JPPIPA 9(4) (2023)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

Correlation Among Rainfall, Humidity, and The El Niño-Southern Oscillation (ENSO) Phenomena in Bengkulu City During the Period from 1985-2020

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Received: January 22, 2023
Revised: February 27, 2023
Accepted: April 25, 2023
Published: April 30, 2023

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DOI: 10.29303/jppipa.v9i4.2971

Abstract: A correlation analysis is needed to see the relations among the three variables, rainfall with El Niño-Southern Oscillation (ENSO) and Humidity with ENSO. The instability of rainfall and the decrease in the humidity in Bengkulu City can be affected by La Nina and El Nino phenomena. This research aimed to analyze the correlations among rainfall, humidity, and ENSO with Pearson correlation analysis. The rainfall and humidity data were collected from BMKG, and the ENSO data were obtained from NOAA PSL for the 1985-2020 period. The results of the correlation analysis of rainfall and ENSO for the last 35 years generally show a moderately strong correlation. However, a strong correlation in the La Nina phase specifically occurred in 1988-1989, 1998-1999, 1999-2000, 2007-2008 and 2010-2011 with values of 58.6, 40.1, 61.4, 96, 4, and 89.2%. Meanwhile, the correlation >80% (very strong) during the El Nino phase occurred in 1987, 1991-1992, 1997, 2015. The correlation analysis results of humidity and ENSO show little correlation in the La Nina phase of >70% (1988-1989, 1998-1999, 2010-2011) and the El Nino phase of <70% (1997, 2015, 2016). The humidity correlations with ENSO do not influence the humidity change in Bengkulu City. The decrease in the humidity in Bengkulu City can be affected by other factors, such as land use change to housing due to population growth in Bengkulu City.

Keywords: El Nino; Humidity; La Nina; Rainfall

Introduction

Bengkulu City is the capital city of Bengkulu Province which is located on the west coast of the island of Sumatra. Geographically, Bengkulu City is located between 3°45'-3°59' South Latitude and 102°14'-102°22' East Longitude with an area of 539.3 km^2 which consists of a land area of 151.7 km^2 and a sea area of 387.6 km^2 (Verawati, 2019). The location of Bengkulu City which faces the Indian Ocean causes the air in the Bengkulu City area to be relatively hot with monthly rainfall levels ranging from 200-600 mm (Fernalia et al., 2022). The location causes Bengkulu City to be prone to natural disasters caused by weather/climate. Based on the Schmith-Ferguson climate classification, Bengkulu City is classified as climate type A (very wet) with 10 wet months starting from October to July. The period of May to October is the dry season Hadi et al. (2010), hence from December to January, there will be heavy rain. Several sub-districts in the Bengkulu City area are frequently flooded and one of the factors is the increased intensity of rainfall (Anwar et al., 2018; Pramudia et al., 2021).

The effect of increased rainfall intensity in Bengkulu City can be indicated as a result of the El Niño-Southern Oscillation (ENSO) or La Nina and El Nino phenomena. The phenomenon of La Nina and El Nino is a form of global influence that greatly influences rainfall and affects the climate around the Pacific Ocean. Scientifically, El Nino is a phenomenon that occurs in the interaction system of the ocean and the global atmosphere, which causes the sea surface temperature to

How to Cite:
Wardani, A., Akbar, A.J., Handayani, L., & Lubis, A.M. (2023). Correlation Among Rainfall, Humidity, and The El Niño-Southern Oscillation (ENSO) Phenomena in Bengkulu City During the Period from 1985-2020. *Jurnal Penelitian Pendidikan IPA*, *9*(4), 1664–1671. https://doi.org/10.29303/jppipa.v9i4.2971

rise above its normal temperature (Nabilah et al., 2017). Oppositely, La Nina is a phenomenon that occurs because the sea surface temperature in the Pacific has decreased compared to its normal temperature (Kug & Ham, 2011). The phenomenon of La Nina and El Nino leads to climate change globally, where the unstable level of rainfall and humidity greatly affects the quality, production, and growth of crops such as rice, corn, wheat, and other crops (Naylor et al., 2007; Takama et al., 2014).

Other physical parameter that may affected by ENSO is humidity where it shows the number of intensity levels of water vapor in the air. Thus, the high and low level of humidity in a place is strongly influenced by several factors, namely air pressure, temperature, and wind movement (Lovell-Smith & Pearson, 2005). Humidity is one of the factors that may be controlling the quality of hot and cold air in an environment (Cobantoro et al., 2019). It is very important to looking at factors that affect humidity levels including the humidity relationship with ENSO. Research using humidity parameters to see its relationship to ENSO was conducted in Sulawesi. Based on Hidayat et al. (2021) the humidity in Sulawesi has a fairly strong relationship with ENSO with a correlation value of 47.9%. Considering that the humidity in Sulawesi is strongly correlated with ENSO, we would like such kind relationship (between humidity and ENSO) in Bengkulu City, Sumatra.

This study aims to determine the correlation of rainfall, humidity and ENSO phenomena in the Bengkulu City area for the last 35 years. We also aimed to determine the trend humidity changes in Bengkulu City during 1985-2020. This correlation analysis is needed and very important to study in order to better understanding relationship rainfall, humidity to the La Nina and El Nino phenomena in reginal scales.

Method

The Location and Data

In this study, we used monthly rainfall and humidity data obtained from the Meteorology, Climatology and Geophysics Agency (MCGA) of Bengkulu Province station. We also utilized the ENSO data acquired from the NOAA PSL site. Rainfall, humidity, and ENSO data were collected for a period of last 35 years (BPS, 2020). With the 35 years data spans, it is expected that we could find the correlation among rainfall, humidity, and La Nina and El Nino phenomena in the Bengkulu City area.

Data Processing

At first step we calculated the average of both monthly rainfall and humidity value using equation (1) during the last 35 years data in Bengkulu City (Hermansah, 2017) as follows:

$$\bar{X} = \frac{\sum_{i=1}^{n} x_i}{n} \quad (1)$$

Where, $\bar{X}$ is average rainfall or humidity; n indicates number of data samples; X_i are rainfall or humidity data at month i. The next stage calculation was to find the anomaly value of rainfall and humidity in the past 35 years using equation (2):

$$X_{i(Anomali)} = X_i - \bar{X} \quad (2)$$

Where $X_{i(Anomali)}$ is rainfall or humidity anomaly data at point i. The anomaly values of both rainfall and humidity can be determined by calculating the difference between ith data of monthly and their average values. To calculate the correlation (r), we used equation (3), Pearson correlation analysis formula as follow (Habib et al., 2001):

$$r = \frac{n\sum XY - \sum X \sum Y}{\sqrt{(n\sum X^2 - (\sum X)^2)(n\sum Y^2 - (\sum Y)^2)}} \quad (3)$$

Where, Y is the time events of La Nina and El Nino (ENSO) Pearson correlation coefficient value (r) is existed in the range of $-1 \leq r \leq 1$. If r is close to -1 then the correlation both parameters is strong but inversely proportional, if r is 0, there is no correlation, while if r is close to 1, it means both parameters is strongly correlated (directly proportional) (Bewick et al., 2003).

Finally, we displayed both monthly rainfall and humidity using graphs as well as for normal distribution of rainfall and humidity, their correlation, their anomalies and ENSO event for the last 35 years (BPS, 2020) in Bengkulu City.

Result and Discussion

Rainfall

We have calculated the rainfall average during the last 35 years. The rainfall means the amount of rain that falls in a certain period of time (Lee, 2015). In this study, the average monthly rainfall in the Bengkulu City area was 281 mm for the last 35 years where it can be categorized as normal rainfall (Kurniawan, 2020). It can be seen in Figure 1(a) shows that monthly rainfall data in Bengkulu City for the last 35 years has varied from below 100 mm to above 600 mm. This shows that rainfall in Bengkulu City looks unstable due to indications of La Nina and El Nino phenomena, as it is known that the La Nina and El Nino phenomena greatly affect the level of rainfall intensity, especially in the Bengkulu City area (Athoillah et al., 2017).

Figure 1(b) shows that the distribution of rainfall data in the Bengkulu City area during the last 35 years. From Figure 1(b), it is seen that the monthly rainfall in

Bengkulu city was not normally distributed. In accordance with Figure 1(a) and Figure 1(b), the rainfall in Bengkulu City for the last 35 years (BPS, 2020) is classified as unstable. This is also supported by that huge rainfall data are outside the curve of normal distribution. Variation of rainfall can be caused by several factors, such us local physical parameters and also the La Nina and El Nino events. Figure 1(a) shows that the rainfall changes seasonally, but there is drastic change in some time period.

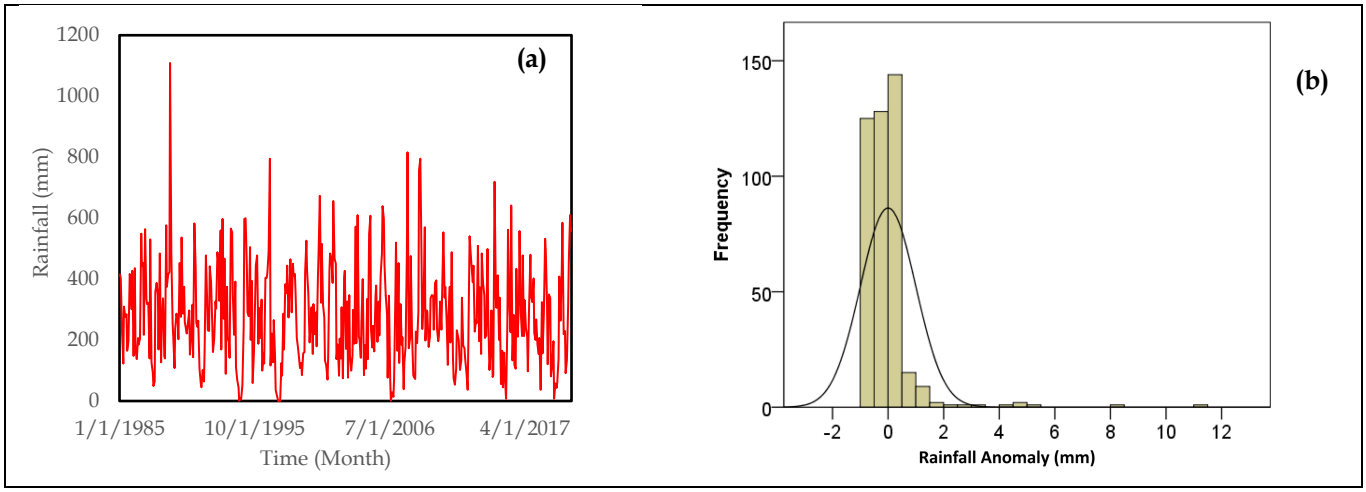

Figure 1. (a) The Graph of Monthly Rainfall for 35 Years in Bengkulu City based On MCGA data, (b) The Normal Distribution Curve of Rainfall in Bengkulu City.

Humidity

During the period 1985-2020, the Bengkulu City area was experiencing changes in humidity levels with an average humidity of 85%. From Figure 2(a), it can be seen that there was not observed spike humidity value and the average humidity is the normal humidity in the Bengkulu City area. Moreover, we can see a linear trend of humidity changes for the last 35 years (Figure 2(a)). Changes in humidity levels in the Bengkulu City area had decreased significantly over the last 35 years from the value of 86.6% to 83.4%. The humidity in Bengkulu City has been decreased by 5%. Such kind phenomenon impact to air quality and temperature (An & Kim, 2019). Hence, further analysis is needed regarding finding in the Bengkulu City.

During the period 1985-2020, The highest humidity was before El-Nino event in 1997, which was 91%. Meanwhile, the lowest humidity of 80% which is about 5% lower from the average humidity occurred six times (in 2003, 2006, 2012, 2015, 2016 and 2018).

Figure 2(b) shows that the distribution of humidity data for the last 35 years (BPS, 2020). It can identificated that humidity data are normally distributed so far where the humidity data is mostly under the curve. the humidity data outside of the curve, we assumed as outliers according to Ahsanullah et al. (2014).

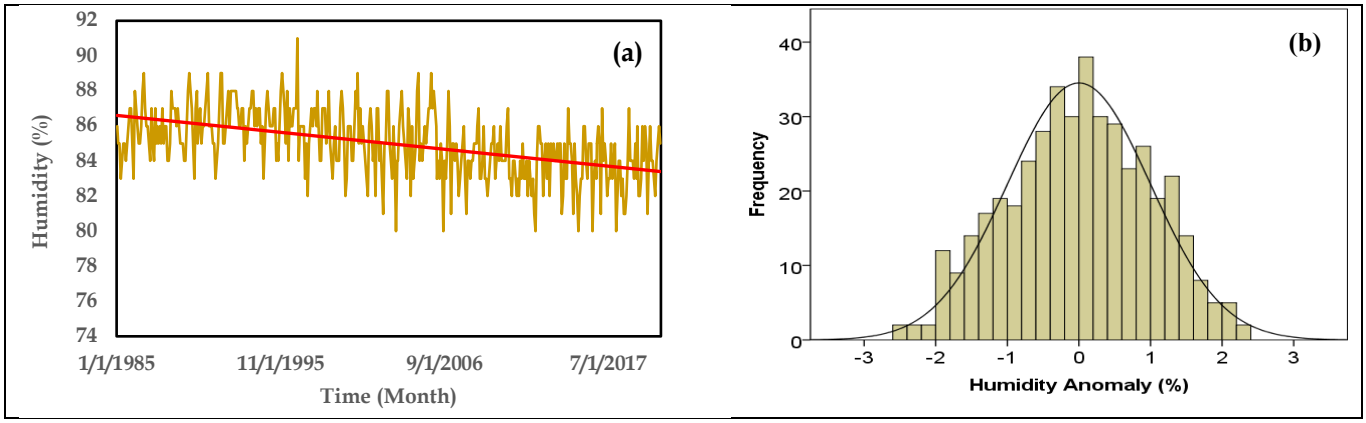

Figure 2. (a) The Graph of Monthly Humidity for 35 Years in Bengkulu City Based on MCGA Data, (b) The Normal Distribution Curve of Humidity in Bengkulu City.

Correlation of Rainfal and Humidity Anomalies to ENSO

In this study, the Pearson correlation analysis was used to investigate the relationship among rainfall, humidity, and ENSO for the last 35 years (1985-2020) in the Bengkulu City area. Figure 3 shows the correlation between rainfall and ENSO index NINO 3.4. The

anomaly with a positive sign indicates that rainfall has increased above the average normal rainfall in Bengkulu City, while an anomaly with a negative sign means that rainfall has decreased below the average normal rainfall.

Figure 3 shows very strong negative correlations between rainfall and ENSO at some points in the graph, with a total correlation for 35 years of -0.188 (18,8%). The correlation indicates that for 35 years, only some points in the graph experienced strong La Nina and El Nino events. For further analysis, we needed to classify the La Nina and El Nino events in Bengkulu City to see the strong correlations between the events and rainfall.

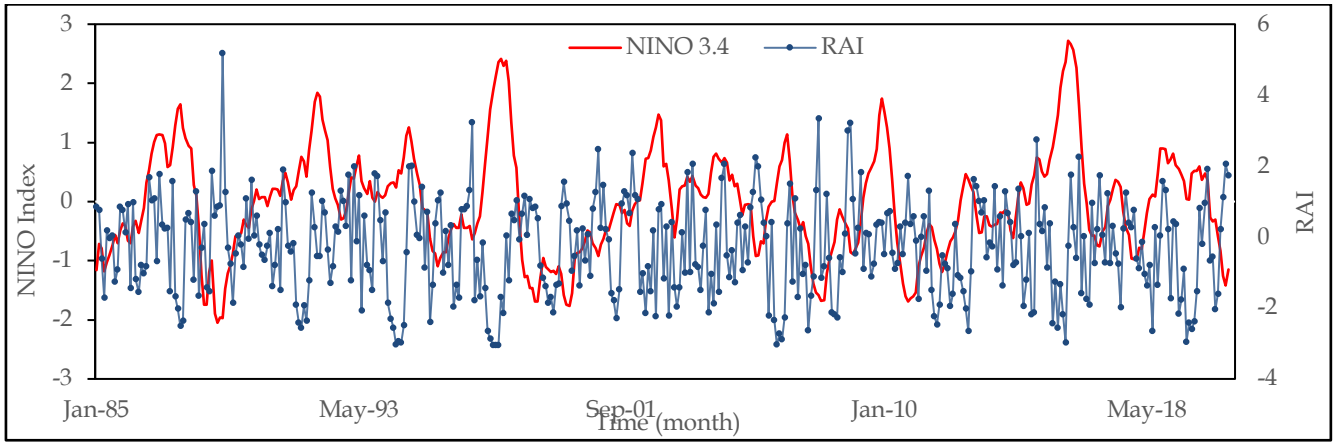

Figure 3. Correlation of Monthly Rainfall Anomalies to ENSO For 35 Years in Bengkulu City

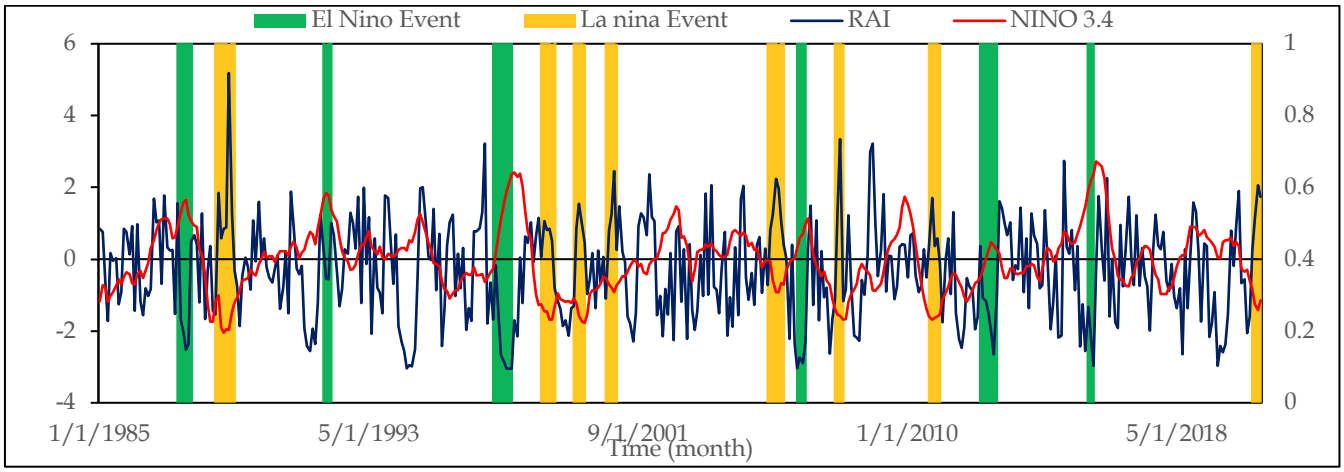

Figure 4. The Time Span with a Strong Correlation on La Nina and El Nino Events For 35 Years in Bengkulu City

Table 1. Classification of Strong Correlation of Rainfall with ENSO

Year	Phenomena	Correlation Coefficient	Information
1987	El Nino	-0.854	Very Strong
1988-1989	La Nina	-0.401	Moderate
1991-1992	El Nino	-0.959	Very Strong
1997	El Nino	-0.832	Very Strong
1998-1999	La Nina	-0.466	Moderate
1999-2000	La Nina	-0.614	Strong
2000-2001	La Nina	-0.975	Very Strong
2005-2006	La Nina	-0.776	Strong
2006	El Nino	-0.619	Strong
2007-2008	La Nina	-0.964	Very Strong
2010-2011	La Nina	-0.892	Very Strong
2012	El Nino	-0.833	Very Strong
2015	El Nino	-0.988	Very Strong
2020	La Nina	-0.877	Very Strong

(Source: Akoglu, 2018)

Figure 4 presents 14 events of La Nina and El Nino with a strong correlation on rainfall in Bengkulu City (1987, 1988-1989, 1991-1992, 1997, 1998-1999, 1999-2000, 2000-2001, 2005-2006, 2006, 2007-2008, 2010-2011, 2012, 2015, 2020). The classification shows that rainfall in Bengkulu City strongly correlates with La Nina and El Nino phenomena. Table 1 shows that the strong La Nina phases (1988-1989, 1998-1999, 1999-2000, 2007-2008, 2010-2011) have a strong correlation with correlation levels of 96.4%, 89.2% (very strong), and 61.4% (strong) which were happened in 2007-2008, 2010-2011, and 1999-2000. In 1988-1989 and 1998-1999, the correlations between rainfall and La Nina events were strong, with correlation levels of 58.6% and 40.1% (Moderate). Almost all the La Nina events strongly correlated with rainfall in Bengkulu City, but the correlations are only moderately strong at some points. The correlation that is not very strong can be influenced by the local condition,

such as topography, sea surface temperature, local convective, and orographic effect (Senatore et al., 2020; Kozu et al., 2006).

The El Nino phases (1987, 1991-1992, 1997, 2015) in Table 1 show very strong correlations on rainfall in Bengkulu City (85.4%, 95.9%, 83.2%, and 98.8%). The correlations show negative correlations because when the La Nina happens in the Pacific Ocean, high rainfall will happen in Bengkulu City. Lin et al. (2019) said that the negative correlation is influenced by the far distance-where ENSO is in the Pacific Ocean, and other factors, such as Walker Circulation Anomaly and Surface Anomaly centered in Philippines. The rainfall in Bengkulu City also can be influenced by a local factor, for instance, geographical conditions among different areas (Fransiska et al., 2020). Based on the correlation data for 35 years, Bengkulu City's rainfall is strongly influenced by the La Nina and El Nino phenomena.

In Figure 5, we show the monthly humidity anomaly and ENSO index NINO 3.4. It can be seen that there is a humidity anomaly with negative and positive signs, where a positive sign indicates that the humidity level is higher than the normal average humidity and a negative sign indicates a lower humidity level from its normal state. Figure 5 shows low correlations between humidity and ENSO for 35 years of 0.028 (2.8%).

A classification of Nina and El Nino was conducted to see the correlation between humidity and the strong La Nina and El Nino events. In addition, the humidity graph of Bengkulu City for 35 years is a sinusoidal wave and runs into a decrease, so the impact can affect the air quality in the city. The air quality change can be indicated as the impact of land use change on housing.

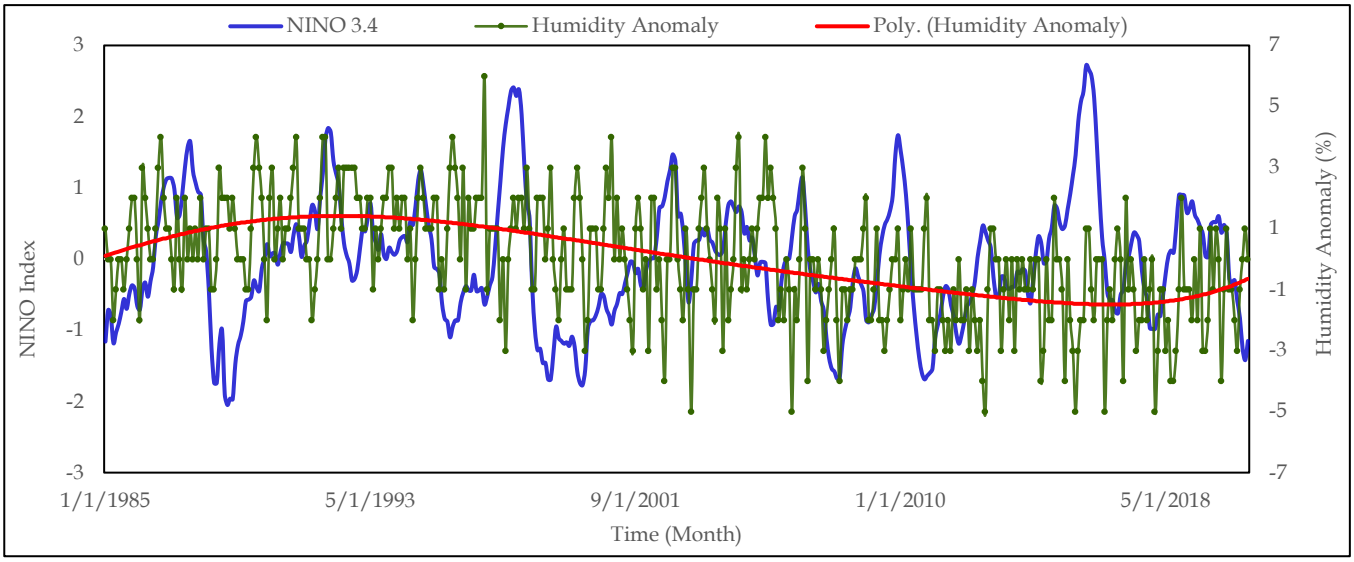

Figure 5. The Correlation of Monthly Humidity Anomaly to ENSO for 35 Years in Bengkulu City.

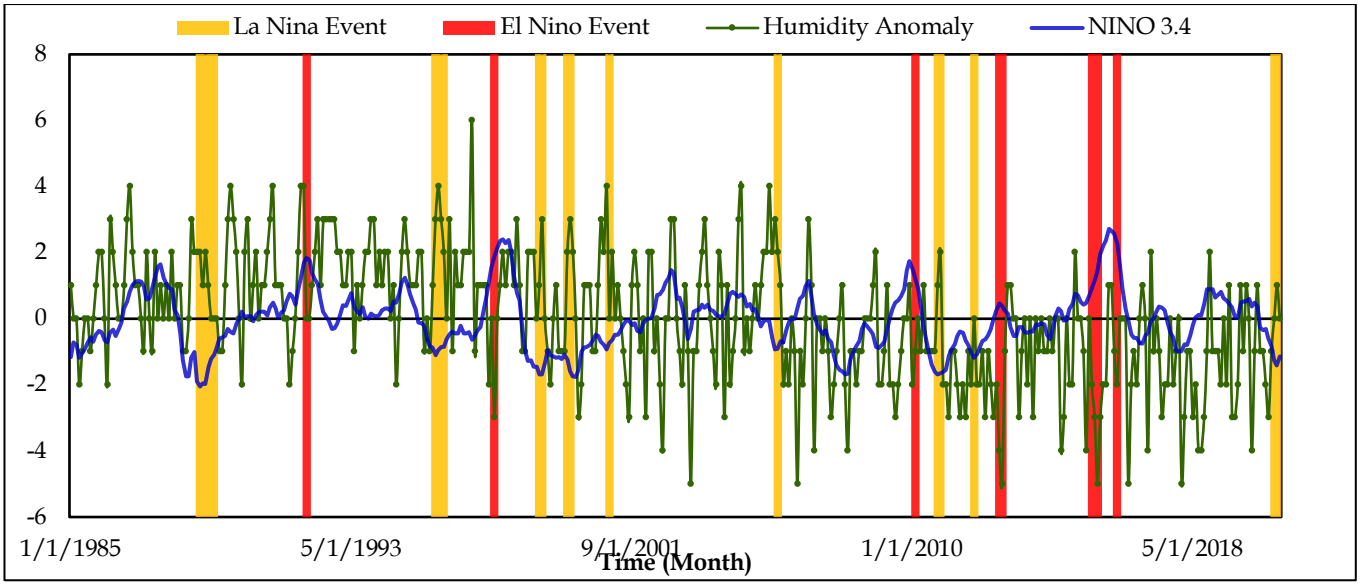

Figure 6. The Time Span with a Strong Correlation on La Nina and El Nino Events for 35 Years in Bengkulu City

Figure 6 shows 15 events of La Nina and El Nino with high correlations on rainfall in Bengkulu City (1988-1989, 1991-1992, 1995-1996, 1997, 1998-1999, 1999, 2000-2001, 2005-2006, 2010, 2011, 2012, 2015, 2016, 2020). Table 2 shows more detailed correlations between El Nino and La Nina events and humidity. Table 2 shows that four La Nina events were strongly correlated with humidity with correlation levels of 91.4%, 77.5%, 72.6%, dan 99.7% (1988-1989, 1998-1999, 2010, 2011). In three El Nino phases (1997, 2015, 2016), the correlation levels are 9.0% (very weak), 68.1% (strong), and 66.0% (strong). There is only little strong correlation between humidity and La Nina and El Nino events in Bengkulu City. However, from the data, the change in humidity that happened in Bengkulu City for 35 years is not affected by La Nina and El Nino.

Table 2. Classification of Strong Correlation of Humidity with ENSO

Year	Phenomena	Correlation Coefficient	Information
1988-1989	La Nina	-0.914	Very Strong
1991-1992	El Nino	-0.917	Very Strong
1995-1996	La Nina	-0.753	Strong
1997	El Nino	-0.090	Very Weak
1998-1999	La Nina	-0.775	Strong
1999	La Nina	-0.721	Strong
2000-2001	La Nina	-0.644	Strong
2005-2006	La Nina	-0.883	Very Strong
2010	El Nino	-0.997	Very Strong
2010	La Nina	-0.726	Strong
2011	La Nina	-0.997	Very Strong
2012	El Nino	-0.800	Very Strong
2015	El Nino	-0.681	Strong
2016	El Nino	-0.660	Strong
2020	La Nina	-0.966	Very Strong

(Source: Akoglu, 2018)

According to previous research, one of the factors that affect humidity levels is the diversity of vegetation that grows in the local area (Atmajayani, 2020). This proves that a green environment is very important such as forests and trees that may be reduced due to houses developing as increased population growth in Bengkulu City (Sakti & Ikhwan, 2019). We consider that it can affect the humidity level in the Bengkulu City area. Based on data from the Central Statistics Agency (CSA) in 2020, the population of Bengkulu Province has been increased by 4.06% every year, and it was linked to land use change from agriculture to housing in the Bengkulu City area. This idea was supported by Landsat Imageries from 2008-2018 that houses development in Bengkulu City was increased from 3,383.51 ha to 5,485.10 ha, which is equal to increasing by 5.0% annually (Susiloningtyas et al., 2021). Moreover, the land use change is not only related to housing development but also industrial factories, toll roads, and other developments.

The change in land use for housing is also felt by the people of Bengkulu City because people are starting to feel the air around the city of Bengkulu getting hotter (Akbar & Lubis, 2022). In previous studies, there were several communities responding to the impact of land change into housing with a percentage of 70.75% that the change in land use into housing had a negative impact on the local community environment and humidity levels (Siska et al., 2020).

Another factor that causes humidity levels to decrease is the depletion of the ozone layer, where the increase in the greenhouse effect, vehicle pollution, and factory emissions greatly triggers a decrease in humidity levels so that CO emissions and ozone concentrations increase (Wang, 2020). Changes in humidity are influenced by population growth and expansion of development so that there is a transfer of land into housing, industrial factories, and other developments. Thefore serious efforts should be taken in order to keep the earth suitable for the future.

Conclusion

In this study, we investigated the relationship between rainfall and humidity with ENSO for the last 35 years in Bengkulu City using the NINO Index 3.4. Bengkulu City in the La Nina phase shows a very strong correlation with the most correlation > 60%, and the El Nino phase is categorized as very strong with a correlation value of > 80%. At some points, the relationship doesn't correlate because several factors such as the distance of the ENSO location in the Pacific Ocean, pedestrian circulation anomalies, and differences in geographical conditions. The correlations between humidity and ENSO show a fairly strong correlation in several La Nina and El Nino events. The correlations of humidity with La Nina events are >70% and the humidity correlations with El Nino events are <70%. However, the correlations are weaker than rainfall with ENSO and only occur at certain times. Thus, humidity is not correlated with La Nina and El Nino events, but there are also other factors such as an increase in population, changes in land use for housing and industry, and the greenhouse effect that are influence the humidity. Based on this analysis, further research is suggested to make predictions of rainfall based on the ENSO phenomenon in Bengkulu City. Information about rainfall forecasts can be very important in many ways.

Acknowledgments

The authors would like to thank the Department of Physics, Faculty of Mathematics and Natural Sciences, Bengkulu University, which has funded this research with contract number 255.c/UN30.12/FIS/HK/2021.

The authors thank the Meteorology, Climatology and Geophysics Agency (BMKG) of Bengkulu Province for providing rainfall and humidity data.

References

Akbar, A. J., & Lubis, A. M. (2022). Analysis of Land and Sea Temperatures Trend During 1985-2021 Period to Understand Local or Global Warming Effect in Bengkulu City. *Indonesian Review of Physics, 5*(1), 16-24. https://doi.org/10.12928/irip.v5i1.6073

Akoglu, H. (2018). User's guide to correlation coefficients. *Turkish journal of emergency medicine, 18*(3), 91-93. https://doi.org/10.1016/j.tjem.2018.08.001

Anwar, A., Sudjatmiko, S., & Barchia, M.F. (2018). Pergeseran Klasifikasi Iklim Oldeman dan Schmidth-Fergusson Sebagai Dasar Pengelolaan Sumberdaya Alam di Bengkulu. *Jurnal Penelitian Pengelolaan Sumber Daya Alam dan Lingkungan*, *7*(1), 1-9. https://doi.org/10.31186/naturalis.7.1.9261

An, E. J., & Kim, H. D. (2019). Analysis of the correlation between urban high temperature phenomenon and air pollution during summer in Daegu. *Journal of Environmental Science International*, *28*(10), 831-840. https://doi.org/10.5322/JESI.2019.28.10.831

Ahsanullah, M., Kibria, B.M.G., & Shakil, M. (2014). *Normal and Student's t Distributions and Their Applications (Vol. 4)*. Paris: Atlantis Press. Retrieved from https://link.springer.com/book/10.2991/978-94-6239-061-4

Athoillah, I., Sibarani, R.M., & Doloksaribu, D.E. (2017). Analisis Spasial El Nino Kuat Tahun 2015 dan La Nina Lemah Tahun 2016 (Pengaruhnya Terhadap Kelembapan, Angin dan Curah Hujan di Indonesia). *Jurnal Sains & Teknologi Modifikasi Cuaca*, *18*(1), 33-41. https://doi.org/10.29122/jstmc.v18i1.2140

Atmajayani, R.D. (2020). Hutan Kota Dalam Kajian Tingkat Kenyamanan Bagi Masyarakat (Studi Kasus Hutan Kota Blitar). *Jurnal Riset dan Konseptual*, *5*(3), 627-635. http://dx.doi.org/10.28926/briliant. v3i4.503

Bewick, V., Cheek, L., & Ball, J. (2003). Statistics review 7: Correlation and regression. *Critical care, 7*(6), 1-9. https://doi.org/10.1186/cc2401

BPS. (2020). *Potret Sensus Penduduk 2020 Provinsi Bengkulu Menuju Satu Data Kependudukan Indonesia*. BPS Provinsi Bengkulu.

Cobantoro, A.F., Setyawan, M.B., & Wibowo, M.A.B. (2019). Otomasi Greenhouse Berbasis Mikrokomputer RASPBERRY PI. *Jurnal Ilmiah Teknologi Informasi Asia*, *13*(2), 115-124. https://doi.org/10.32815/jitika.v13i2.360

Fernalia., Pawiliyah., Triana, N., Colin, V., Listiana, D., Herman, A., Dwiana, D., Sasmita, F.N., Refwan., Elese, V. (2022). Pembentukan Kelompok Masyarakat Terlatih Water Rescue di Kampung Binaan Segana Kota Bengkulu. *Jurnal Kreativitas Pengabdian Kepada Masyarakat (Pkm), 5*(3), 705-710. https://doi.org/10.33024/jkpm.v5i3.6195

Fransiska, H., Sunandi, E., & Agustina, D. (2020). Peramalan Curah Hujan Provinsi Bengkulu dengan Generalized Space-Time Autoregressive. *Journal of Mathematics Education, Science and Technology, 5*(2), 130-142. http://dx.doi.org/10.30651/must.v5i2.5326

Habib, E., Krajewski, W. F., & Ciach, G. J. (2001). Estimation of rainfall interstation correlation. *Journal of Hydrometeorology*, *2*(6), 621-629. https://doi.org/10.1175/1525-7541(2001)002<0621:EORIC>2.0.CO;2

Hadi, A.I., Suwarsono., & Herliana. (2010). Analisis Karakteristik Intensitas Curah Hujan di Kota Bengkulu. *Jurnal Fisika FLUX*, *7*(2), 119-129. http://dx.doi.org/10.20527/flux.v7i2.3086

Hermansah. (2017). Uji Rata-Rata Satu Sampel Menggunakan R untuk Mengetahui Pengaruh Model Belajar Terhadap Hasil Belajar Mata Kuliah Analisis Vektor. *Jurnal Program Studi Pendidikan Matematika*, *6*(2), 161-166. https://doi.org/10.33373/pythagoras.v6i2.915

Hidayat, U., Prasetyo, S., Haryanto, Y.D., Riama, N.F. (2021). Effect of ENSO on Rainfall and Relative Humidity and Sea Surface Temperature in Sulawesi. *Jurnal Buletin GAW Bariri*, 2(2), 88-96. https://doi.org/10.31172/bgb.v2i2.56

Kozu, T., Reddy, K.K., Mori, S., Thurai, M., Ong, J.T., Rao, D.N., & Shimomai, T. (2006). Seasonal and Diurnal Variation of Raindrop Size Distribution in Asian Monsoon Region. *Journal Of The Meteorology Society Of Japan*, 84A, 195-209. https://doi.org/10.2151/jmsj.84A.195

Kug, J. S., & Ham, Y. G. (2011). Are there two types of La Nina?. *Geophysical Research Letters*, 38(16). https://doi.org/10.1029/2011GL048237

Kurniawan, A. (2020). Evaluasi Pengukuran Curah Hujan Antara Hasil Pengukuran Permukaan (AWS, HELLMAN, OBS) dan Hasil Estimasi (Citra Satelit= GSMaP) Di Stasiun Klimatologi Mlati Tahun 2018. *Jurnal Geografi, Edukasi dan Lingkungan (JGEL)*, *4*(1), 1-7. https://doi.org/10.29405/jgel.v4i1.3797

Lee, H. S. (2015). General rainfall patterns in Indonesia and the potential impacts of local season rainfall intensity. *Water*, 7(4), 1751-1768. https://doi.org/10.3390/w7041751

Lin, Y., Oey, L. Y., & Orfila, A. (2019). Two 'faces' of ENSO-induced surface waves during the tropical cyclone season. *Progress in oceanography*, *175*, 40-54. https://doi.org/10.1016/j.pocean.2019.03.004

Lovell-Smith, J. W., & Pearson, H. (2005). On the concept of relative humidity. *metrologia*, *43*(1), 129. https://doi.org/10.1088/0026-1394/43/1/018

Nabilah, F., Prasetyo, Y., & Sukmono, A. (2017). Analisis Pengaruh Fenomena El Nino Dan La Nina Terhadap Curah Hujan Tahun 1998-2016 Menggunakan Indikator Oni (Oceanic Nino Index). *Jurnal Geodesi Undip*, 6(4), 402-412. Retrieved from https://ejournal3.undip.ac.id/index.php/geodesi/article/view/18170

Naylor, R. L., Battisti, D. S., Vimont, D. J., Falcon, W. P., & Burke, M. B. (2007). Assessing risks of climate variability and climate change for Indonesian rice agriculture. *Proceedings of the National Academy of Sciences*, 104(19), 7752-7757. https://doi.org/10.1073/pnas.070182510

Pramudia, A., Susanti, E., & Auranda, M. (2021, July). Analysis of rainfall data to develop the classification criteria for identifying agro-climate resources on the field. *In IOP Conference Series: Earth and Environmental Science*, *824*(1), 012065. https://doi.org/10.1088/1755-1315/824/1/012065

Sakti, B., & Ikhwan, J. (2019). Model Sistem Dinamik Ketersediaan Lahan Terbangun di Provinsi Bengkulu. *Jurnal Ekonomi dan Kebijakan Publik*, 2(2), 1-12. https://doi.org/10.32663/pareto.v2i2.1024

Senatore, A., Furnari, L., & Mendicino, G. (2020). Impact of high-resolution sea surface temperature representation on the forecast of small Mediterranean catchments' hydrological responses to heavy precipitation. *Hydrology and Earth System Sciences*, *24(1),* 269-291. https://doi.org/10.5194/hess-24-269-2020, 2020

Siska, S., Barcia, A., & Brata, F.B. (2020). Analisis Faktor Penyebab dan Strategi Pengendalian Alih Fungsi Sawah Menjadi Perumahan dan Dampaknya Terhadap Lingkungan di Kota Bengkulu. *Jurnal Penelitian Pengelolaan Sumberdaya Alam dan Lingkungan*, 9(2), 43-50. https://doi.org/10.31186/naturalis.9.2.13505

Susiloningtyas, D., Lesy, A.A., & Supriatna. (2021). Dynamic System Model of Land Use Affected by Sea Level Rise in the Coastal Area of Bengkulu City, Indonesia. *Journal of Hunan University (Natural Sciences)*, 48(4), 119-126. Retrieved from http://www.jonuns.com/index.php/journal/article/view/54 6.

Takama, T., Setyani, P., & Aldrian, E. (2014). *Climate change vulnerability to rice paddy production in Bali, Indonesia*. Handbook of climate change adaptation, 1-23. https://doi.org/10.1007/978-3-642-40455-9_84-1

Verawati. (2019). *Pergeseran Adat Bimbang Balai di Desa Jeranglah Kecamatan Manna Kabupaten Bengkulu Selatan Pada Tahun 1990-2017 (Sumbangan Materi Pada Mata Kuliah Sejarah Kebudayaan)* (Skripsi). Universitas Sriwijaya, Indonesia.

Wang, M. H. S., Wang, L. K., & Shammas, N. K. (2020). Glossary of Climate Change, GlobalWarming and Ozone Layer Protection. In *HANDBOOK OF ENVIRONMENT AND WASTE MANAGEMENT: Acid Rain and Greenhouse Gas Pollution Control*, 689-718. https://doi.org/10.1142/9789811207136_0020