Impact of Global Warming Due to Climate Change on Equatorial Rain-Patterned Regions

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Impact of Global Warming Due to Climate Change on Equatorial Rain-Patterned Regions

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Abstrak: Annual and inter-year climate variability in Indonesia is unique in that not all regions are equal, affecting weather patterns and rainfall. Indonesia's climate is influenced by the global exchange of air mass flows across its territory. Climate patterns in Indonesia can be divided into three main climate patterns, namely monsoon patterns, equatorial patterns, and local patterns based on annual rainfall patterns. The advantage of climate distribution based on rainfall patterns is that the coherence of each region is relatively the same only for applied climate control. This is because when climatic conditions change, newly formed precipitation patterns will prevail. This incident has repeatedly occurred in almost all parts of Indonesia. The analysis used is mean, variance and geo-statistics using secondary data sources from BPS and BMKG in the three regions of East Kalimantan. In the Berau region there is a change in the pattern towards the monsoon winds indicating a rain peak or a pattern of the letter U. In other regions such as Penajam Paser Utara and Paser, an equatorial pattern with two rain peaks remains. Rainfall in the Berau region showed an increase and decrease in the Penajam Paser Utara and Paser regions. The Berau, Paser and Penajam Paser Utara regions will experience a trend of 0.44°C in temperature increases over a 14-year period from 2005-2018, or by 0.03°C per year. Regions that show a shift in rainfall patterns to the equatorial type are particularly sensitive to monsoon winds, which experience rainfall spikes and affect cropping patterns.

Keywords: Air Temperature Trend, Climate Control, Local Pattern, Monsonal Pattern, Rainfall Trend

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Introduction

Annual and inter annual climate variability in Indonesia is quite unique because all regions are not the same and have an effect on weather patterns and rainfall (Haylock & McBride, 2001). Indonesia's climate cannot be separated from the influence of global exchange from the flow of air masses that pass through this region. Such an archipelago arrangement makes Indonesia have climate characteristics that are local, tropical, and tropical Monsoon. Climatologically, climate patterns in Indonesia based on rainfall patterns for a year can be divided into three main climate patterns, namely monsoon patterns, equatorial patterns and local patterns (Tjasjono, 2004). Then, based on the analysis of the amplitude and the annual oscillation phase of the average amount of average precipitation. Indonesia's classified into four climatological regions (Lestari et al., 2019). They found similar characters from the three regions the researchers mentioned earlier and intermediate regions that did not have clear rainy and dry seasons. The Monsoon pattern is characterized by a unimodal form of rain pattern, which is one peak of the rainy season (Mensah et al., 2016). During the six months the rainfall is relatively high, which is called the rainy season and the next six months are low, which is called the dry season. In general, the dry season lasts from April to September and the rainy season from October to March.

The equator pattern is characterized by a rain pattern with a bimodal shape, which is two rain peaks that occur around March and October, namely when the sun is near the equator or when the equinox occurs (Rathgeber, 2019). The local pattern is characterized by the unimodal rain pattern shape, which is one rain peak but opposite in shape to the rain pattern in the Monsoon type. The advantage of climate division based on rainfall patterns is the consistency of each part or region only on the same applicable climate controller (Kalkuhl & Wenz, 2020). This is because the conditions of climate control are different because they change, so the newly formed rainfall pattern will apply. This incident always occurs in almost all parts of Indonesia.

Global climate change has affected rainfall intensity and patterns (Trenberth, 2008). *Climate change* is unavoidable due to *global warming* and is believed to have a broad impact on various aspects of life (R. M. Santos & Bakhshoodeh, 2021). Too much rainfall can cause flooding and vice versa if the rainfall is too low it can cause drought. Climate change is a natural phenomenon where climate patterns change and have an impact on changes in weather patterns in an area over a relatively long period of time such as an increase in extreme events and shifts in planting time (Clarke et al., 2022). Climate change results in changes in environmental conditions that have an impact on plant growth and development (Abdou Zayan, 2020). Plant growth is disrupted under suboptimal conditions, which results in a decrease in the quantity and quality of production and yield.

Climate change has brought challenges to commodities and local communities (F. D. Santos et al., 2022). Currently, climate change has major implications for the future of commodity production and people's livelihoods in many parts of Indonesia (Hannoeriadi A. et al., 2022; Resosudarmo et al., 2019), including East Kalimantan. The diversity of rain and other extreme weather/climate events continues to affect several aspects of the regency area in East Kalimantan due to increased temperature and rainfall variability and has the potential to worsen environmental degradation in commodity-producing areas (Ummenhofer & Meehl, 2017).

In addition, economic factors such as falling prices, inefficient supply chains, have hit the commodity sector and farmers in some districts to the bottom level (Baffes & Nagle, 2022). A farmer with dependence on a single commodity suffers the worst impact, as does the regional economy of the region (Rozaki, 2021). The farmer and his region have been directed to a single commodity by market forces. Such a perspective must change with increased capacity and a thorough assessment of alternatives that could be the way out of the problem.

The consistency of each region only on the prevailing climate controller is relatively the same. This or problem can be formulated in areas where climate control conditions are different because they have changed, so a newly formed rainfall pattern will apply. The formation of new territories always occurs in almost all parts of Indonesia which has an impact on shifting planting patterns. Therefore, the purpose of this study is to analyze changes in rainfall patterns in the study area which are of the equatorial rainfall pattern type affected by climate change.

Research Method

The data types used are primary and secondary. Primary data were obtained from interviews with BMKG, Ministry of Agriculture and Forestry. Secondary climate data was obtained from BPS in the form of numerical sub-districts at three meteorological and geophysical stations in the BMKG area of East Kalimantan. The survey was conducted in 3 districts in East Kalimantan in 2019/2020. East Kalimantan is the fourth largest province after Papua, Central Kalimantan and West Kalimantan. East Kalimantan is located between 113°35'31" and 119°12'48" East Longitude and 2°34'23" North Latitude and 2°44'14" South Latitude. Because of this special geographical position, East Kalimantan is crossed by the equator. Therefore, East Kalimantan is a tropical region with high temperature and humidity. As shown in the picture, the survey points are in three districts in East Kalimantan, namely Berau, Penajam Paser Utara and Paser (Figure **Error! Reference source not found.**).

In this study, climatological calculations were used to describe the average variability of the data. Climatological calculations using the following equation,

$$\bar{X}_i = \frac{\sum_{j=1}^{N} x_{ij}}{N}$$

$\bar{X}_i$ is the average value of climatology for a given month, N is the sum of the data for the year of observation, and i and j are the month and year of observation. Based on the average value of this climatology, a graph of the distribution of rain was made from January to December. Rainfall patterns will be determined based on this analysis.

The standard deviation is calculated using the following equation,

$$S = \frac{\sqrt{\sum(x_i - \bar{x})^2}}{n-1}$$

S is the standard deviation, is the original data, is the average value, and n is the sum of the data.

Regional rainfall is forecast by geostatistics. Divide the annual rainfall climate data period into three periods to obtain rainfall variability during the 2010-2020 range. Rainfall and temperature data were obtained from the BMKG station in East Kalimantan and analyzed using geostatistics to obtain regional rainfall. Geostatistics is used to see the relationship between variables measured at a given point and the same variable measured at a point at a certain distance from the first point (spatial data), and when the date is unknown. These geographical data are characterized by their independence and heterogeneity. Independence is caused by the error of observations of calculations, the results tested at one point are determined by another point in the system, and heterogeneity is due to differences in regions. The results of data processing are used to represent changes in mass after a certain period of time. The above statistical analysis uses SPSS software version 22 and Arc Geographic Information System (GIS) version 10.0 to create a map of rainfall distribution and its changes.

Result and Discussion

General Profile of Climate Elements

With a tropical climate, East Kalimantan has a dry and rainy season similar to other regions in Indonesia. The dry season usually lasts from May to October and the rainy season from November to April. This state of affairs continues every year, punctuated by transitional periods of certain months (Hamada et al., 2002). However, in recent years, the seasons in East Kalimantan have sometimes been unpredictable. In a month that is supposed to rain but not at all, or vice versa, in a month that shouldn't rain, only rain becomes a paradise, prolonging the season. The PPU region has an average maximum temperature of 28.3 °C in October and a minimum of 27.2 °C in August. The highest average humidity was 86.0% in May and the lowest was 76.0% in December. The average wind speed is 3.9 knots. In 2017, the average rainfall was 213.9 mm and the number of wet days was 20.58, with May having the most rainfall, with 535.4 mm of rainfall. The highest average temperature in the Paser region is 28.1 °C in October and the lowest is 26.8 °C in August. The highest average humidity in August was 89.0% and the lowest in October was 81.0%. The average wind speed is 3.6 knots. In 2017, the average rainfall was 259.3 mm, with rainfall of 21.7 mm, with May having the highest rainfall, with rainfall of 535.4 mm. The highest average temperature around Tanjung Redep Station is 27.7 °C in October, and the lowest is 26.4 °C in March. The highest average humidity occurred in March at 88.0% and the lowest in July, September, October and December at 84.0%. The average wind speed is 3.7 knots. The average rainfall in 2017 was 183.7 mm with 18.4 wet days with the highest intensity occurring in February with 307.3 mm of rainfall.

Changes in Rainfall and Air Temperature Conditions in 2010, 2015, 2020

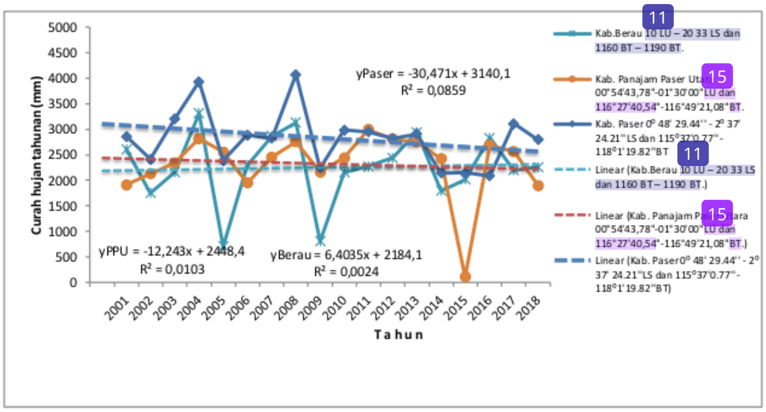
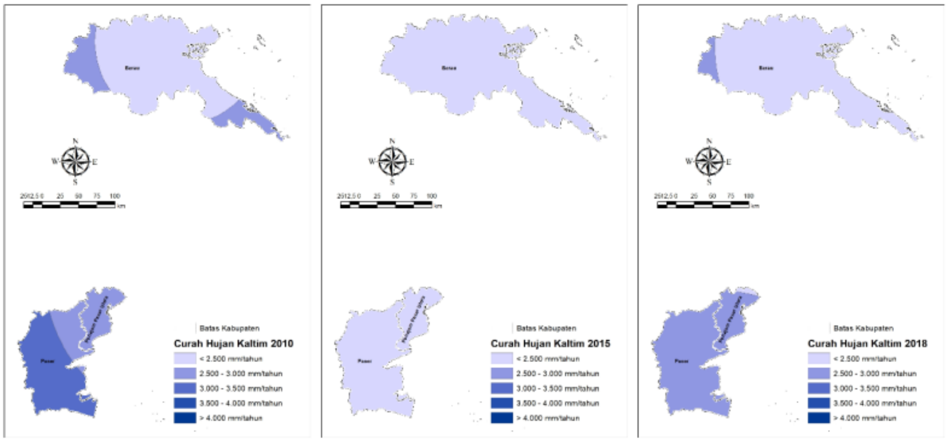


Figure 1. Rainfall Trend in Berau, Panajam and Panajaman Paser Utara Regions, East Kalimantan



2010 2015 2018

Figure 2. Rainfall Conditions in Berau, Panajam and Panajaman Paser Utara, East Kalimantan for the Period of 2010, 2015, and 2018.

Changes in air temperature during the periods 2010, 2015 and 2018 are presented in **Error! Reference source not found.**. Berau, Paser and Penajam Paser Utara regions have a tendency to increase their air temperature, around 0.44 O C for 14 years from 2005 - 2018 or 0.03OC per year.

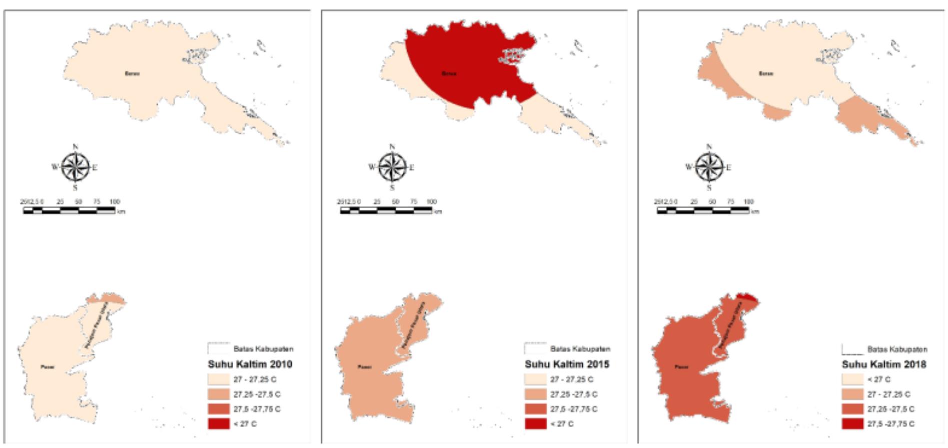


Figure 3. Air Temperature Conditions in Berau, Paser and Panajaman Paser Utara Regions, East Kalimantan for the Period of 2010, 2015 and 2018

Rainfall patterns in the study area are presented in **Error! Reference source not found.**. Based on the analysis of moving averages, it can be seen that the Berau region shows a change in the pattern towards the monsoonal or letter U pattern. While other regions such as Paser and Penajam Paser Utara still show an Equatorial pattern with two rain peaks. In this pattern of rain, the rainy season (MH) occurs from March to May and

August to December, while the dry season (MK) occurs in January to February and June to July.

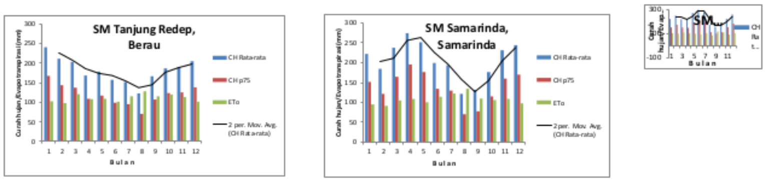


Figure 4. Water Balance of the Study Area

The length of the wet and dry periods or the length of the plant growth periods is shown in Figure 4. At a 75% chance of rainfall, rainfall occurs from 1,427 mm to 1,886 mm per year with a deficit period of 1 to 4 months of 19 mm to 96 mm. Therefore, the length of the wet period ranges from 8 to 11 months which occurs in the Berau, Paser and Panajam Paser Utara regions.

Oil palm plants grow well in areas with annual rainfall between 1750 - 3000 mm and spread evenly throughout the year (Teh & Sung, 2016). The even distribution of rainfall in question is that there is no noticeable difference from one month to the next and there is no monthly rainfall below 60 mm so that the plants do not experience depression. Based on observations made on oil palm plantations in Indonesia, it is known that the minimum annual rainfall for oil palm crops is 1,250 mm without dry months (monthly rainfall is less than 60 mm). Similarly, regions with monsoonal-type rain patterns because the region is highly sensitive to extreme climatic events such as El-Niño and La-Nina.

Typology of Climate Risks and Potential Adaptation at the District Level

The tendency towards precipitation and air temperature is presented in **Error! Reference source not found.**. The rainfall range between 2000 mm 3500 mm per year is suitable for oil palm plants while the air temperature range in East Kalimantan is between 26 - 27.5 ° C. This temperature range makes oil palm plants grow and develop well because of their requirements in areas that have an annual average air temperature of 24 - 28° C (Ferwerda, 1977). The BMKG prediction (2019) also shows the same pattern for the East Kalimantan region, both increasing rainfall in the Berau region and experiencing a reduction in the Paser and PPU regions. Meanwhile, the air temperature also experienced a moderate increase ranging from 0.76 to 0.91°C (**Error! Reference source not found.**).

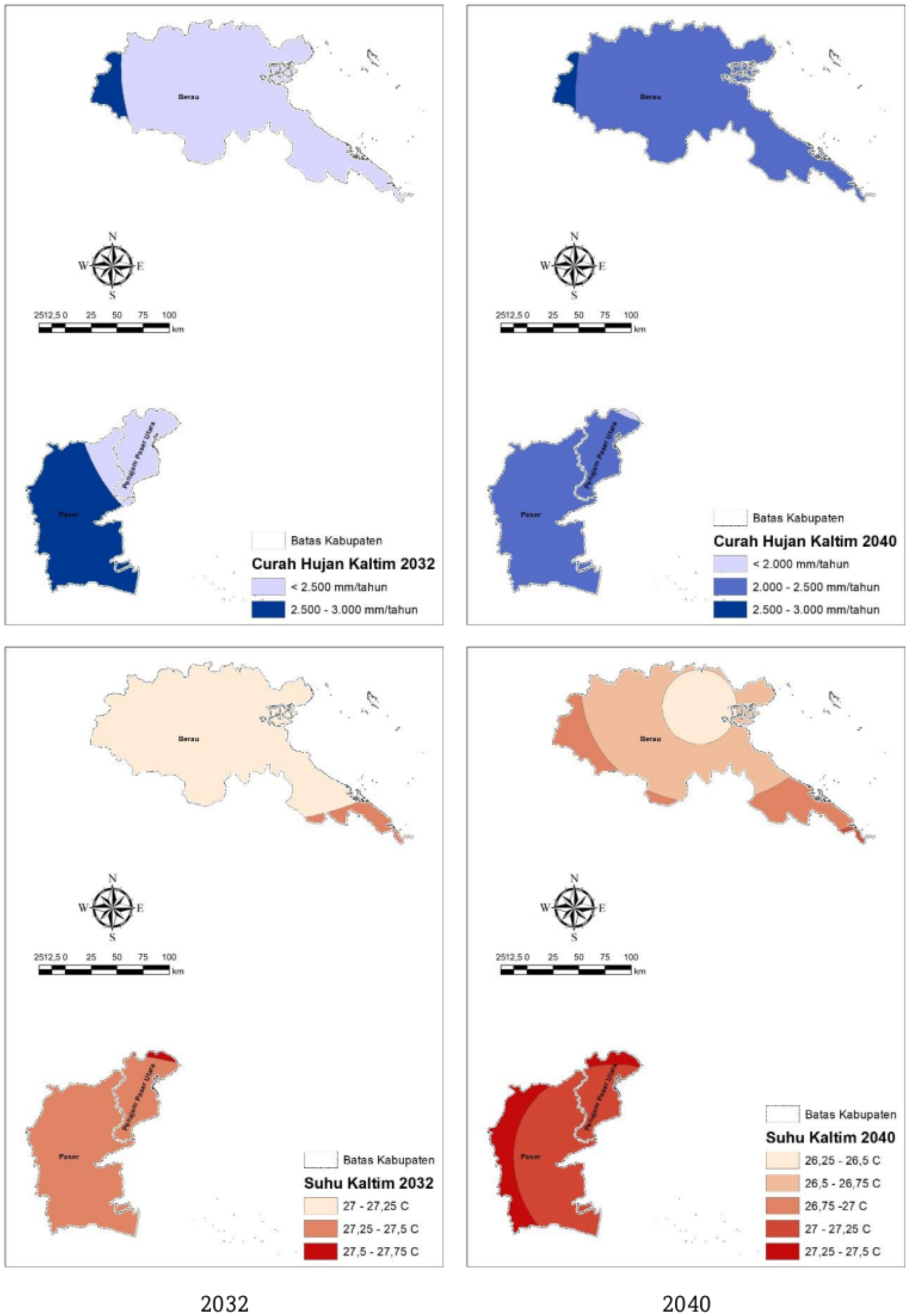


Figure 5. Prediction of Rainfall and Air Temperature in East Kalimantan in 2032 and 2040

Climate change can occur as a result of global warming. Global warming is caused by increasing concentrations of greenhouse gases, including CO2, in the Earth's atmosphere. From 400,000 years ago to 1950, the CO2 content in the atmosphere was less than 300 ppm and the average temperature was about 15 °C. But now the concentration of CO2 in the earth's atmosphere has reached 400 ppm. A study conducted by PPKS in North Sumatra from 1971 to 2005 showed an increase in average temperature up to 0.47 °C. The increase in global average temperatures is now reported to have reached up to 1°C. Many experts believe that global warming has led to an increase in extreme weather events in different parts of the World Bank. Increased melting of polar ice caps, rising sea levels, droughts, floods, heat waves, etc. In Indonesia, extreme climate events (especially rainfall) are associated with the ENSO/El Niño Southern Oscillation event. The intensity and frequency of ENSO is increasing, which is thought to be due to the effects of global warming (Boer, 2017). A developing El Niño event can bring heavy rains under normal conditions. During the period from 1950 to 2019, El Niño frequencies were highest, with intensities of 1, 2, 3, 4, 4, 4, 5, and 4 times respectively with a probability of about 18.2%, at 22.7%. of %. La Niña occurs once a year, with a maximum frequency of 10 and a probability of 41.7%. Thus, the chance of extreme El Niño and La Niña events is 64.4%. La Nias coexists with El Nios 13 times, and El Nios generally precedes La Nias by about 50% every two years (Rusmayadi et al., 2022).

The relationship between Julys SOI and the beginning and duration of the rainy season (MH) is shown in **Error! Reference source not found.**. If the July SOI is around zero (normal), then the beginning of the rainy season (MH) is around the beginning of May. If the SOI value rises by 10 from zero (La-Nina), then the beginning of MH will advance to April, on the other hand, if it falls by 10 (El-Nino), then the beginning of MH retreats to June.

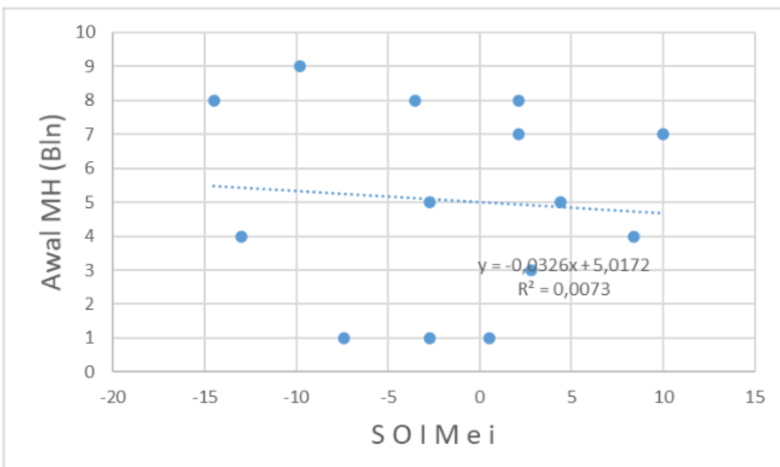


Figure 6. Relationship of July SOI with the Beginning of the Rainy Season (Moon) in the Berau Region

If the May SOI is around zero (normal) the length of the rainy season is expected to be 10 months. If the SOI value rises by 10 from zero (La-Nina), then the length of MH becomes 12 months. In return, if SOI drops by 10 (El-Nino), the length of MH will be 9 months.

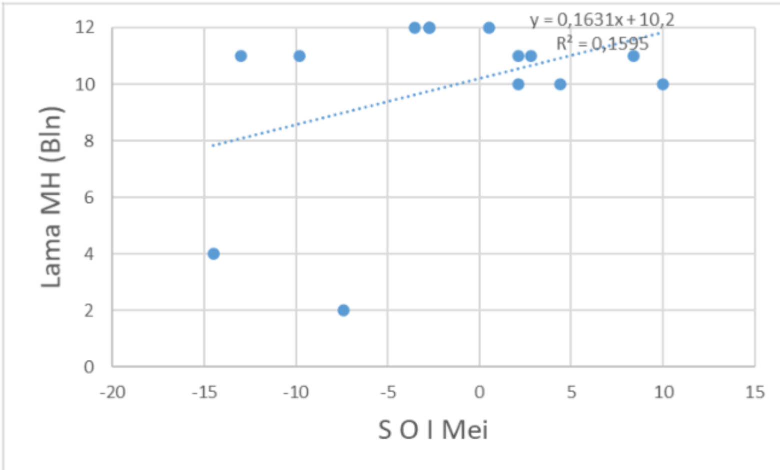


Figure 7. Relationship between May SOI and Length of Rainy Season (Moon) in Berau Region

If in May the SOI Phase falls into the La-Nina category, then the initial chances of MH will advance to be large and the length of MH relatively becomes more significant than the El-Nino phase (**Error! Reference source not found.**). Conversely, if the SOI Phase in May is in the El-Nino category, then the chances of a rainy season (MH) occurring aresmaller than other normal phases or La-Nina (**Error! Reference source not found.**).

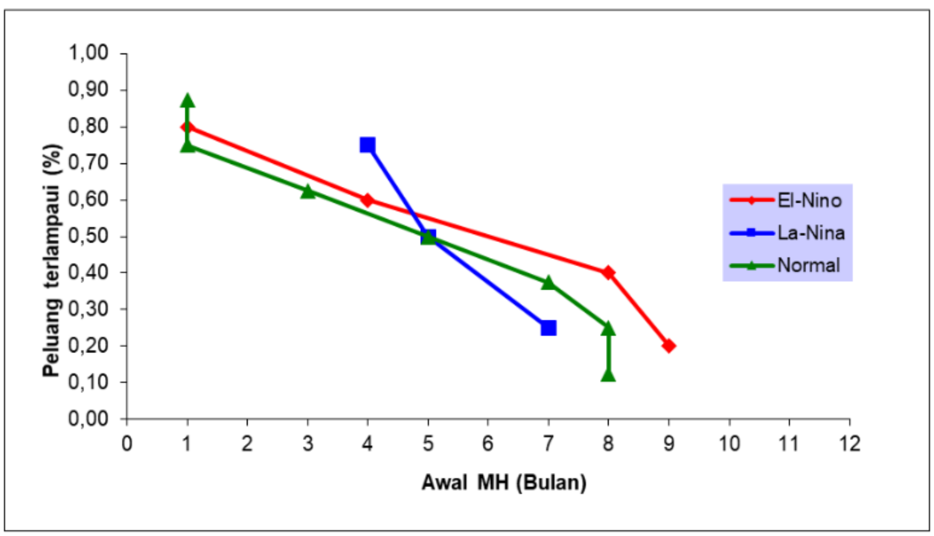


Figure 8. MH Preliminary Predictions Based on the May SOI Phase

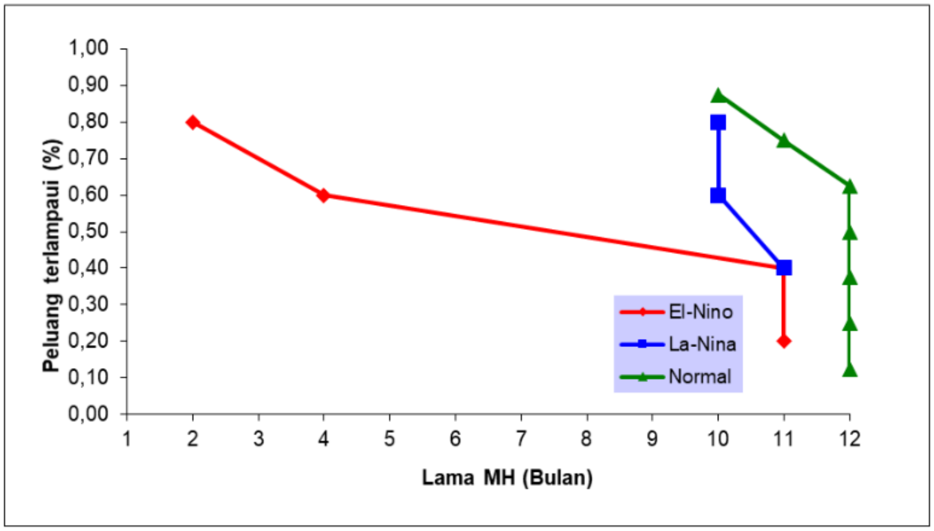


Figure 9. MH Old Prediction Based on May SOI Phase

The potential for climate change, especially future rainfall, requires adaptation and mitigation efforts in agricultural systems (Malhi et al., 2021; Sekaranom et al., 2021). In general, adaptation and mitigation efforts can be carried out such as the use of drought-tolerant cultivars, increasing nutrient utilization efficiency through nanofertilizer technology, and adapting cultivation techniques. Related to oil palm plantations, negative ENSO/El Niño events can cause prolonged droughts, affect growth and development and reduce crop yields. The southern and eastern parts of Indonesia are drought-prone areas. Due to climate change, Sumatra is expected to be relatively wet, while the rest of Indonesia will be relatively dry in the future. In addition, the proportion of annual rainfall that falls during the rainy season is expected to increase. This indicates an increase in the frequency and intensity of extreme climate events (Boer, 2017).

Conclusions

1. The Berau area of East Kalimantan shows a change in rainfall patterns from the equator type to the lunar-solar type. This means that areas that originally had two precipitation events now have one, making them very sensitive to monsoon winds. This affects the change in cultivation pattern.
2. In the East Kalimantan region, rainfall increased in the Berau region and decreased in the North Penajam and Penajam Pasel regions. On the other hand, temperatures in 2010, 2015 and 2018 will change. The Berau, Pasell and North Market Regions have a tendency to increase by about 0.44 °C over 14 years from 2005 to 2018, or 0.03 °C per year.
3. If the May SOI is near zero (usually), the length of the rainy season is expected to be 10 months. Since the SOI value increases by 10 from zero (La-Nina), the length of the MH is 12 months. Conversely, when SOI drops by 10 (El Niño), the length of MH is 9 months. When the SOI phase falls into the La Niña category in May, the probability of the initial MH increases and the duration of the MH is relatively longer than the El Niño phase. Conversely, if the May SOI phase falls into the El Niño category, the probability of a long rainy season (MH) is lower than that of other normal phases or La Niña.

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