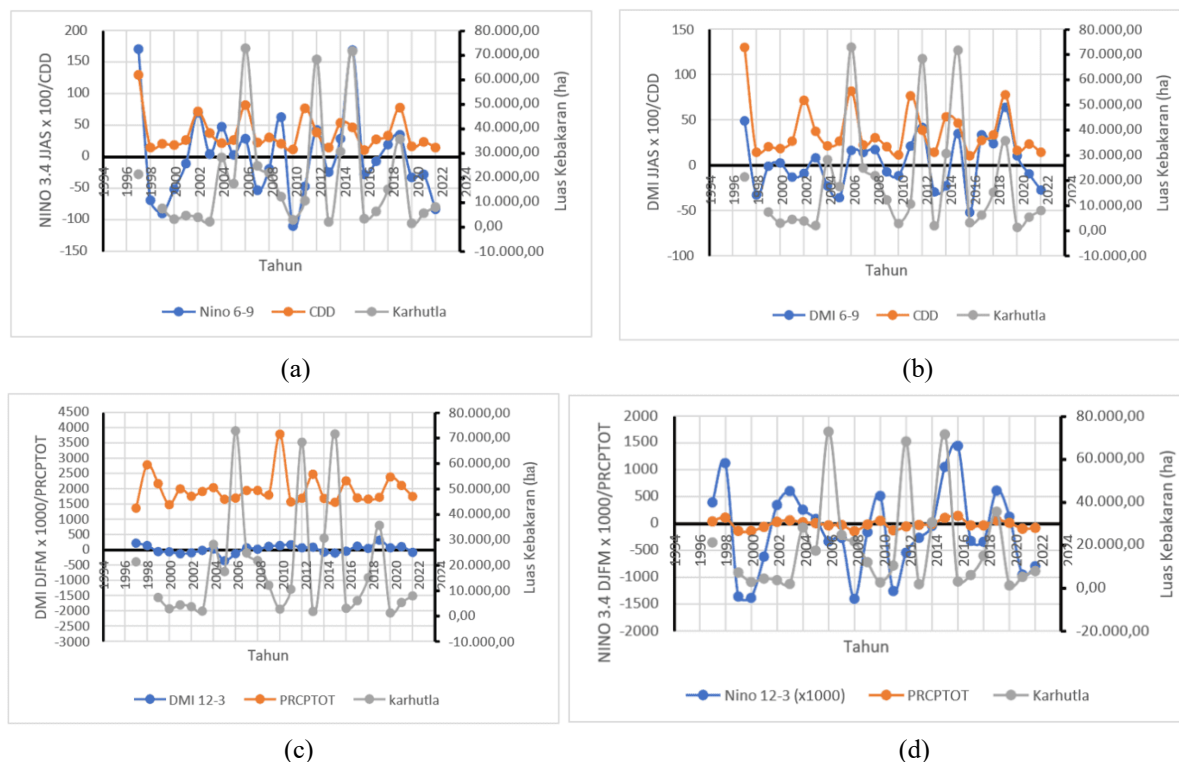


Figure 14. (a) CDD. DMI JJAS x 100. Karhutla (b) CDD. NINO 3.4 JJAS x 100. Karhutla (c) PRCPTOT. DMI DJFM x 1000. Karhutla (d) PRCPTOT. DMI DJFM x 1000. Karhutla

The figure above shows the trend of increasing CDD and decreasing trend of annual total wet day rainfall or PRCPTOT for Lampung Province. These results suggest that the region is becoming drier with an increase in average temperature during the day and night, potentially leading to the expansion of drought-prone land and contributing to an increased risk of wildfires in the area. This projection is in line with a previous study by (Supari, Tangang, Juneng, et al., 2017b) which estimated extreme annual rainfall changes in Southeast Asia, suggesting that there is consistency between the current projected findings and the results of previous studies.

The graph shows the consistency of the relationship between forest and land fires combined with the increase in CDD, NINO 3.4 index and DMI index. Based on the problem approach in this study which investigated fires in Lampung Province from 1997-2022, it should be noted that in 1998 there were no fires because fires are not a time series. This study aims to explore the existing relationship between land fires and DMI and ENSO using 2 climate indices namely CDD and PRCPTOT, with the aim of deepening the understanding of the dynamics of interaction between these climate factors and land fire activity. Data from the period 1997 to 2022 were used in the analysis to examine the area burned and how it relates to the climate index. Overall, this study shows that there is a positive relationship between forest and land fire incidents and the incidence of ENSO/IOD, which is in line with research (Akhsan et al., 2023).

From June to September 2006, for four consecutive months, it was recorded that the average value of the Nino index of 3.4 was 28. This value is consistently in line with the DMI which reached 15.95, while in that period there was also a series of 81 consecutive dry days (CDD). In that year, the burned area reached a very large area, namely 72,566.00ha, equivalent to 15% of the total land area burned for 25 years.

4. CONCLUSION

The characteristics of extreme rainfall in the Lampung Province area based on the analysis of climate data at the Radin Inten Lampung meteorological station 1981-2022 are: (a) CDD (a series of days without rain of 2.5 days will be longer than now) (b) the total amount of rainfall in one year (PRCPTOT) will decrease by 114.07mm/century

(c) R50mm (heavy intensity rainfall) will be shorter, namely 3.78 days/century (d) CWD (a series of wet days will also decrease so that the series of wet days will be reduced by 0.16 days/century.

The temperature characteristics of the Lampung Province area based on the results of climate data analysis at the Radin Inten II meteorological station in the period 1981-2022 are: (a) the average daytime temperature (TMAXmean) has increased by 2.17°C, (b) the average night temperature (TMINmean) has increased by 3.3°C, (c) the cold temperature at night (TNn) has increased by 4°C, (d) the hottest temperature at night (TNx) has increased by 2.87°C, (e) the cold temperature at day (TXn) has increased by 3°C (F) the hottest temperature of the day (TXx) increased by 1.4°C (g) the difference between day and night temperature (DTR) also increased by 1.1°C.

Results of the MK test analysis for data on meteorological stations Radin Inten II from 1981 to 2022 shows that: trend data for extreme rainfall such as R50mm, CDD, and CWD are insignificant. As for PRCPTOT, it is significant with The significance level is 95% (**). Meanwhile, in the temperature trend, the TXx trend is insignificant and for the DTR trend is insignificant but the trend is positive, while TMAXmean, TMINmean, TNn, TNx, show a trend of 97.5% (***), and for TXn show a trend significance of 95% (**).

The characteristics of rainfall carried out by the pearson correlation one tile test can be concluded that: (a) the correlation to DMI shows a very high level of CDD significance (****) and for CWD shows a high level of significance, while PRCPTOT and R50mm do not show significant significance. (b) the correlation with ENSO showed a very high level of significance for CDD (****) and for other indices i.e. PRCPTOT, R50mm, and CWD showed insignificant.

The highest peak of very heavy rainfall was in three years, namely in 2010 which reached 22 days. And the results obtained where Nino and Negative IOD are accompanied by high rainfall, this can be said to be consistent. One of the causes of flooding is natural factors where the intensity of rain and high and long duration of rain can cause the river to be unable to accommodate water anymore so that it overflows and inundates the surrounding area.

For four consecutive months from June to September 2006, the average value of the Nino index of 3.4 reached 28, in line with the stable DMI of 15.95. During this period, there was a series of 81 consecutive dry days (CDD). The area burned that year reached 72,566.00 m², equivalent to 15% of the total land area burned in the span of 25 years.

REFERENCES

- Aditama. (2000). Impact of haze from forest fire to respiratory health: Indonesian experience. In *Respirology* (Vol. 5).
- Aguilar, E., Barry, A. A., Brunet, M., Ekan, L., Fernandes, A., Massoukina, M., Mbah, J., Mhanda, A., do Nascimento, D. J., Peterson, T. C., Umba, O. T., Tomou, M., & Zhang, X. (2009). Changes in temperature and precipitation extremes in western central Africa, Guinea Conakry, and Zimbabwe, 1955- 2006. *Journal of Geophysical Research Atmospheres*, 114(2). <https://doi.org/10.1029/2008JD011010>
- Akhsan, H., Irfan, M., Supari, & Iskandar, I. (2023). Dynamics of Extreme Rainfall and Its Impact on Forest and Land Fires in the Eastern Coast of Sumatra. In *Science and Technology Indonesia* (Vol. 8, Issue 3, pp. 403–413). Magister Program of Material Sciences, Graduate School of Sriwijaya University. <https://doi.org/10.26554/sti.2023.8.3.403-413>
- Ariska, M., Akhsan, H., Muslim, M., Sudirman, & Kistiono. (2022). Pengaruh El Niño Southern Oscillation(ENSO) dan Indian Ocean Dipole(IOD) Terhadap Curah Hujan dan Korelasinya dengan Consecutive Dry Days(CDD) Provinsi Sumatera Selatandari Tahun 1981-2020. *Jurnal Ilmu Fisika Dan Pembelajarannya (JIFP)*, 6(2), 31–41. <http://jurnal.radenfatah.ac.id/index.php/jifp/>
- Badsha, M. A. H., Abdulla, M., Kafi, H., Hashnat Badsha, M. A., Kafi, M. A. H., Islam, M. Z., & Islam, T. (2016). Analysis of the Trends in Temperature and Precipitation Variables for SylhetCity of Bangladesh using Rclimindex Toolkit. In KUET. <https://www.researchgate.net/publication/290649725>
- Beherea, S. K., & Yamagata, T. (2001). Subtropical SST dipole events in the southern Indian Ocean. *Geophysical Research Letters*, 28(2), 327–330. <https://doi.org/10.1029/2000GL011451>
- Chang, C.-P., Wang, Z., McBride, J., & Liu, C.-H. (2005). Annual Cycle of Southeast Asia-Maritime Continent Rainfall and the Asymmetric Monsoon Transition.
- Chervenkov, H., & Slavov, K. (2019). STARDEX and ETCCDI climate indices based on E-OBS and CARPATCLIM: Part two: ClimData in use. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 11189 LNCS, 368–374.

https://doi.org/10.1007/978-3-030-10692-8_41

- Collischonn, B., Collischonn, W., & Tucci, C. E. M. (2008). Daily hydrological modeling in the Amazon basin using TRMM rainfall estimates. *Journal of Hydrology*, 360(1–4), 207–216. <https://doi.org/10.1016/j.jhydrol.2008.07.032>
- Fitriyah, N., Krisnando Nathanael, G., Daud, R. F., Winangsih, R., Kania Kurniawati, N., Mitrin, A., Akib, S., Putra Ode Amane, A., & Winarti, Y. (2023). Metode Penelitian Ilmu Komunikasi. www.penerbitwidina.com
- Fuso Nerini, F., Sovacool, B., Hughes, N., Cozzi, L., Cosgrave, E., Howells, M., Tavoni, M., Tomei, J., Zerriffi, H., & Milligan, B. (2019). Connecting climate action with other Sustainable Development Goals. In *Nature Sustainability* (Vol. 2, Issue 8, pp. 674–680). Nature Publishing Group. <https://doi.org/10.1038/s41893-019-0334-y>
- Hackert, E. C., & Hastenrath, S. (1986). Mechanisms of Java rainfall anomalies. *Monthly Weather Review*, 114(4), 745–757. [https://doi.org/10.1175/1520-0493\(1986\)114<0745:MOJRA>2.0.CO;2](https://doi.org/10.1175/1520-0493(1986)114<0745:MOJRA>2.0.CO;2)
- Hadiansyah, R., Indranata, A. L., Silitonga, A. K., & Agus Winarso, P. (2018). Kajian Kondisi Atmosfer saat Kejadian Hujan Ekstrem di Padang Sumatera Barat (Studi Kasus Tanggal 14 Februari 2018). *Prosiding SNFA (Seminar Nasional Fisika Dan Aplikasinya)*, 246–257. <http://apps.ecmwf.int/datasets/data/interim-full->
- Hadiansyah, R., Indranata, A. L., Silitonga, A. K., Agus Winarso, P., Studi Klimatologi, P., Tinggi Meteorologi Klimatologi dan Geofisika, S., Perhubungan No, J. I., Betung, P., Aren, P., & Selatan, T. (2018). Kajian Kondisi Atmosfer Saat Kejadian Hujan Ekstrem di Padang Sumatera Barat (Studi Kasus Tanggal 14 Februari 2018). *Prosiding SNFA (Seminar Nasional Fisika Dan Aplikasinya)*. <http://apps.ecmwf.int/datasets/data/interim-full->
- Hanugraheni, J. S. I., & Iriawan, N. (2016). Pemodelan Bayesian Hirarki Data Curah Hujan Ekstrem di Jakarta. *JURNAL SAINS DAN SENI ITS*, 5(1), 2337–3520. <https://media.neliti.com/media/publications/15740-ID-pemodelan-bayesian-hirarki-data-curah-hujan-ekstrem-di-jakarta.pdf>
- Hidayat, N. M., Pandiangan, A. E., Pratiwi, A., Klimatologi, P., Tinggi, S., Klimatologi, M., Geofisika, D., & Selatan, T. (2018a). IDENTIFIKASI PERUBAHAN CURAH HUJAN DAN TEMPERATURE UDARA MENGGUNAKAN RCLIMDEX DI WILAYAH SERANG. In *Jurnal Meteorologi Klimatologi dan Geofisika* (Vol. 5, Issue 2).
- Hidayat, N. M., Pandiangan, A. E., Pratiwi, A., Klimatologi, P., Tinggi, S., Klimatologi, M., Geofisika, D., & Selatan, T. (2018b). IDENTIFIKASI PERUBAHAN CURAH HUJAN DAN TEMPERATURE UDARA MENGGUNAKAN RCLIMDEX DI WILAYAH SERANG. In *Jurnal Meteorologi Klimatologi dan Geofisika* (Vol. 5, Issue 2).
- Hidayat, R., & Ando, K. (2014). Variabilitas Curah Hujan Indonesia dan Hubungannya dengan ENSO/IOD: Estimasi Menggunakan Data JRA-25/JCDAS. *Jurnal Agromet*, 28(1), 1–8. <http://journal.ipb.ac.id/index.php/agromet>
- Hidayat, R., Donni Haryanto Program Studi Meteorologi, Y., Tinggi Meteorologi Klimatologi dan Geofisika, S., Perhubungan No, J. I., Meteo, K., Betung, P., Aren, P., & Tangerang Selatan, K. (2023). Analisis Proyeksi Curah Hujan Tahunan (2016-2040) Menggunakan Skenario RCP4.5 di Kabupaten Lampung Selatan. 12(2), 255–261. <https://doi.org/10.25077/jfu.12.2.255-261.2023>
- Hutapea, E. (2019). Bencana Banjir di Sulsel Disebut Akibat Penyalahgunaan Tata Ruang.
- Klein Tank, A. M. G., Zwiers, F. W., & Zhang, X. (2009). Guidelines on Analysis of extremes in a changing climate in support of informed decisions for adaptation.
- Kusumawardhani, I. D., & Gernowo, R. (2015). Analisis Perubahan Iklim Berbagai Variabilitas Curah Hujan dan Emisi Gas Metana (CH₄) dengan Metode Grid Analysis and Display System (GrADS) di Kabupaten Semarang. In *Youngster Physics Journal* (Vol. 4, Issue 1).
- Letcher, T. M. (2018). Why do we have global warming? In *Managing Global Warming: An Interface of Technology and Human Issues*. Elsevier Inc. <https://doi.org/10.1016/B978-0-12-814104-5.00001-6>
- Malino, C. R., Arsyad, M., & Palloan, P. (2021). ANALISIS PARAMETER CURAH HUJAN DAN

- TEMPERATURE UDARA DI KOTA MAKASSAR TERKAIT FENOMENA PERUBAHAN IKLIM. *Jurnal Sains Dan Pendidikan Fisika (JSPF)*, 17(2), 139–145. <http://ojs.unm.ac.id/jspdf>
- Martono, M., & Komala, N. (2018). Concentration Conditions of Carbon Dioxide in Bukittinggi During the Event of El Niño 2015. *JKPK (Jurnal Kimia Dan Pendidikan Kimia)*, 3(3), 118. <https://doi.org/10.20961/jkpk.v3i3.24860>
- Mulyanti, H., Harjono, H., & Rendra, M. I. (2020). Penurunan Intensitas Hujan Ekstrem di Bengawan Solo Hilir dan Hubungannya dengan ENSO. *Jurnal Ilmu Lingkungan*, 18(1), 73–81. <https://doi.org/10.14710/jil.18.1.73-81>
- Nugroho, D., & Rolia, E. (2022). Klasifikasi Daerah Aliran Sungai di Provinsi Lampung Berdasarkan Permenhut No. 60/2014. *TAPAK*, 11(2), 109–117. <https://ojs.ummetro.ac.id/index.php/tapak/index>
- Nugroho, S. (2019). Analisis Iklim Ekstrem Untuk Deteksi Perubahan Iklim Di Sumatera Barat. *Jurnal Ilmu Lingkungan*, 17(1), 7. <https://doi.org/10.14710/jil.17.1.7-14>
- Nur'utami, M. N., & Hidayat, R. (2016). Influences of IOD and ENSO to Indonesian Rainfall Variability: Role of Atmosphere-ocean Interaction in the Indo-pacific Sector. *Procedia Environmental Sciences*, 33, 196–203. <https://doi.org/10.1016/j.proenv.2016.03.070>
- Qian, J. H., Robertson, A. W., & Moron, V. (2010). Interactions among ENSO, the Monsoon, and Diurnal Cycle in Rainfall Variability over Java, Indonesia. *Journal of the Atmospheric Sciences*, 67(11), 3509–3524. <https://doi.org/10.1175/2010JAS3348.1>
- Rahman As-syakur, A. (2012). Pola Spasial Hubungan Curah Hujan dengan ENSO dan IOD di Indonesia-Observasi Menggunakan Data TRMM 3B43. <https://www.researchgate.net/publication/303458242>
- Rosyidie, A. (2013). Banjir: Fakta dan Dampaknya, Serta Pengaruh dari Perubahan Guna Lahan. *Jurnal Perencanaan Wilayah Dan Kota*, 24(3), 241–249.
- Saji, N. H., Vinayachandran, P. N., Goswami, B. N., & Yamagata, T. (1999). A dipole mode in the tropical Indian Ocean. *NATURE*, 401, 360–363. <https://doi.org/http://dx.doi.org/10.1038/43854>
- Siregar, S. N., Sari, L. P., Purba, N. P., Pranowo, W. S., & Syamsuddin, M. L. (2017). Pertukaran massa air di Laut Jawa terhadap periodisitas monsun dan Arlindo pada tahun 2015. *Depik*, 6(1), 44–59. <https://doi.org/10.13170/depik.6.1.5523>
- Situngkir, A. M. (2022). ANALISIS DATA CURAH HUJAN SEBAGAI PENYEBAB BANJIR DI GEDONG TATAAN LAMPUNG. *JURNAL KELITBANGAN*, 10(1), 95–108. <http://pusatkrisis.kemkes.go.id>
- Supari, Tangang, F., Juneng, L., & Aldrian, E. (2017a). Observed changes in extreme temperature and precipitation over Indonesia. *International Journal of Climatology*, 37(4), 1979–1997. <https://doi.org/10.1002/joc.4829>
- Supari, Tangang, F., Juneng, L., & Aldrian, E. (2017b). Observed changes in extreme temperature and precipitation over Indonesia. *International Journal of Climatology*, 37(4), 1979–1997. <https://doi.org/10.1002/joc.4829>
- Supari, Tangang, F., Salimun, E., Aldrian, E., Sopaheluwakan, A., & Juneng, L. (2017). ENSO modulation of seasonal rainfall and extremes in Indonesia. *Climate Dynamics*, 51(7–8), 2559–2580. <https://doi.org/10.1007/s00382-017-4028-8>
- Surmaini, E., & Faqih, A. (2016). Kejadian Iklim Ekstrem dan Dampaknya Terhadap Pertanian Tanaman Pangan di Indonesia. <https://repository.pertanian.go.id/server/api/core/bitstreams/b80f8843-ae16-43f9-95de-a39ff46ef738/content>
- Surya Prayoga, I., & Ahdika, A. (2021). Pemodelan Kerugian Bencana Banjir Akibat Curah Hujan Ekstrem Menggunakan EVT dan Copula. <https://jurnal.stis.ac.id/index.php/jurnalasks/article/view/273/99>
- Suryadi, Y., Nugroho Sugianto, D., & Hadiyanto. (2017). Identifikasi Perubahan Temperature dan Curah Hujan serta Proyeksinya di Kota Semarang (Vol. 14, Issue 1). www.dataonline.bmkg.
- Thomson, R. E., & Emery, W. J. (2004). *Data Analysis Methods in Physical Oceanography* (Second Edi). Elsevier B.V.
- Tjasyono, B. H., Lubis, A., Juaeni, I., & Woro Harijono, S. B. (2008). Dampak Variasi Temperature Samudera

Pasifik dan India Ekuatorial terhadap Curah Hujan di Indonesia.

- Trenbeth, K. E., Caron, J. M., Stepaniak, D. P., & Worley, S. (2002). Evolution of El Niño-Southern Oscillation and global atmospheric surface temperatures. *Journal of Geophysical Research D: Atmospheres*, 107(7–8), 5–1. <https://doi.org/10.1029/2000jd000298>
- Tukidi. (2010). Karakter Curah Hujan di Indonesia. *Jurnal Geografi*, 2(2), 136–145. <http://journal.unnes.ac.id/nju/index.php/JG/article/view/84>
- Vinayachandran, P. N., Iizuka, S., & Yamagata, T. (2002). Indian Ocean dipole mode events in an ocean general circulation model. In *Deep-Sea Research II* (Vol. 49).
- Webster, P. J., Magaña, V. O., Palmer, T. N., Shukla, J., Tomas, R. A., Yanai, M., & Yasunari, T. (1998). Monsoons: processes, predictability, and the prospects for prediction. *Journal of Geophysical Research: Oceans*, 103(C7), 14451–14510. <https://doi.org/10.1029/97jc02719>
- Welly, M. (2015). Analisa Karakteristik Hujan di Kota Bandar Lampung. *Jurnal Rekayasa*, 19(3).
- Yu, Y., Schneider, U., Yang, S., Becker, A., & Ren, Z. (2020). Evaluating the GPCC Full Data Daily Analysis Version 2018 through ETCCDI indices and comparison with station observations over mainland of China. *Theoretical and Applied Climatology*, 142(3–4), 835–845. <https://doi.org/10.1007/s00704-020-03352-8>
- Zhang, X., Alexander, L., Hegerl, G. C., Jones, P., Tank, A. K., Peterson, T. C., Trewin, B., & Zwiers, F. W. (2011). Indices for monitoring changes in extremes based on daily temperature and precipitation data. In *Wiley Interdisciplinary Reviews: Climate Change* (Vol. 2, Issue 6, pp. 851–870). Wiley-Blackwell. <https://doi.org/10.1002/wcc.147>