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The Impact of El Nino on Rainfall Variability in Buleleng Regency (Case Study: Period 1995-2004)

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Abstract

The climate in Indonesia usually runs yearly; there are times when a decrease in rainfall results in drought, and at other times, the rainfall increases resulting in flooding. One of the causes of changes in precipitation in Indonesia, including in most parts of the world, is ENSO (El Nino-Southern Oscillation), often called El Nino. This study aimed to determine the relationship between ENSO index data (SST Nino 3.4 anomaly) and monthly rainfall data in Buleleng Regency. This study uses secondary data, namely monthly rainfall data at 16 rain posts in Buleleng Regency and ENSO Index data from BMKG Region III Denpasar. Data were collected through observation, document recording, and analyzed using statistical correlation methods. Furthermore, the results are processed spatially, namely by the Isohyet method. The research results show that the impact of El Nino on Rainfall in Buleleng varies spatially and depends on the intensity of El Nino. In June-July-August (JJA/dry season) and September-October-November (SON/transition season), the impact of El Nino on rainfall variability in Buleleng Regency is more significant than other months, strong El Nino causes a decrease in Rainfall in the majority of the Buleleng region with the characteristic of Below Normal rain (30% decrease in precipitation from the average), El Nino of weak - moderate intensity causes a reduction in Rainfall in a small part of the Buleleng area with the dominant rain characteristic of Below Normal.

Keywords: El Nino, Precipitation Variability, and Correlation Index.

INTRODUCTION

The climate in Indonesia is influenced by monsoon activity in which there are alternately high and low-pressure winds from the continents of Australia and Asia. The Northern Hemisphere (BBU) experiences winter, namely in December, January, and February, when high-pressure winds blow over the Asian continent, while in the Southern Hemisphere at that time, there is summer; as a result, there are low-pressure winds on the Australian continent. Due to the difference in pressure on the two continents, the wind blows from the continent of Asia towards Australia. During this period in most parts of Indonesia, especially in the south of the equator, the wind blows from west to east, practically coinciding with the rainy season. Meanwhile, in summer in the northern hemisphere, the opposite occurs, the wind blows from the Australian continent towards the Asian continent so that the wind in the Indonesian region blows from east to west, which coincides with the dry season, namely in June, July and August (Tjasyono, 2008). Indonesia's topography, which has many hills, mountains, and beaches, contributes to the diversity of Indonesia's climatic conditions (Andri, 2020). This condition indirectly affects Indonesia, which is vulnerable to the effects of global climate phenomena such as ENSO (El Nino Southern Oscillation) (Safitri, 2015).

ENSO is sea surface temperature (SST) anomalies from normal conditions (Sugiarto & Kurniawan, 2009). ENSO is divided into two states, namely El Nino is when the waters experience ENSO warming, and La Nina is when the waters are colder than average conditions (Hidayat et al., 2018), which can cause increased Rainfall (Oktaviani, A. N., Jumarang, I. M., & Ihwan, A. 2014). The occurrence of La Nina in Indonesia resulted in hotter Indonesian sea surface temperatures, which increased convection processes and cloud growth, so Rainfall and seasons in Indonesia changed (Safril, A. 2018). El Nino is marked by a shift in warm pools, usually in Indonesian waters to the east (Central Pacific), and a change in the location of cloud formation in Indonesian territory to the east, namely in the Central Pacific Ocean. El Nino will be directly proportional to prolonged droughts and droughts (Irianto et al., 2004). An extended lack arises in Indonesia by shifting the cloud formation location. Indonesia has experienced drought events where Rainfall is minimal, no less than 47 times, from 1844 to 2009. Of the 47 drought events, only six times did not coincide with the occurrence of the El Nino phenomenon, and the condition is that the variability of Rainfall in Indonesia is primarily influenced by the El-Nino phenomenon (Boer, 2014). From these results, we want to know the spatial distribution of the influence of El Nino events in 2015 and La Nina in 2016 on Rainfall in Indonesia.

ENSO, which consists of El Nino and La Nina, is a global phenomenon with a recurring pattern of climate variability in the eastern Pacific Ocean, which is characterized by an anomaly of sea surface temperature or SST (Sea Surface Temperature) (Hidayat et al.,2018). East along the equator and Sea level pressure-Southern Oscillation anomaly (Tongkukut, 2011). Under these normal conditions, the equatorial wind blows westward to help the process of convection in the West Pacific and subsidence in the East Pacific.

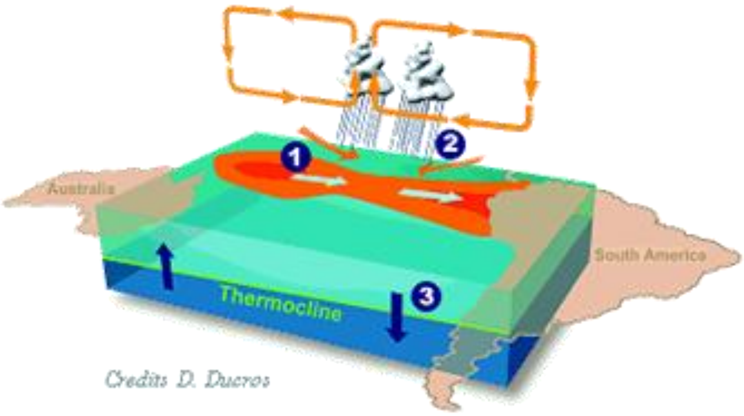


Figure 1. El Nino Phenomenon

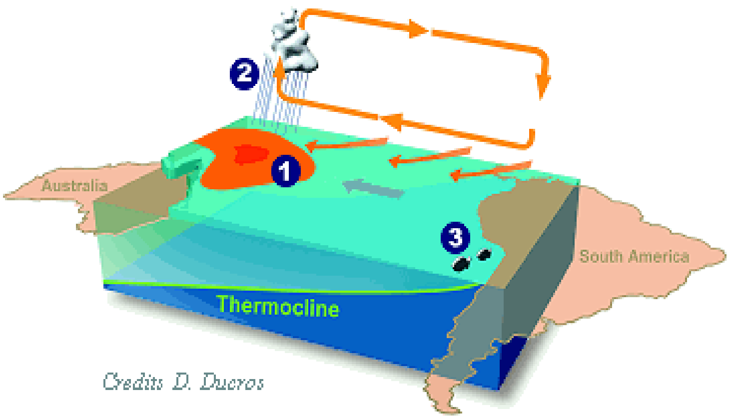


Figure 2. Normal Conditions

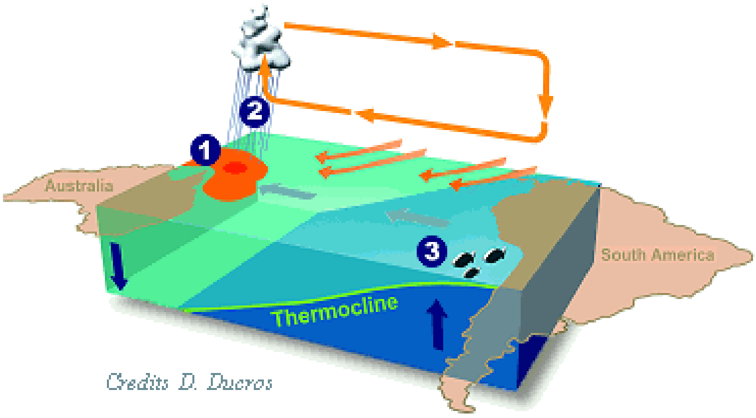


Figure 3. La Nina Phenomenon

El-Nino (figure 1) will occur when hotter waters in the central and eastern Pacific increase the temperature and humidity of the atmosphere above them (Nabilah et al., 2017). This event encourages the formation of clouds, increasing Rainfall around the area. In the western part of the Pacific Ocean, air pressure increases, causing cloud growth to stop over the eastern part of Indonesia, so that in some areas of Indonesia, there is a decrease in Rainfall which is far from average (figure 2). Sea surface temperatures in the central and eastern Pacific are sometimes higher than average, though not always. This situation causes the La-Nina phenomenon (figure 3). Air pressure in the equatorial western Pacific region decreases further west than average, causing more cloud formation and heavy rain in the surrounding area. El Nino and La Nina phenomena can be identified by monitoring sea surface temperature anomalies in the Nino 3.4 region in the Equatorial Pacific Ocean. The area coverage of Nino 3.4 can be seen in Figure 4.

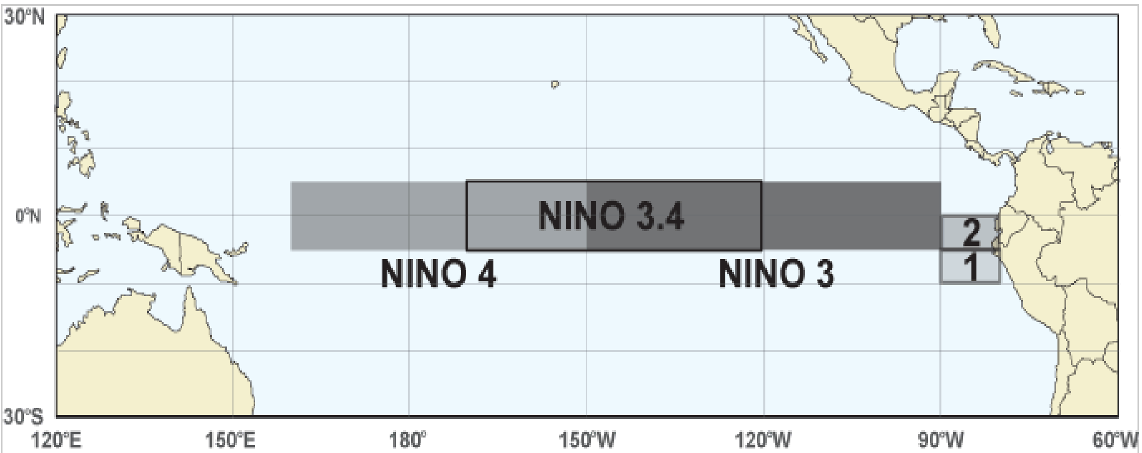


Figure 4. Coverage of the Nino 3.4 Region in the Pacific Ocean to detect El Nino and La Nina

Buleleng Regency is located in the northern hemisphere of Bali Island at the coordinates of 8° 03' 40" LS to 8° 23' 00" LS and 114° 25' 55" E to 115° 27' 28" E. The coastline is 157.05 kilometers long, with a land area of 136,588 hectares or 24.25% of the total area of Bali Province. Topographically, Buleleng Regency has a landscape with various elevations, which consists of morphological units of mountains and hills that run along the southern boundary of the Buleleng Regency area. Then towards the north, it is increasingly sloping with a smoother elevation up to a gentle slope along the coast and coast. The Java Sea borders Buleleng Regency to the north, Jembrana Regency to the west, Karangasem Regency to the east, and Bangli, Tabanan, and Badung Regencies to the south. The coast of Buleleng is generally sloping, and there are several steep places with a height of 0 to 40 meters above sea level. The physical base of the beach sediments consists of grey sandy beaches mixed with pebbles, white sandy beaches, rocky beaches, mangrove forested beaches, and rocky beaches (BPS Buleleng Regency, 2016).

RESEARCH METHODS

The data used in this research is secondary data. Secondary data is obtained from a second source, namely rainfall data during an El Nino event from 16 rainfall posts spread across nine sub-districts and related agencies, in this case, the BMKG, which includes rainfall data. Several techniques are used to collect data, namely observation and direct document recording. Furthermore, the data that has been collected will be processed and then analyzed so that it can become meaningful information related to the problems that will be studied in this study. Furthermore, in data analysis, the collected data will be processed again with a statistical calculation application, namely SPSS.

Observational Rainfall Data Processing

Rain data from each rain post is made the average monthly Rainfall for the 1995-2004 period, using ordinary arithmetic, namely:

$$X_r = \frac{\sum X_i}{n} \quad \ldots\ldots\ldots\ldots\ 1$$

Where :

Xr : Average value

Xi : Data i

N : amount of data

Calculating the Correlation Coefficient With SPSS

The correlation coefficient is a coefficient that describes the level of closeness of a linear relationship between one or more variables. The magnitude of the correlation coefficient does not represent a causal relationship between two or more variables but merely describes a linear relationship between them.

SPSS is an application with relatively high statistical analysis capabilities and a data management system in a graphical environment using descriptive menus and simple dialogue boxes so that it is easy to understand how to operate.

Correlation analysis determined the relationship or influence between ENSO rainfall variability. The correlation coefficient is used to determine how significant the relationship is between the two variables. Correlation correlation is defined as follows (Istiarini and Sukanti, 2012).

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

Where:

r : correlation coefficient between X and Y

X : Percentage of fluctuations in rainfall Data.

Y : Percentage of fluctuations in the ENSO index data

N : amount of data.

The symbol r often denotes the correlation coefficient ranging between -1 and 1 (-1 < r < 1). The r-value, close to 1 or -1, indicates a more intimate linear relationship between the two variables. Meanwhile, the r-value, close to zero, illustrates that the relationship between the two variables is not linear.

Suppose the correlation between X and Y is negative. In that case, an increase in the X variable will cause a decrease in Y, or conversely, a reduction in the X variable will cause an increase in the Y variable.

Meanwhile, if the correlation between X and Y is positive, then an increase in the X variable will be followed by an increase in the Y variable or vice versa, also causing the variable Y. While the price of r will be consulted with the r value interpretation table presented in table 1. Furthermore, in general, the interpretation of the correlation value is explained in Figure 5.

In this study, what was correlated was the anomaly of sea surface temperature Nino 3.4 (ENSO index) with monthly Rainfall in Buleleng Regency. Data from processing the correlation coefficient, which is processed with the SPSS application, then mapping the ENSO index and Rainfall will be assisted using the Arc Gis 10 software.

RESULTS AND DISCUSSION

Correlation Analysis of ENSO Index with Monthly Rainfall in Buleleng Regency

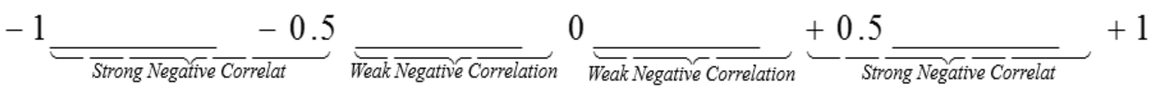
The anomaly of sea surface temperature in the Central Pacific (Nino 3.4) affects the decrease in Rainfall in Buleleng Regency, so a correlation analysis was carried out. Correlation analysis aims to determine the degree of relationship between the sea surface temperature anomaly Nino 3.4, which in this case is represented by the ENSO index, and monthly Rainfall in Buleleng Regency.

The application used to find the level of relationship between the Nino 3.4 sea surface temperature anomaly, which in this case is represented by the ENSO index, and monthly Rainfall in Buleleng Regency is SPPS version 19. The process is to enter ENSO data as the X variable and rainfall data as the variable Y can then directly carry out the process of correlation analysis (correlation analysis). The results of the correlation analysis between the ENSO index and monthly Rainfall in the Buleleng region for 1995 - 2004 are presented in Figure 6 and Table 2.

Table 1. Correlation Coefficient Value Interval and Relationship Level

No	Intervals	Relationship Level
1	0.00 – 0.199	Very low
2	0.20 – 0.399	Low
3	0.40 – 0.599	Strong enough
5	0.60 – 0.799	Strong
6	0.80 – 1.000	Very strong

Source: Sugiyono (2006).



- $r = -1$ shows a perfect negative correlation
- $r = +1$ shows a perfect positive correlation
- $r \geq +0.5$ shows a strong positive correlation
- $r \leq -0.5$ shows a strong negative correlation
- $r < +0.5$ shows a weak positive correlation
- $r > -0.5$ shows a weak negative correlation
- $r = 0$ meaning there is no correlation

Figure 5. The Proportion of Each Section

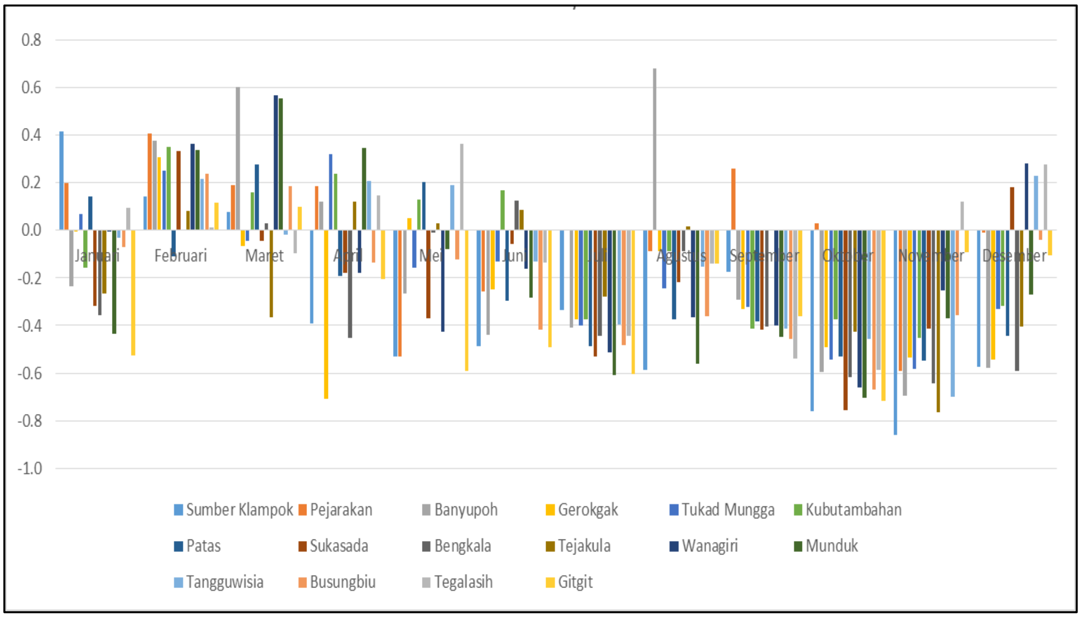


Figure 6. Value of the correlation coefficient (r) between Rainfall vs El Nino in Buleleng Regency from 1995 to 2004. (Source: Processed Result).

Table 2. Value of the correlation coefficient (r) between Rainfall vs El Nino in Buleleng Regency from 1995 to 2004.

No	Name	Latitude	Longitude	correlation coefficient											
				January	February	March	April	May	June	July	August	September	October	November	December
1	Sumber Klampok	-8.17861	114.4847	0.4	0.1	0.1	-0.4	-0.5	-0.5	-0.3	-0.6	-0.2	-0.8	-0.9	-0.6
2	Pejarakan	-8.14389	114.59	0.2	0.4	0.2	0.2	-0.5	-0.3	0.0	-0.1	0.3	0.0	-0.6	0.0
3	Banyupoh	-8.14972	114.6947	-0.2	0.4	0.6	0.1	-0.3	-0.4	-0.4	0.7	-0.3	-0.6	-0.7	-0.6
4	Gerokgak	-8.18833	114.7967	0.0	0.3	-0.1	-0.7	0.1	-0.2	-0.4	-0.1	-0.3	-0.5	-0.5	-0.5
5	Tukad Mungga	-8.14139	115.0569	0.1	0.3	0.0	0.3	-0.2	-0.1	-0.4	-0.2	-0.3	-0.5	-0.6	-0.3
6	Kubutambahan	-8.08222	115.2069	-0.2	0.4	0.2	0.2	0.1	0.2	-0.4	-0.1	-0.4	-0.4	-0.5	-0.3
7	Patas	-8.21222	114.7881	0.1	-0.1	0.3	-0.2	0.2	-0.3	-0.5	-0.4	-0.4	-0.5	-0.5	-0.4
8	Sukasada	-8.13611	115.1011	-0.3	0.3	0.0	-0.2	-0.4	-0.1	-0.5	-0.2	-0.4	-0.8	-0.4	0.2
9	Bengkala	-8.11	115.1814	-0.4	0.0	0.0	-0.5	0.0	0.1	-0.4	-0.1	-0.4	-0.6	-0.6	-0.6
10	Tejakula	-8.12639	115.3419	-0.3	0.1	-0.4	0.1	0.0	0.1	-0.3	0.0	0.0	-0.4	-0.8	-0.4
11	Wanagiri	-8.23722	115.1389	0.0	0.4	0.6	-0.2	-0.4	-0.2	-0.5	-0.4	-0.4	-0.7	-0.3	0.3
12	Munduk	-8.26417	115.0506	-0.4	0.3	0.6	0.3	-0.1	-0.3	-0.6	-0.6	-0.4	-0.7	-0.4	-0.3
13	Tangguwisia	-8.19139	114.9514	0.0	0.2	0.0	0.2	0.2	-0.1	-0.4	-0.2	-0.4	-0.5	-0.7	0.2
14	Busungbiu	-8.26028	114.9703	-0.1	0.2	0.2	-0.1	-0.1	-0.4	-0.5	-0.4	-0.5	-0.7	-0.4	0.0
15	Tegalasih	-8.31556	114.9467	0.1	0.0	-0.1	0.1	0.4	-0.1	-0.4	-0.1	-0.5	-0.6	0.1	0.3
16	Gitgit	-8.20083	115.1378	-0.5	0.1	0.1	-0.2	-0.6	-0.5	-0.6	-0.1	-0.4	-0.7	-0.1	-0.1
Average				-0.1	0.2	0.1	0.0	-0.1	-0.2	-0.4	-0.2	-0.3	-0.6	-0.5	-0.2

Source: Processed Result (2023).

Map of ENSO Index Correlation Coefficient and Rainfall in Buleleng Regency

Spatially, the effect of the sea surface temperature anomaly of Nino 3.4 on the variability of Rainfall in Buleleng Regency every month can be seen on the map or Figure 7.

- The red color indicates the influence of the ENSO phenomenon as indicated by a negative correlation coefficient where when the sea surface temperature in the Equatorial Pacific warms (-), rain in the Buleleng Regency region decreases (-), and otherwise.
- The blue indicates no influence of the ENSO phenomenon, as indicated by a positive correlation coefficient. When the sea surface temperature in the Equatorial Pacific cools (+), the rain in the Indonesian region also increases (+), and the otherwise.

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Correlation Analysis of ENSO Index with Monthly Rainfall in Buleleng Regency

The analysis results show that July to November is the period when Rainfall in most of the Buleleng area is affected by sea surface temperature anomalies in the Central Pacific Ocean (ENSO index). The value of the correlation coefficient indicates this in that period where the majority of areas have a weak-strong negative correlation, which means that when there is a positive anomaly of sea surface temperature in the Central Pacific Ocean in the Nino 3.4 region (positive ENSO index), then in the majority of the Buleleng region there is a decreasing rainfall varies spatially and vice versa. This was also supported by the significance test results on the correlation analysis performed on the SPSS version 19 application. From July to November, the correlation coefficient was identified as significant.

Naturally, the impact will be increasingly felt if the sea surface temperature anomaly in the Nino 3.4 region (ENSO index) becomes higher in value above -0.5, indicating an El Nino phenomenon. These conditions will have an impact on decreasing Rainfall in the majority of Buleleng areas from July to November. The magnitude of the decrease in Rainfall cannot be separated from various factors that influence rainfall variability in Buleleng, both on a global and local scale, so the El Nino phenomenon is one of the factors that play a role in the formation of Rainfall, will interact with other factors which in the end the resulting impact will vary both spatially and temporally.

ENSO Index Correlation Coefficient and Rainfall in Buleleng Regency

The El Nino phenomenon will have a very significant effect on the dry season in Buleleng Regency, where during this dry season, the peak occurs in June, July, and August (JJA) and during the transition from the dry season to the rainy season in September, October, November (SON). This condition is strengthened and supported by previous research, namely from all the analyzes that have been carried out, it can be concluded that the relationship between El Nino and Rainfall in Indonesia and the influence of the El Nino phenomenon on Rainfall in Indonesia occurs at its most significant in the dry season (JJA) (Tristania, 2012). However, during peak rainfall conditions, there is a shift or anomaly, where theoretically, the moonshine rainfall that occurs in Indonesia occurs in December, January, and February (DJF) (Sipayung, S. B., Avia, L. Q., & Dasanto, B. D, 2010). During the DJF period, when the sun is in the south, which is the position farthest from Indonesia, it can conduct maximum water vapor, while in the JJA period, when the sun is in the north of Indonesia, the air produced will be dry as a result of passing through the Australian continent, which has many deserts (Risnayah, S. 2021). In addition, local factors, namely the topography of Buleleng Regency, also influence the significance of the El Nino effect, where the coastal topography that extends from east to west significantly affects El Nino. These local factors make the coastal areas experience less rain compared to the southern province of Buleleng Regency, which is mainly dominated by highland regions, where there will be a lot of rain in the highland areas. Areas in the lowlands are more strongly affected by ENSO" (Rafi, 2012).

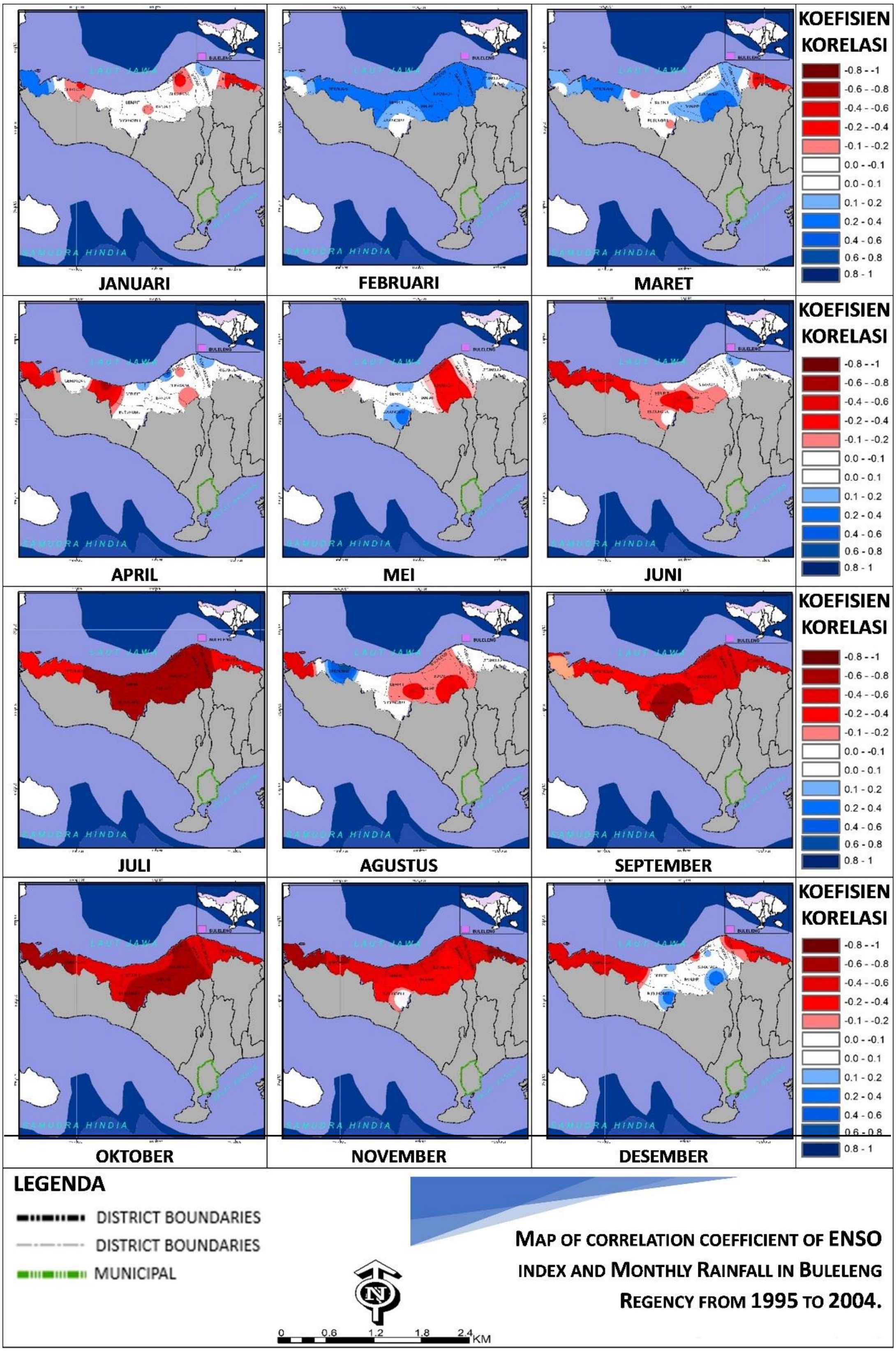

Figure 7. Map Of Correlation Coefficient Of ENSO Index and Monthly Rainfall in Buleleng Regency From 1995 to 2004

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CONCLUSION

Based on the processing, data analysis, and discussion results, it can be concluded that El Nino affects rainfall variability in Buleleng. The impact of El Nino on Rainfall in Buleleng varies spatially and also depends on the intensity of El Nino. In June-July-August (JJA/dry season) and September-October-November (SON/transition season), the impact of El Nino on rainfall variability in Buleleng Regency is most significant compared to other months. Vigorous El Nino intensity (strong El Nino) causes a decrease in Rainfall in most Buleleng.

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